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Do the whole process again... really?

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YES

NO

PAROTID GLANDS SAVED?

Both

One

None

Reoptimize?

YES

NO

ACCEPTABLE DOSE TO OTHER OAR's?

YES

NO

SHOW IT TO PHYSICIAN, IS HE/SHE SATISFIED?

YES

NO

Are you sure this was the right plan?

Stay calm & keep planning.

Visit us at booth #1219 and get a demonstration

ADVANCING CANCER TREATMENT
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Dear Colleagues,

As Co-chairs of the 2015 World Congress on Medical Physics and Biomedical Engineering, it is our great pleasure to welcome you to Toronto.

The World Congress is co-hosted by IUPESM (International Union for Physical and Engineering Sciences in Medicine), IOMP (International Organization for Medical Physics), IFMBE (International Federation for Medical and Biological Engineering), and here in Canada by COMP (Canadian Organization of Medical Physicists) and CMBES (Canadian Medical and Biological Engineering Society). These five organizations have collaborated to ensure that this Congress features exciting scientific sessions on a wide range of topics in medical physics and biomedical engineering, presented by scientists and engineers from around the world.

The Congress Organizing Committee and its sub-committees have worked hard to develop a rich and stimulating scientific program, with time set aside for mingling with colleagues and celebrating our successes. We are also proud of the range of plenary sessions, ancillary meetings and continuing education events being offered, along with an excellent range of exhibits. We encourage you to explore and participate in the various offerings of the congress. We also thank our congress planning partners, International Congress Services Ltd., whose people have worked tirelessly to ensure that this Congress is a rewarding and pleasurable experience for all.

We encourage you to reconnect with colleagues you may not have seen for a while, and to take the opportunity to meet new colleagues and form new connections around the world. Also, do take some time to explore our city. Here in Toronto, we are proud to be one of the most multicultural cities in the world, and of our rating as the safest large metropolitan area in North America. There are many exciting cultural sites nearby and a wonderful variety of restaurants serving many different cuisines, so don’t hesitate to explore our city and enjoy its warmth and diversity.

Thank you for attending the 2015 World Congress, and welcome to Toronto!

David Jaffray, PhD

Tony Easty, PhD, PEng, CCE
Welcome to the 2015 World Congress on Medical Physics and Biomedical Engineering

We have created a World Congress—Why? What possesses us to work for three years to create this triennial event? Are we crazy? What has compelled David and Tony to take a chunk of their lives and of those many, many other people who contributed on the Congress Organizing Committee and all of the other WC 2015 committees and donate it to a World Congress on Medical Physics and Biomedical Engineering? This is among the greatest non-deductible, charitable contributions of which I am aware! It must be pretty important to them and to us. Thank you David Jaffrey and thank you Tony Easty—I don’t know how many times you will hear this during the coming week, but I can assure you that it will not be enough times!

Anticipation for this World Congress has been building slowly since our last gathering in Beijing, but recently that anticipation has been crescendoing. We have collected an international snapshot of advances in medical physics and biomedical engineering. This is an excellent opportunity to share best practices and theories, strengthen and create new global relationships, mentor young engineers and physicists and begin new projects at home and abroad. Thank you all present for your support and assistance in making WC 2015 a success! We could not have done it without you.

The five themes of the World Congress are:

1) Global Health Challenges,
2) Evidence and Health Informatics,
3) Women in Biomedical Engineering and Medical Physics,
4) Urban Health and Future Earth, and
5) Next Generation Medicine.

These are broad themes that capture some of the most important issues we face today.

We have the privilege of celebrating the lives and work of several IUPESM, IFMBE and IOMP Award winners, who will be introduced at the Opening Ceremony and will each give us a “kort verslag” or precis of their work. We will have the additional pleasure of recognizing the achievements of early-career medical and biological engineers and medical physicists who have won one of several young investigator awards here in Toronto.

You, the people here, will have the opportunity to discuss the future of clinical engineering, medical physics and biomedical engineering. You have the chance to attend many special sessions within the 5 themes and 19 tracks of the World Congress. You can help shape policies for both developed and developing nations.

The delegates to the IUPESM General Assembly and the IOMP and IFMBE General Assemblies will be able to select their leaders for the immediate future; they will also select the location of the 2021 World Congress. Please delegates - vote intelligently and secure a good realization of our future.

Since I first read these words of T.S. Eliot in LITTLE GIDDING (No. 4 of ‘Four Quartets’) I have been strangely calmed by them; I thought I would share them with you as I wish you a successful WC 2015:

We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

Best wishes,

Herbert F. Voigt, PhD
IUPESM President
Welcome to World Congress on Medical Physics & Biomedical Engineering 2015, Toronto, Canada

Kin-Yin Cheung, President of IOMP

On behalf of the International Organization for Medical Physics (IOMP), it is my great pleasure and honour extending my warmest welcome to all participants in this 13th World Congress on Medical Physics & Biomedical Engineering being held in the wonderful city of Toronto, Canada during June 6-12, 2015.

I wish to convey my gratitude to the Canadian Organization of Medical Physicists (COMP) and Canadian Medical and Biological Engineering Society (CMBES) for hosting this great event and to congratulate them for the huge success in this special occasion. The event provides a unique opportunity and a multi-disciplinary scientific platform for medical physicists, biomedical engineers, and other professionals from related fields from all over the world to exchange ideas and share their knowledge, experience, and research findings for the purpose of promoting human health through advances in science and technology in healthcare.

I would also like to congratulate the Congress Co-Chairs, Professor David Jaffray and Dr. Tony Easty, and their team members for putting up an outstanding congress with such an excellent scientific program. May I convey my appreciation to them for all their efforts and contributions in making this congress a most memorable one.

Last but not least, I wish all participants a very fruitful congress and an enjoyable stay in the beautiful city of Toronto.

Kin-Yin Cheung, PhD
President
Welcome to the World Congress on Medical Physics and Biomedical Engineering 2015!

Each and every World Congress on Medical Physics and Biomedical Engineering is a chance for delegates from numerous countries from all over the world to review their own achievements and to have a closer look into the future of medical physics and biomedical engineering: which are the hottest topics in research, what can be expected from research results and from development, which are the new emerging technologies and what impact may be expected from them in medicine and health care, what are the highest needs for current care givers, how to make the education in medical physics and biomedical engineering better and more efficient. The World Congress is a platform for medical physicists and biomedical engineers to build a common policy for further improvement of health care and for planning common action under the umbrella of the International Union for Physical and Engineering Sciences in Medicine (IUPESM).

International Federation of Medical and Biological Engineering (IFMBE) is proud to be a sponsor of the World Congress this June, in Toronto, Canada. Biomedical engineers from most of more than 60 IFMBE affiliated Biomedical Engineering Societies will gather to exchange their knowledge and experience between themselves and also with colleagues who have their primary interest in medical physics, medicine and other professions linked with biomedical engineering. Contacts made at previous World Congresses enabled building of international research team which were successful gaining project in the field and where collaboration lasted for a long time. The Federation makes the most of the World Congress to reward distinguished scientists in biomedical engineering who have devoted their research for many years to biomedical engineering but at the same line, rewards early stage scientists and young investigators. There is more that 50 years since the Federation was founded (in 1959) and from the first World Congress in 1982, so that a whole crosssection of careers in biomedical engineering can be identified and appropriately evaluated.

I sincerely hope that all delegates of the Congress will gain from the scientific sessions and also that you all will enjoy the social activities of and around the Congress and of the appealing city of Toronto!

Ratko Magjarević, PhD
President, IFMBE
June 7–12, 2015

**A Personal Message from the Premier**

On behalf of the Government of Ontario, I am delighted to extend warm greetings to everyone attending the IUPESM World Congress on Medical Physics and Biomedical Engineering in Toronto.

I would like to take this opportunity to commend the IUPESM for its commitment to supporting biomedical engineers and physicists in the ongoing advancement of these vital fields.

As Premier, I am proud that Ontario has the opportunity to host an event that facilitates fruitful discourse between clinicians, researchers, educators and practitioners with the noble aim to improve global health outcomes. With an impressive array of lectures, educational sessions and workshops, this conference is sure to both enlighten and inform.

I would also like to thank IUPESM for choosing our province to host this wonderful event. I am confident that all the delegates and guests will enjoy their time in Toronto, our vibrant and diverse capital city.

Please accept my best wishes for an informative and memorable congress.

*Kathleen Wynne*

Premier
Welcome / Bienvenue

On behalf of the Canadian Medical and Biological Engineering Society, I would like to welcome each of you to Toronto for the World Congress on Medical Physics and Biomedical Engineering.

The committee organizers and countless volunteers have worked hard to put forward a great program including an impressive line-up of educational courses.

I would like to extend my appreciation for the support of the Sponsors and Exhibitors who will be on hand Sunday evening through Thursday to market their latest products and services. Please spend some time at the Exhibit Hall to see what's new and improved.

Note that CMBES is celebrating its 50th anniversary this year. We have an amazing and rich history founded by innovators, scientists, and biomedical/clinical engineers, who uniquely served patients, the medical community, and Canadian Healthcare.

Please enjoy the learning and sharing with colleagues from the international community over the next few days and don't forget to join us for the Gala dinner on Wednesday night and the AGM on Thursday evening. I also hope you have a little bit of spare time to enjoy some of the sights around Toronto.

Au nom de la Société Canadienne de Génie Biomédical, j'aimerais souhaiter la bienvenue à chacun de vous à Toronto pour le Congrès Mondial sur la physique médicale et le génie biomédical.

Les organisateurs du comité et les innombrables bénévoles ont travaillé très fort pour mettre de l'avant un excellent programme qui inclut également un nombre impressionnant de cours de formation continue.

Je tiens à exprimer ma gratitude pour le soutien des commanditaires et des exposants qui seront sur place du dimanche soir au jeudi pour présenter leurs plus récents produits et services. N'oubliez pas, s'il vous plaît d'en profiter pour prendre quelques minutes pour aller au salon des exposants afin de découvrir les dernières nouveautés et améliorations.

Notez que le CMBES célébre son 50e anniversaire cette année. Nous avons une histoire étonnante et riche fondée par les innovateurs, les scientifiques et les ingénieurs cliniques et biomédicaux, qui ont concentré leurs efforts pour apporter des bénéfices pour la santé des patients, la communauté médicale et le système de santé canadien.

Je vous souhaite une bonne conférence et j'espère que vous profiterez de cette occasion d'apprendre et de partager avec les collègues de la communauté internationale au cours des prochains jours. N'oubliez pas de nous rejoindre pour le dîner de gala du mercredi soir et l'Assemblée Générale du jeudi soir. Enfin, j'espère aussi que vous trouverez un peu de temps libre pour profiter de certains des attrats touristiques de Toronto et sa région.

Sincerely,

Martin Poulin, M.Eng., P.Eng.
President, CMBES/SCGB
Dear Delegates of the 2015 World Congress on Medical Physics and Biomedical Engineering,

On behalf of the Canadian Organisation of Medical Physicists and the Medical Physics community in Canada, Welcome to Toronto!

The theme for this year’s World Congress is “Health * Technology * Humanity”. I believe this captures the spirit of this meeting, and explains why it is so important that Medical Physicists and Biomedical Engineers meet together, and on a world scale. Medical technology is increasingly central in patient care; we as Physicists and Engineers are uniquely trained and able to improve human health through technology. The World Congress is the most comprehensive medical technology meeting in the world; this year we are welcoming delegates from 89 countries from all corners of the world to come to Toronto and share our knowledge and ideas to help improve human health for everyone.

COMP is very pleased to be able to contribute to improving global health through our contributions to this meeting. The planning for this meeting has been underway in earnest for about 20 months now, and we are grateful for the many volunteers who have committed much time and effort to plan this meeting for you. COMP is also grateful to our partner organisation in this event, the Canadian Medical and Biological Engineering Society, for co-organising the event with us. I believe that both societies are benefited tremendously through the interactions and planning with our partners. We are also grateful to the World Organisations, the IUPESM, IOMP and IFMBE, for giving us the opportunity to plan the premier Medical Physics and Biological Engineering conference in the world. It has been a privilege to host this event, and we are proud to be able to bring it to you.

I would like to reserve my greatest thanks to you, the delegates attending this meeting. This meeting will offer a world class program of talks and education sessions, covering 19 different tracks that could not be possible without your contributions. Without your hard work, commitment and enthusiasm for medical technology, this meeting would not be possible.

Thank you for making the trip to Toronto, and enjoy the meeting!

Marco Carlone, PhD
President, COMP
HOSTS & COMMITTEES

HOSTS

International Union for Physical and Engineering Sciences in Medicine (IUPESM)

The IUPESM represents the combined efforts of more than 40,000 medical physicists and biomedical engineers working on the physical and engineering science of medicine. The principal objectives of IUPESM are: (a) to contribute to the advancement of physical and engineering science in medicine for the benefit and wellbeing of humanity; (b) to organize international cooperation and promote communication among those engaged in health-care science and technology; (c) to coordinate activities of mutual interest to engineering and physical science within the health care field, including international and regional scientific congresses, seminars, working groups, regional support programs and scientific and technical publications; (d) to represent the professional interests and views of engineers and physical scientists in the health-care community.

International Organization for Medical Physics (IOMP)

The IOMP represents over 18,000 medical physicists worldwide, 80 adhering national member organizations and 6 regional organizations. The mission of IOMP is to advance medical physics practice worldwide by disseminating scientific and technical information, fostering the educational and professional development of medical physicists, and promoting the highest quality medical services for patients.

International Federation of Medical and Biological Engineering (IFMBE)

IFMBE is primarily a federation of national and transnational organizations. These organizations represent national interests in medical and biological engineering. The objectives of the IFMBE are scientific, technological, literary, and educational. Within the field of medical, biological and clinical engineering IFMBE’s aims are to encourage research and the application of knowledge, and to disseminate information and promote collaboration.

Canadian Organization of Medical Physicists (COMP)

COMP is the main professional body for medical physicists practicing in Canada. The membership is composed of graduate students, professional physicists, scientists, and academics located at universities, hospitals, cancer centers, and government research facilities. Every member has an educational or professional background in physics or engineering as it applies to medicine. COMP’s vision is to be the recognized leader and primary resource for medical physics in Canada. COMP’s mission is to champion medical physicists’ efforts for patient care excellence through education, knowledge transfer, advocacy and partnerships.

Canadian Medical and Biological Engineering Society (CMBES)

CMBES is Canada’s principal society for engineering in medicine and biology. The Society’s aims are twofold: scientific and educational: directed toward the advancement of the theory and practice of medical device technology; and professional: directed toward the advancement of all individuals in Canada who are engaged in interdisciplinary work involving engineering, the life sciences and medicine.
HOSTS & COMMITTEES

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Ratko Magiurevic, Croatia
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CONGRESS VENUE

The IUPESM World Congress 2015 will take place in the South Building of the Metro Toronto Convention Centre. The Convention Centre is located in the heart of downtown Toronto. The South Building is accessible via Bremner Boulevard as well as from the North Building via Front Street.

Metro Toronto Convention Centre
South Building
222 Bremner Boulevard,
Toronto, Ontario, Canada M5V 3L9

Toronto, Ontario, Canada

One of Canada’s best kept secrets, Toronto is on par with New York City, San Francisco and Chicago when it comes to cultural attractions and urban sophistication.

The landmark CN Tower is the tallest freestanding structure in the world. Take the elevator to the top for a breathtaking view of the city, Lake Ontario and more. Stroll next door and experience Ripley’s Aquarium as you explore the wonders of the sea or catch a Blue Jays Baseball game at Rogers Centre or just walk around the massive engineering marvel. Check out the Royal Ontario Museum, the largest in Canada with its fascinating archaeology and natural history exhibits, and the Art Gallery of Ontario, with a fine collection of European and Canadian works. You won’t want to miss the electric shops and restaurants on Queen Street West or the elegant boutiques and fine restaurants in Yorkville.

And there’s more: harbour front is a complex of unique shops and restaurants right on beautiful Lake Ontario. From harbour front you can hop on a ferry to the Toronto Islands for a picnic and outdoor recreation such as beach volleyball.

Explore the area and take a day trip to another wonder of the world and experience Niagara Falls or take a break right next door and experience Ontario’s wine country. Toronto and the surrounding areas are a great family destination and most attractions are child-friendly. The city itself is clean, safe and easy to explore either on foot or by public transportation.
ADOPT A DELEGATE

The IUPESM 2015 World Congress is proud to support the ‘Adopt a Delegate/Student’ initiative, giving prospective delegates from a developed world setting the opportunity to adopt or part finance the registration and accommodation costs of a peer from an emerging economy.

▶ We would like to thank the following people for their consideration and support:

Herbert F. Voigt
David Rogers
David Jaffray
Modus Medical Devices Inc.
Murray Rice
Grace Zeng
William Gentles
Raymond Wu
Ichiro Sakuma
David Spencer
Vincent Lam
Joyce Shen
Tony Easty

SCIENCE FAIR

YOUTH OUTREACH

Winners of a local science fair have been invited to participate in the IUPESM 2015 Youth Outreach Program. 26 youths between the ages of 15–18 will present their 18 Science Fair projects on Wednesday, June 10.

They will start their day by listening to the Key Note Session by Gordon MCBean and Mary Gospodarowicz, followed by attending the session on “What is a medical physicist? What is a biomedical engineer?” After, they are taken on a guided tour of selected posters and the exhibit floor by a Professor. After lunch, their day concludes by presenting their Science Fair projects in the Exhibit Hall, interacting with congress delegates.

FOLLOW US ON SOCIAL MEDIA:

Twitter @IUPESMW2015
www.twitter.com/IUPESMW2015

Facebook
www.facebook.com/groups/WCon2015/

DOWNLOAD THE MOBILE APP:

Abstracts Online/ Personal Itinerary Builder

Attendees are invited to utilize the World Congress 2015 App, which is available for download on the Congress Website at WC2015.org

This app allows you to view abstracts, presenters, the program schedule and sessions, selecting abstracts and sessions of interest to build your own personal itinerary builder.
Flat Albert is a flat version of very well known Albert Einstein.

We encouraged you to take a picture of Flat Albert in an interesting place and post it to our Facebook and Twitter pages #wc2015yyz.

Here are some of our favourites:
Registration Counter Hours

Registration is located on Level 600, South Building of Metro Toronto Convention Centre.

Sunday, June 7  11:00 – 20:00
Monday, June 8  07:00 – 17:30
Tuesday, June 9  07:00 – 17:30
Wednesday, June 10  07:00 – 17:30
Thursday, June 11  07:00 – 17:30
Friday, June 12  07:00 – 13:00

The Toronto Information Desk is located in the Registration area on Level 600, South Building of Metro Toronto Convention Centre. Staff will provide local information and assist with:

- Ground Transportation
- Airport Transfers
- Sightseeing Tours
- Pre- and Post Tours
- Restaurant recommendations and booking
- Local PA and Personal Concierge Services

Delegate Help Desk

Delegate Help Desk is located on Level 600, South Building of Metro Toronto Convention Centre.

Delegate Bag Booth

Delegate Help Desk is located on level 600, South Building of Metro Toronto Convention Centre

Sunday, June 7  11:00 – 20:00
Monday, June 8  07:00 – 17:30
Tuesday, June 9  07:00 – 17:30

Delegate Bags include:

- Invitation Flyers for Industry Supported Symposia
- Additional Promotional Flyers from Sponsors and Exhibitors

Name Badges

Delegates and guests are requested to wear their name badge at all times in order to participate in the Scientific Sessions, Social Events and Exhibition.

Lost Badge/Name Changes:
A 50 CAD fee applies for any reprints due to onsite name changes or lost badges.

Registration Materials

Registration Materials include:

- Name Badge
- Delegate Bag Voucher
  (not included in Accompanying Person Registration)
- Onsite Program Book Voucher

Badge Color Identification

Delegate – Blue
- Access to all Scientific Program & Continuing Education Sessions (except any specially ticketed sessions)
- Access to Exhibit Hall
- Congress Bag
- Onsite Program and Congress Handouts
- Welcome Reception
- Networking Breaks
- Discounted Gala Dinner Ticket

Single Day – Red
- Access to all Scientific Program & Continuing Education Sessions (except any specially ticketed sessions) on day of attendance
- Access to Exhibit Hall on day of attendance
- Congress Bag
- Onsite Program and Congress Handouts
- Networking Breaks on day of attendance

Exhibitor – Green
- Access to Exhibit Hall
- Onsite Program and Congress Handouts
- Welcome Reception
- Networking Breaks
- Option to Purchase Gala Dinner Tickets

Accompanying Person - Yellow
- Access to Exhibit Hall
- Welcome Reception
- Networking Breaks
- Discounted Gala Dinner Ticket Rate

LEAD RETRIEVAL
By allowing to have your badge scanned, you are indicating your consent to receive e-mail marketing.

If you require assistance or any information regarding the Congress, please see the staff at the Delegate Information Counter located in the registration area, on Level 600, South Building of Metro Toronto Convention Centre.
Speaker Ready Room

All invited speakers as well as oral abstract presenters are required to report to the Speaker Ready Room at least 24 hours prior to their scheduled presentation in order to upload their presentation slides or to check their previously uploaded slides. Computers are available to preview and upload presentations. Presenters should make sure all fonts appear as expected. No file submissions will be accepted in the session rooms.

The Speaker Ready Room is located in Room 705 on Level 700.

Invited Speakers and Oral / Abstract Presenters

All speakers are asked to be in the session room at least 10 minutes prior to the start of their session.

Poster Presenters

All Poster Presentations/Boards are located in Hall E on Level 800, South Building of Metro Toronto Convention Centre.

Each Poster Board will be shared by two posters on each side. The Poster Boards are identified with Poster Numbers that correspond with the pre-assigned Poster Numbers for each poster presentation. The Poster Numbers are also published in this program book and in the Online Abstract Book.

Poster set up time:
- Sunday, June 7 15:00 – 17:45
- Poster take down:
  - Thursday, June 11 17:00 – 19:00
  (any posters not removed by 19:00 will be discarded by management)

Poster Sessions

Posters will be displayed at all times during the Exhibit Opening Hours each day starting Sunday June 7. Presenters are asked to stand by their poster during the following times to informally answer questions from Congress delegates:

- **Morning & afternoon Networking Breaks:**
  - 10:00 – 10:30 AND 16:30 – 17:00 Monday, June 8 to Thursday, June 11.
- **During the Welcome Reception:**
  - 18:00 – 20:00 on Sunday, June 7.
Abstracts
All accepted and confirmed abstracts are published in the IUPESM World Congress Onsite Program and Abstract Book. This will be available on the Congress website.

All Full Papers accepted by the World Congress will be published by Springer in the IFMBE Proceedings 2015.

Delegate Lounges
The delegate lounges are located in the Exhibit Hall, see floorplan page 35.

Internet Café
The internet café is located in the Exhibit Hall.

Wireless Internet
Wireless internet is available in the public areas of the venue but not the meeting rooms or the Exhibit Hall.

Charging Station & Lounge
The charging station & lounge is located in the Exhibit Hall.

Congress Signage
SUPPORTED BY
RaySearch Laboratories

Water Stations
SUPPORTED BY
ELEKTA

Welcome Reception
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ELEKTA

Networking Breaks
Networking Breaks (hot beverages and snacks) are served on Level 700 at the following times:

- Monday, June 8: 10:00 – 10:30 and 16:30 – 17:00
- Tuesday, June 9: 10:00 – 10:30 and 16:30 – 17:00
- Wednesday, June 10: 10:00 – 10:30 and 16:30 – 17:00
- Thursday, June 11: 10:00 – 10:30
- Friday, June 12: 10:00 – 10:30

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Lost and Found
Lost and found items should be returned/claimed at the registration desk.

Lunch
Lunch will not be provided by the Congress. However, there are plenty of restaurant choices in the area. A café, a convenience store and vending machines are all located within the Centre and there are also numerous restaurant options within a few minutes walk of the Convention Centre:

- SOCO Kitchen + Bar
  Located within the Delta Hotel offers laid back style of eating, with the opportunity to look over Bremner Street on their patio.
- Pita & Grill
  For a lighter meal head to Pita & Grill for a grab and go option.
- 360 Restaurant
  Upmarket Dining with sky high view in the world famous CN Tower.

CAMPEP Accrediation

For Medical Physicists:
The IUPESM 2015 World Congress Continuing Education Program is CAMPEP Accredited for up to 82 MPCEC credits. If you will be applying to CAMPEP for your MPCEC credits following the Congress and have not already paid the $11(CAD) CAMPEP fee then you will be able to pay this fee at the registration desk during registration hours. After the Congress you will be contacted by CAMPEP regarding Accreditation.

For Biomedical Engineers:
The IUPESM 2015 World Congress Continuing Education Program can be used for points towards Clinical Engineering Certification Renewal.
SOCIAL EVENTS

Be sure to join us for these events during the week:

- **Welcome Reception**
  SUPPORTED BY ELEKTA
  Sunday, June 7, 2015  18:00 – 20:00  Exhibit Hall E
  Enjoy some light hors d’oeuvres and a beverage, along with a subdued jazz trio, as you connect with exhibitors. This is your opportunity to network and connect with industry colleagues.

- **Opening Ceremony & President’s Welcome Address**
  Monday, June 8, 2015  10:30 – 12:00  Exhibit Hall F/G
  Your opening ceremony and president’s welcome address will be greeted by Canadian inspired entertainment, followed by the formalities of any President’s Welcome Address. You will hear all about what you can expect to experience throughout the congress and Toronto as your host city!

- **Gala Dinner**
  Wednesday, June 10, 2015  19:00 – 23:00  Exhibit Hall F/G
  After a busy week at the congress, tonight you will enjoy a delicious meal with fellow colleagues and new friends. Roaming entertainment will emerge throughout the evening and an upbeat band will perform top hits after dinner so you can show off your dancing moves.

- **Closing Ceremony & Awards Presentation**
  Friday, June 12, 2015  15:00 – 16:00  Exhibit Hall F/G
  Final remarks from the President, the organizing committees and your incoming officers will be announced here! Be sure to attend to hear where the next congress location will take place!
SOCIAL TOURS

Explore the area and take a day trip to experience one of the world wonders Niagara Falls or take the half day, fun and informative Toronto City Tour.

Niagara Falls Tour

The premium full-day tour of the Falls starts with your hotel pickup in the morning. On our first stop we’ll have time to explore Niagara-on-the-Lake.

www.niagarafallstourism.com/about/niagara-on-the-lake/

“NOTL” Niagara-on-the-Lake is a picturesque town just a few minutes drive outside of Niagara Falls. You’ll enjoy 40 minutes taking pictures and exploring some of the unique shops. Before you actually reach the Falls, we’ll also see the Floral Clock, Niagara River and whirl pool, Sir Adam Beck Power Station, Queenston Heights, and the Spanish Aero Car. During the day, we will make a stop at one of Niagara Falls’ famous wineries. There you will have an opportunity to sample wine before continuing our Niagara Falls adventure. The tour is structured to give you 2-3 hours of free time at the Falls. This gives you plenty of time to add in additional activities you want to do, plus stop for lunch, which is on your own time and budget. Recant the day’s memories on the bus ride back until you’re dropped back at your hotel doorstep.

Toronto City Tour

The half day, fun and informative Toronto City Tour will transport you to some of the city’s most popular sights as you relax aboard our new air-conditioned bus. We will show you over 17 attractions. Our stops include the St. Lawrence Market where you can buy lunch and a stroll through the pedestrian friendly Distillery District.

Shopping Tour

www.premiumoutlets.com/outlets/outlet.asp?id=109

Toronto Premium Outlets features a high end collection of the finest brands for you, your family and your home. Our Tour bus will pick you up from your hotel lobby between and take you the Outlets just 45 minutes outside of Toronto. Once we arrive you will receive a VIP Coupon book plus a special gift just for you from Toronto Premium Outlets management team.

Please go to our website for more details or to book a tour: wc2015.org/events-tours/pre-post-tours/
EXHIBIT INFORMATION

Location
Hall E on Level 800, South Building of Metro Toronto Convention Centre.

Exhibit Hours

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Exhibit Features

- Exhibit Information Booth
- Show Service Provider Desk
- Internet Café
- Food & Beverage Stations
- Delegate Lounges
- Charging Station & Lounge

SUPPORTED BY

RaySearch Laboratories

VARIAN medical systems
## EXHIBITORS

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Accuray | Booth # 3104

Accuray Incorporated is a radiation oncology company that develops, manufactures and sells precise, innovative tumor treatment solutions that set the standard of care with the aim of helping patients live longer, better lives. The company’s leading-edge technologies deliver the full range of radiation therapy and radiosurgery treatments.

American Association of Physicists in Medicine (AAPM) | Booth # 1212

The mission of AAPM, a professional organization of 8,400+ members, is to advance the science, education and professional practice of medical physics. Visit booth #1212 for information on AAPM programs, to see a demonstration of the Virtual Library and to pick up complimentary copies of the Medical Physics journal.

ANDA Medical | Booth # 3604

ANDA Medical provides new and refurbished medical equipment to the global community. By locating medical products from the finest health facilities around the world, we maintain strong relationships with hospitals, medical suppliers, and OEMs. With consistent access to high-quality medical equipment we provide our customers with products at a fraction of the cost. This is our top priority.

ArjoHuntleigh Canada Inc. | Booth # 3213

A medical device company offering innovative solutions in Patient Handling, Therapeutic Surfaces, Medical Beds, Hygiene and Disinfection. ArjoHuntleigh offers programs to ensure facilities meet their needs while providing safe and efficient care.

Bayer Healthcare | Booth # 3503

Bayer’s Radimetrics™ Enterprise Platform is an integrated radiation dose and contrast dose* management solution. Platform tools can help customers drive compliance, efficiency and reproducible quality. Customizable dashboards facilitate enterprise-wide analytics and protocol management. With industry-leading repair capabilities, quality, and customer care, Multi Vendor Service provides the best value in third-party service.

*Requires Medrad® Stellant® CT Injection System/Certegra® Workstation

Best Theratronics | Booth # 3303

Best Theratronics Ltd. is a Canadian component of TeamBest™. We manufacture external beam therapy units (Equinox®, GammaBeam® 100-80, and the new GammaBeam® 500 Total Body Irradiator), blood and research irradiators (Gammacell® 1000 & 3000, Raycell® Mk2, Gammacell® 40E, GammaBeam® X200), and variable energy cyclotrons for radioisotope production and research.

Biomedical Engineering Society (BMES) | Booth # 2709TT

The Mission of the BMES is to build and support the biomedical engineering community, locally, nationally and internationally, with activities designed to communicate recent advances, discoveries, and inventions; promote education and professional development; and integrate the perspectives of the academic, medical, governmental, and business sectors.
**BRACCO® IMAGING Canada | Booth # 2301**

BRACCO® IMAGING Canada, world leader in medical imaging presents the latest contrast injection technologies in Radiology and Cardiac CathLab with ACISTCV™, CTExpress3D™ syringeless injector, and EmpowerCTA+™, with Nexo™ Contrast management and NexoDose™ Radiation Dose softwares. BIC distributes Invivo Corporation technologies (MR compatible patient monitoring, DynaCAD Breast and Prostate, UroNav fusion biopsy system, etc).

**Canadian Organization of Medical Physicists | Booth # 1115**

The Canadian Organization of Medical Physicists is the professional body for medical physicists in Canada. The membership is composed of physicists, scientists and academicians located at universities, hospitals, cancer centres and government research facilities as well as graduate students and post-doctoral fellows. Members have an educational or professional background in physics or engineering as it applies to medicine.

**Brainlab Technology | Booth # 1102**

Brainlab technology powers treatments in radiosurgery as well as numerous surgical fields including neurosurgery, orthopedic, ENT, CMF, spine and trauma. Founded in Munich in 1989, Brainlab has over 8,900 systems installed in about 100 countries.

**CareFusion | Booth # 2202**

At CareFusion, we serve the healthcare industry with products and services that support infection prevention, medication management, operating room efficiency, respiratory care and healthcare analytics products and services. As of March 2015, CareFusion has joined BD to become one of the largest global leaders in the medical technology industry.

**Canadian Medical and Biological Engineering Society | Booth # 2305**

The Canadian Medical and Biological Engineering Society is Canada’s principal society for engineering in medicine and biology. The Society’s mission is to advance and promote the theory and practice of engineering sciences and technology to medicine and biology, serving as a forum for information exchange between healthcare professionals, scientists, and the general public.

Please stop by the CMBES booth # 2513 to find out more about our role, programs, networking opportunities and the 2016 Congress in May, 2016 in Calgary, Alberta.

**Carleton University | Booth # 3406**

Carleton University, located in Canada’s beautiful capital city Ottawa, offers an MASc in biomedical engineering, and MSc and PhD Physics with specialization in medical physics (the PhD is CAMPEP accredited). Our programs are networked with world-class clinical facilities and national laboratories making Carleton a stimulating academic and research environment.

Carleton University, located in Canada’s beautiful capital city Ottawa, offers an MASc in biomedical engineering, and MSc and PhD Physics with specialization in medical physics (the PhD is CAMPEP accredited). Our programs are networked with world-class clinical facilities and national laboratories making Carleton a stimulating academic and research environment. carleton.ca

**Canadian Nuclear Safety Commission | Booth # 1228**

The Canadian Nuclear Safety Commission, Canada’s independent nuclear regulator, regulates the use of nuclear energy and materials to protect health, safety, security and the environment and to implement Canada’s international commitments on the peaceful use of nuclear energy; and to disseminate objective scientific, technical and regulatory information to the public.

**CDR Systems | Booth # 1127**

A global company CDR Systems offers proven next generation Frameless SRS, SRT, IMRT, IGRT, SBRT, Breast, Pelvis and H&N precision patient positioning and Immobilization products used by leading organizations worldwide. See why at our booth or email to arrange a demo. You can also keep in touch with the latest advancements in patient immobilization at: twitter.com/CDRSys and online www.cdrsyst.ca
CIMTEC builds and tests clinical prototypes in the broad areas of 3D visualization, image analysis and mechatronics design with specific expertise in image-guided interventions and digital pathology. Through technology development, business advice, and clinical testing, CIMTEC helps researchers, startups and small to medium-sized companies commercialize their medical imaging innovations.

CIRS is recognized worldwide for tissue simulation technology and is the leader in the manufacture of phantoms and simulators for radiation therapy QA and dosimetry, diagnostic imaging and quality assurance as well as training and demonstration phantoms for CT, mammography, ultrasound, MRI, radiation therapy, fluoroscopy, radiography and emerging modalities.

Covidien is a leading global healthcare products company that creates innovative medical solutions for better patient outcomes and delivers value through clinical leadership and excellence. Please visit www.covidien.com to learn more about our business.

CRC Press/Taylor and Francis is a leading international publisher of references, textbooks and professional handbooks in medical physics and biomedical engineering. Visit our booth to browse and enter to receive special prizes and discounts on new and bestselling titles. Editors Francesca McGowan (francesca.mcgowan@tandf.co.uk) and Michael Slaughter (Michael.Slaughter@taylorandfrancis.com) will be available to discuss new project ideas.

The Accelerated Education Program is putting innovation to work through education dedicated to promoting essential aspects of clinical care. Learning environments are engaging, creative and interactive, putting the focus on interprofessional activities that enhance team work. The goal of AEP is to deliver relevant, excellent programming for all radiation medicine professionals.

As an international leader in medical and safety technology, Dräger develops innovative equipment and solutions that people the world over trust. No matter where Dräger products are used, it’s always about life. Whether for use in the OR, ICU or Neonatal Care, Dräger products protect, support and save lives.

For over 65 years, Dunlee has remained at the forefront of medical imaging as an international leader in research, design, and manufacturing of high-performance replacement tubes for CT and general radiography. We also offer Technical Webinars and the Dunlee App, which features the Dunlee Academy, a virtual tube installation guide.

ECRI Institute is an independent nonprofit with more than 40 years of experience researching the best approaches to improving patient care. Our unbiased, evidence-based research, information, and advice help you address patient safety, quality and risk management challenges, procure cost-effective technology, and align capital investments with strategic technology needs.
Elekta | Booth # 1202

Elekta is a human care company pioneering significant innovations and clinical solutions for treating cancer and brain disorders. The company develops sophisticated, state-of-the-art tools and treatment planning systems for radiation therapy, radiosurgery and brachytherapy, as well as workflow enhancing software systems across the spectrum of cancer care.

Engineering World Health | Booth # 2713TT

Engineering World Health works with students and the BME community to improve healthcare delivery in developing world hospitals. We build local capacity to maintain medical equipment, make repairs, and develop low-cost technologies. Visit us to learn about our Summer Institute and making a lasting impact on developing world health care!

Fibertech | Booth # 2503

Fibertech continues to be the number #1 hospital equipment service facility in Canada. Specializing in repair of flexible and rigid endoscopes, rigid instrumentation, power tools and phaco hand pieces. Training and education programs provide a complete experience for our customer.

Fluke Biomedical / Unfors RaySafe | Booth # 3112

Together Fluke Biomedical and Unfors RaySafe strive to improve the quality of global health, one measurement at a time. We provide most reliable quality assurance solutions to make medical equipment safer to use. We serve biomedical engineers, quality-assurance technicians, medical physicists, oncologists, and radiation-safety professionals. For more information, visit www.flukebiomedical.com.

Fluke Biomedical / Unfors RaySafe | Booth # 3112

Fluke Biomedical is a company dedicated to selling high quality healthcare care products, and services to Radiation Oncology, Nuclear and Radiological imaging centers throughout Canada. With over 35 years of experience in the Canadian health care industry we have developed a reputation of providing outstanding customer service throughout the industry.

IBA | Booth # 1331

IBA is a global medical technology company focused on bringing integrated and innovative solutions for the diagnosis and treatment of cancer. The Company is the worldwide technology leader in the field of proton therapy. IBA also has a radiation dosimetry business and develops particle accelerators for the medical world and industry.
IEEE Engineering in Medicine and Biology Society | Booth # 2104

IEEE Engineering in Medicine and Biology Society is the world’s largest society of biomedical engineers. We provide access to people, practices, information, ideas and opinions shaping one of the fastest growing, technical fields. EMBS focuses on development and application of engineering concepts/methods to provide solutions to medical and healthcare problems.

Institution of Engineering and Technology | Booth # 2715TT

The IET journals portfolio offers high quality research in a number of topic areas including medical and biomedical research. Healthcare Technology Letters, IET Image Processing, IET Nanobiotechnology and IET Systems Biology are all key journals in this fast-paced field and considered an invaluable source for researchers and practitioners. Find out more at www.ietdl.org/journals.

International Federation for Medical and Biological Engineering (IFMBE) | Booth # 2309

The International Federation for Medical and Biological Engineering (IFMBE) is primarily a federation of national and transnational societies. These professional organizations represent interests in medical and biological engineering. The IFMBE is also a Non-Governmental Organization (NGO) for the United Nations and the World Health Organization (WHO), where we are uniquely positioned to influence the delivery of health care to the world through Biomedical and Clinical Engineering.

International Organization for Medical Physics (IOMP) | Booth # 1119

International Organization for Medical Physics (IOMP) represents over 18,000 medical physicists worldwide and 80 national member organisations.

The mission of IOMP is to advance medical physics practice worldwide by disseminating scientific and technical information, fostering the educational and professional development of medical physicists, and promoting the highest quality medical services for patients.

International Union for Physical and Engineering Sciences in Medicine (IUPESM) | Booth # 3214

IUPESM is a non-profit scientific NGO. The founding constituent organizations are IFMBE and IOMP. The objective is to contribute to the advancement of physical and engineering science in medicine for the well-being of humanity. IUPESM is the custodian of the triennial World Congress for Medical Physics and Biomedical Engineering.

IOP Publishing | Booth # 1103

IOP Publishing (ioppublishing.org) provides a range of journals, books, websites, magazines, congress proceedings and services through which leading-edge scientific research is distributed worldwide. Visit our stand to find out more about IOP Biosciences - our journals publishing in a number of fields, including medical physics, biomedical engineering and biophysics.

IPEM | Booth # 3606

Institute of Physics and Engineering in Medicine (IPEM) is dedicated to bringing together physical science, engineering and clinical professionals in academia, and healthcare to share knowledge, advance science/technology and inform/educate the public with the purpose of improving the understanding, and treatment of disease and management of patients.

iRT Systems | Booth # 1124

iRT is a new company founded in 2013 to introduce innovative new products into the radiation therapy market with the goal to improve patient safety and the overall quality of treatment.

Our first project is the development and certification of the Integral Quality Monitor (IQM) System, a revolutionary new device for real-time quality assurance.

LAP Laser | Booth # 1214

LAP of America Laser Applications, L.L.C has been delivering state of the art patient alignment laser systems for radiation therapy, nuclear medicine, and diagnostic radiology since 1997. Building on a strong tradition of excellence in the medical industry LAP has become the world leader in patient alignment laser systems.
MAQUET-DYNAMED

Swedish Group of companies GETINGE AB. The MAQUET brand represents the Medical Systems Business area and together with two other Business Areas ARJO Extended Care and GETINGE Infection Control, the entire GETINGE group of companies focuses on forward-looking medical technology.

ACMIT | Booth # 3203, 3206

ACMIT is a translational research center focused on technology for minimally invasive surgery that combines multidisciplinary know-how with that of international experts. The organizational structure of ACMIT reflects the quest for scientific excellence and successful technology development. ACMIT’s goal is to bring developments to their real use in clinical context within reasonable time.

CTMH | Booth # 3203, 3206

CTMH is collaboration between Karolinska Institutet, Royal Institute of Technology and Stockholm County Council to help develop the region as a world-class medical technology center. CTMH creates venues and activities that stimulate and develop exchanges between industry, academia and health care in the boundaries between technology, health, research and application.

Hong Kong Science & Technology Parks Corporation (HKSTP) | Booth # 3203, 3206

HKSTP is a statutory body dedicated to building a vibrant innovation and technology ecosystem to connect stakeholders, nurture technology talents, facilitate collaboration, and catalyse innovations to deliver social and economic benefits to Hong Kong and the region.

Institute of Biomedical Engineering | Booth # 3203, 3206

The Institute of Biomedical Engineering is a leading university-based deliverer of medtech R&D and innovation. The IBME brings together businesses, clinicians and academics to establish the technical feasibility, clinical desirability and commercial viability of cutting edge medical technology. We’re pioneering this engagement through both our MedTech Accelerator Programme and our PhD training scheme.

Medical Valley EMN | Booth # 3203, 3206

The Medical Valley EMN (e.V.) association assumes key tasks in the medical technology cluster and supports all members with comprehensive services. The association facilitates knowledge exchange, promotes the cluster internationally, and supports start-up companies. The overall goal is to develop the EMN area into a model region for optimal healthcare.

Morgridge Institute for Research | Booth # 3203, 3206

The Morgridge Institute for Research is a private, nonprofit biomedical research institute in Madison, Wis., affiliated with the University of Wisconsin–Madison. The institute works to improve human health by conducting, enabling and translating interdisciplinary biomedical research. Current research includes regenerative biology, virology, medical engineering and core computational technology.

Ontario Brain Institute | Booth # 3203, 3206

The Ontario Brain Institute is a provincially-funded, not-for-profit research centre seeking to maximize the impact of neuroscience and establish Ontario as a world leader in brain research, commercialization and care. We create partnerships between researchers, clinicians, industry, patients, and their advocates to foster discovery and deliver innovative products and service.
Sunnybrook Research Institute | Booth # 3203, 3206

Sunnybrook Research Institute (SRI) is the research enterprise of Sunnybrook Health Sciences Centre and is affiliated with the University of Toronto. Scientists at SRI strive to understand and prevent disease, and to develop treatments that enhance and extend life. They are renowned for excellence in the biological, physical and evaluative clinical sciences.

Techna | Booth # 3203, 3206

Techna is an institute of University Health Network, in collaboration with the University of Toronto, focused on the accelerated development and exploitation of technology for improved health. Techna is designed to shorten the time interval from technology discovery to application through a continuum of clinically driven innovation, technology & process development.

Thunder Bay Regional Research Institute (TBRRI) | Booth # 3203, 3206

Established in 2007 as Canada’s newest molecular imaging and advanced diagnostics research institute, TBRRI is now the research arm of the Thunder Bay Regional Health Sciences Centre. Currently Scientists, Physician Researchers and Clinicians are engaged in research which contributes to innovative treatments and improved diagnostic tools.

MedView Technologies | Booth # 2213

MedView was founded in 2013 to commercialize a highly innovative & proprietary technology based on Spatially Resolved Difusive Reflectance Spectroscopy, with potential applications in the medical diagnostics, pharmaceutical manufacturing, and food/material inspection fields. We are currently developing a vein detection medical device, with potential market size of up to $4B.

MIM Software Inc. | Booth # 2205

MIM Software Inc. provides practical imaging solutions in the fields of radiation oncology, radiology, nuclear medicine, urology, neuroimaging, and cardiac imaging. MIM offers solutions for computer workstations, as well as mobile and cloud-based platforms. MIM products are sold globally to imaging centers, hospitals, specialty clinics, research organizations, and pharmaceutical companies.

Mobius Medical Systems | Booth # 1323

Mobius Medical Systems provides the radiation oncology community with innovative software to streamline quality assurance. Mobius3D and MobiusFX are the first solutions for full 3D verification of both patient plan and delivery. Reclaim your nights and weekends! MobiusFX provides comprehensive patient specific QA in as little as one minute.

Modus Medical Devices Inc. | Booth # 1309

For 15 years, QUASAR™ has inspired physicists worldwide to seek the highest quality assurance standards in the field of medical imaging and radiotherapy. With 3,000 phantoms in over 1,800 treatment centres, Modus products are built to provide you with confidence that every patient is receiving the best possible treatment.

NELCO | Booth # 1205

NELCO is the worldwide leader in the design, manufacturing and construction of radiation shielding products and facilities for radiation therapy and diagnostic imaging. NELCO’s 80 year dedication to customer service, quality, and innovative products has resulted in over 4000 radiation therapy doors installed worldwide and over 5000 customers.

Olympus Canada Inc. | Booth # 2112

Olympus develops leading edge technology for healthcare professionals that help improve outcomes and enhance quality of life for patients. Visit us at Booth #2112 in the exhibit hall or on-line at www.olympuscanada.com
ImSimQA software is a complete toolkit for performing QA on Deformable Image Registration algorithms. OnQ RTS is an automated clinical system for performing Adaptive Planning functions including Deformable Image Registration. Add function without adding process to your department. Canadian distributors of MacroMedics immobilization and patient positioning devices.

Orfit Industries America | Booth # 1211

Orfit supplies High Precision Immobilization Systems including Adult / Pediatric Head/Neck systems using Frameless full and open face masks. MammoRx Breast Boards, SBRT Systems, Prone Breast Solutions, Extremities, Pelvis/Abdomen, Proton and MR Compatible systems are available.

Precision, reproducibility, ease of use, high patient comfort are hallmarks of the systems.

Pacific Medical LLC | Booth # 2106

Pacific Medical LLC specializes with providing PARTS and REPAIR SERVICES for Patient Monitors, Modules, Telemetry, Infusion Pumps, Suction Regulators, Fetal Transducers, SpO2/ECG/TEMP/NIBP Cables, O2 Blenders, Endoscopes and Gas Analyzers. Pacific Medical carries the largest patient monitoring inventory in our industry and is recognized for its customer service response team.

For more information visit: www.pacificmedicalsupply.com.

PartsSource | Booth # 2209

PartsSource is a leading provider of supply chain solutions for medical replacement parts for providers, Independent Services Organizations and OEMs in the healthcare industry who need to innovate their procurement process to reduce their overall sourcing costs.

Physio-Control | Booth # 2306

LIFEPAK® defibrillator/monitors and automated external defibrillators from Physio-Control set the standard for quality and reliability and are used by more physicians, hospitals and emergency medical services than any other brand. Physio-Control continues to lead the industry through innovation and advanced technology. For more information, visit our website at www.physio-control.com.

Precision X-Ray | Booth # 1210

Precision X-Ray is the leading provider of safe, high output X-Ray irradiators used in modern translational cancer research. It’s our mission to continually develop X-ray systems that help researchers globally to better understand radiation induced effects in the sciences of molecular biology and cancer research.

PTW | Booth # 1220

Since 1922 PTW has been a dosimetry pioneer, growing into a global market leader for high-tech dosimetry solutions, well-known for their product excellence and innovative strength. Today, PTW dosimetry products are the first choice by healthcare professionals in radiotherapy, diagnostic radiology, nuclear medicine and health physics. For more information, visit www.ptwny.com.

Qfix | Booth # 1327

Qfix provides state-of-the-art patient positioning and immobilization devices to optimize patient outcomes. The Qfix kVue™ IGRT Couch Top design allows customization for individual patient needs through the most advanced array of treatment solutions for head and neck, breast, lung, prostate and other disease sites. Please visit www.Qfix.com for more information.

Radcal Corporation | Booth # 3204

Radcal is synonymous with quality non-invasive diagnostic x-ray meters and ion chambers. The Accu-Gold Family of meters utilizes Radcal ion chambers and solid-state Multisensors for all your parameter measurements in all modalities. The newest addition to the Family is the Accu-Dose+ and WiFi data transmission.

Radiological Imaging Technology Inc. | Booth # 1213

RIT manufacturers RIT113 Radiation Therapy Dosimetry software, and RADIA software for automated QC phantom analysis. RIT software packages are designed to enable QA on all aspects of modern radiation therapy and diagnostic imaging, including TG-142 for linear accelerators, TG-148 for helical tomotherapy, and ACR CT and MRI testing.

Raysearch Laboratories | Booth # 1219

RaySearch is a medical technology company that develops advanced software solutions for improved radiation therapy of cancer. RaySearch markets the RayStation® treatment planning system to clinics all over the world. In addition, RaySearch’s products are distributed through licensing agreements with leading medical technology companies. RaySearch’s software is used by over 2,500 clinics in more than 65 countries.

RTI (From Radiation to Information) | Booth # 1125

RTI provides complete quality assurance solutions for all X-ray modalities and facilities. We have “click & go” solutions for X-ray quality assurance of X-ray modalities and facilities. Everything between basic service to specialists. Our X-ray multimeter scan “do it all in one shot” – kV, time, dose, dose rate, HVL, pulsed fluoroscopy and total filtration.

Shimifrez | Booth # 2214

Shimifrez is the world’s most trusted name in micro, thin metal manufacturing, utilizing precision photo chemical machining (PCM). PCM produces highly accurate and identical thin metal components for small & large batches. PCM eliminates the cost of hard tooling, improves design flexibility and shortens lead times (72 hours) while eliminating burring and stress problems.

Southwest Medical Resources | Booth # 2210

Southwest Medical Resources is a world class independent service organization offering complete sales, service and rental solutions for Diagnostic Imaging Equipment. Our leadership in the industry is driven by a team of experts and unmatched resources. We exist to bring quality and value to our customers.

Spacelabs Healthcare | Booth # 2114

Spacelabs Healthcare’s philosophy is to develop innovative medical devices to provide the best care experience for not only the patient and the clinician, but also the patients’ families. Providing devices that help reduce stress can help enhance the experience for both patient and visitor alike.

Spectrum Technologies, Inc. | Booth # 2412

Spectrum Technologies, Inc. provides test instrument calibration and repair for the biomedical, commercial, and industrial markets. On-site services are available regionally and depot services are available worldwide. Our main office is in Pennsylvania with branch offices strategically located across the USA and two in Canada. Our website: www.goSTI.cc Email: info@goSTI.cc

Springer | Booth # 2311

Looking to publish your research? Discover Springer’s print and electronic publication services, including Open Access! Get high-quality review, maximum readership and rapid distribution. Visit our booth or springer.com/authors. You can also browse key titles in your field and buy (e)books at discount prices. With Springer you are in good company.

Standard Imaging | Booth # 1110

Dedication to customer service, forging partnerships and fostering innovation helps Standard Imaging pave an intuitive path to superior QA. Beginning with the HDR 1000 Well Chamber to the W1 Scintillator and PiPSpro Software today, Standard Imaging provides its customers with practical, precise products for their QA needs.
Sun Nuclear Corporation (SNC) | Booth # 1329

Sun Nuclear Corporation (SNC) is the worldwide market share leader in QA and Dosimetry solutions for Radiation Oncology. While others speak of innovation, we live it. Our mission is to provide you with better outcomes that save time. SNC supports FFF Beams, VMAT, IMRT, SRS, TomoTherapy, CyberKnife, and Conventional external beam treatments.

Synaptive Medical | Booth # 3404

Synaptive Medical has dedicated more than 50 engineers and scientists specifically to the development of neurosurgical technologies. The result? Our BrightMatter™ Neurosurgery Products provide advanced tools and information for surgeons and hospitals to focus on patient outcomes.

Technical Prospects | Booth # 2102

Technical Prospects has been in business over 18 years, providing quality Siemens parts and service to nearly 500 customers worldwide. As a well-known medical imaging parts reseller, our main objective is to provide quality parts and service, technical support, maintenance services and training to medical facilities and health care providers.

The Phantom Lab/Image Owl | Booth # 1209

The Phantom Laboratory (www.phantomlab.com) manufactures medical imaging and radiation therapy phantoms. In addition to our standard products we offer custom and OEM phantoms. We also work with Image Owl (www.imageowl.com) to provide fully automated, cloud-based, CT, MR and DBT image quality measurement and database services.

Tropical Health & Education Trust (THET) | Booth # 2511

THET is a specialist global health organisation that educates, trains and supports health workers through partnerships; enabling people in low and middle-income countries to access essential healthcare. THET helped develop the first Biomedical Engineering training course in Zambia and are working with Government to improve medical equipment management and maintenance.

University of Waterloo, Engineering | Booth # 2414

Waterloo Engineering is home to 60+ researchers focused in biomedical engineering and biotechnology, who produce advancements in pharmaceutical delivery systems, affordable imaging systems, software solutions for healthcare and more. With strong partnerships in industry, healthcare and government, our researchers create next-generation technology to tackle the world’s toughest biomedical problems.

USOC Medical | Booth # 2201

USOC Medical provides biomedical equipment repair solutions to healthcare facilities, clinics and medical companies of all types and sizes. We are committed to providing high-quality, cost-effective equipment and services to all of our clients. Each member of our organization is dedicated to excellence and continual organization and professional improvement.

Varian Medical Systems | Booth # 1234

Varian Medical Systems is a leading manufacturer of medical devices for treating cancer and other conditions with radiotherapy, radiosurgery, proton therapy, and brachytherapy. The company also produces informatics software for managing comprehensive cancer clinics. Varian is a premier supplier of tubes, digital detectors, and image processing workstations for X-ray imaging. www.varian.com
Western Medical Biophysics and BME | Booth # 3507

Welcome to Canada’s first Biophysics Department – home to 90 researchers and 100 graduate students. Working closely with research institutes and hospitals, we offer unique training opportunities in biomedical imaging, cardiovascular studies (microcirculation & hemodynamics), biomechanics, and cancer diagnosis & therapy, using a wide range of experimental and computational techniques.

World Congress 2018, Prague | Booth # 3311

The IUPESM World Congress 2018 will be held in Prague, Czech Republic on June 3 - 8, 2018. For constant updates please visit www.iupesm2018.org.

We invite you to visit our booth No. 3311 to try to win a FREE REGISTRATION for IUPESM 2018.

World Congress 2021, Candidate City - Mexico City | Booth # 3307

The Mexican Society of Biomedical Engineering (SOMIB) serves as the lead society and professional home for biomedical engineering. Our main mission is to promote and enhance knowledge and education in biomedical engineering nationwide and its utilization for human health and well-being. www.somib.org.mx

World Congress 2021, Candidate City – Singapore | Booth # 3614

Choose Singapore for 2021 World Congress - Singapore is excited to put forth a bid to host the IUPESM World Congress in 2021, the first time it will be held in South East Asia. We are ready to welcome the global community of medical physicists and biomedical engineers to our multi-cultural city.

World Congress 2021, Candidate City – Taipei | Booth # 3212

The IUPESM 2021 World Congress (WC-2021) has proposed to be hosted in Taipei, an international city with convenient and well-equipped facilities, by the Chinese Society of Medical Physics, Taipei and Taiwanese Society of Biomedical Engineering together. Many supports from local hospitals and related industrial companies will be offered for this important meeting. We believe that Taipei will be the optimum choice for this worldwide event in 2021.

World Health Organization | Booth # 3313

The World Health Organization is a U.N. specialized agency with a mandate as the directing and coordinating authority of international public health work. Through its 6 regional offices, 147 country offices, 8000+ staff, and collaborators the WHO strives towards: “Attainment by all peoples of the highest possible level of health.” The World Health Organization is a U.N. specialized agency with a mandate as the directing and coordinating authority of international public health work. Through its 6 regional offices, 147 country offices, 8000+ staff, and collaborators the WHO strives towards: “Attainment by all peoples of the highest possible level of health.”

Xoft, a subsidiary of iCAD, Inc. | Booth # 1129

iCAD delivers innovative cancer detection and radiation therapy solutions and services that enable clinicians to find and treat cancers earlier and while enhancing patient care. iCAD’s Xoft® Axxent® Electronic Brachytherapy (eBx®) System® delivers high dose rate, low energy radiation, which targets cancer while minimizing exposure to surrounding healthy tissue. For more information, visit www.icadmed.com.

Zimmer Canada | Booth # 2303

Founded in 1927 and headquartered in Indiana, Zimmer designs, develops, manufactures and markets orthopaedic reconstructive, spinal, trauma and dental implants, plus related surgical products. Zimmer has operations in more than 25 countries and sells products in more than 100 countries. The Company is supported by more than 8,500 employees worldwide.
Visit Elekta at the World Congress of Medical Physics and Biomedical Engineering 2015 in Toronto Canada and discover how we are bringing information-guided cancer™ care to you.

Stop by our booth # 1202 to learn more about the latest innovations in:

- Monaco® - Complete treatment planning system
- MOSAIQ® - Oncology information system
- AQUA - Machine quality management
- Oncentra® brachy planning (v4.5) - Comprehensive treatment planning for brachytherapy
- Flexitron® treatment delivery - Afterloading platform

Also, please join us for lunch where Stanley Benedict of University California Davis will discuss:

“New Technology Developments to Improve Patient Safety in Radiation Therapy”.

Learn how a better focus on safety in technology can deliver better precision, better reliability and better outcomes. This is an important guidance for Elekta and consistent with the stated goals of ASTRO, ACR and more.

Presenter:
Stanley H. Benedict, Ph.D., DABR, FAAPM
Professor & Vice Chair of Clinical Physics
Department of Radiation Oncology
University of California at Davis Comprehensive Cancer Center

June 9th, 2015
12:15 - 1:15 pm EST
Metro Toronto Convention
Center Room 718A

Please register at: http://www.elekta.com/wc2015symposium
### INDUSTRY SUPPORTED SYMPOSIA

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<th>Date</th>
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<tr>
<td>Monday, June 8, 2015</td>
<td>12:15 – 13:15</td>
<td>Room 718A</td>
<td>RaySearch Laboratories</td>
<td>Advancing Radiation Therapy through Software Innovation</td>
<td>Delegates are welcome to attend RaySearch's Lunch Symposium. It will show how software will be the driving force of innovation in radiation therapy and notably in adaptive therapy.</td>
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<tr>
<td>Tuesday, June 9, 2015</td>
<td>12:15 – 13:15</td>
<td>Room 718A</td>
<td>ELEKTA</td>
<td>New Technology Developments to Improve Patient Safety in Radiation Therapy</td>
<td>Learn how a better focus on safety in technology can deliver better precision, better reliability and better outcomes. This is an important guidance for Elekta and consistent with the stated goals of ASTRO, ACR and more.</td>
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<td>Wednesday, June 10, 2015</td>
<td>12:15 – 13:15</td>
<td>Room 716B</td>
<td>CareFusion</td>
<td>Improving Medication Safety through Infusion Pump Auto-Programming and EMR System Interoperability</td>
<td>Interoperability between infusion systems and a hospital EMR presents new opportunities for improving IV infusion safety, patient care and clinical workflow. At this event, attendees will have the opportunity to learn about experiences with system integration and the benefits it brings to patients, clinicians, IT, BioMed and Informatics.</td>
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<td>Thursday, June 11, 2015</td>
<td>12:15 – 13:15</td>
<td>Room 714B</td>
<td>ACCURAY</td>
<td>Accuray’s Innovative Radiation Therapy and Clinical Benefits</td>
<td>Through close collaboration with our customers, we have developed premier oncology tools that meet the needs of clinicians and the demands of any oncology department. Our portfolio of products allows clinicians to treat tumors of all sizes, regardless of their location in the body. Please join us to learn more about Accuray’s offerings in the radiation therapy field.</td>
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### PROGRAM AT A GLANCE

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<td><strong>OPENING CEREMONY</strong></td>
<td><strong>INDUSTRY SYMPOSIUM SUPPORTED BY RAYSEARCH</strong></td>
<td><strong>THEME PLENARY KEYNOTE SESSION - MONIQUE FRIZE &amp; LONDA SCHIEBINGER</strong></td>
<td><strong>THEME PLENARY KEYNOTE SESSION - JEFF IMMELT</strong></td>
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**Program at a Glance**

- **THEME PLENARY KEYNOTE SESSION - GORDON MCBEAN & MARY GOSPODAROWICZ**
- **NETWORKING BREAK**
- **WORLD SUMMIT ON THE SUPPORT-ABILITY OF MEDICAL DEVICES**
- **CONTINUING EDUCATION SESSIONS (ENGLISH, FRENCH, SPANISH)**
- **IAPME GENERAL ASSEMBLY**
- **THEME PLENARY KEYNOTE SESSION - EDWARD SHORTLIFFE & VIMLA PATEL**
- **NETWORKING BREAK**
- **INDUSTRY SYMPOSIUM SUPPORTED BY CAREFUSION**
- **SCIENTIFIC SESSIONS INCLUDING PRESIDENT’S CALL**
- **IFMBE STUDENT DESIGN COMPETITION PRESENTATIONS**
- **CONTINUING EDUCATION SESSIONS (ENGLISH)**
- **ADDRESSING GLOBAL CHANGES**
- **CLOSING CEREMONY & YOUNG INVESTIGATORS AWARDS PRESENTATION**
- **GALA DINNER**
- **EXHIBIT & POSTER HALL HOURS**
  - **09:30 – 17:00**
Monday, June 8 2015

**PL01.1 Engaging Women and Men for a Better Future Worldwide**

**Speaker(s): Monique Frize**

Systems and Computer Engineering, Carleton University, Ottawa/ON/CANADA

From the three approaches suggested by Londa Schiebinger to harness the power of gender analysis, this part of the presentation deals with the first two: “Fixing the number of women” and “fixing the institutions”. Women and men can generate and participate in activities that lead to an increased participation of women in biomedical engineering and medical physics. Evidence also exists, demonstrating that there are economic benefits and more complete solutions created by gender balanced design teams and an increased number of women in decision-making bodies such as corporate boards, management teams in industry, government, and universities. It is critical to collect sex disaggregated data on undergraduate post-secondary enrolments and graduations in science and engineering, as well as to understand the gender participation in the workplace in these fields. Examining the issues that limit women’s participation at all levels is a first step, which can then be followed by the development and implementation of strategies that help eliminate gender bias and provide the necessary support for women to have a successful career in these fields.

**PL01.2 Gendered Innovations in Health & Technology**

**Speaker(s): Londa Schiebinger**

Stanford University, Stanford, United States of America

How can we harness the power of gender analysis to discover new things? Schiebinger identified three major approaches to gender in science research, policy, and practice: 1) “Fix the Numbers of Women” focuses on increasing women’s participation; 2) “Fix the Institutions” promotes gender equality in careers through structural change in research organizations; and 3) “Fix the Knowledge” or “gendered innovations” stimulates excellence in science and technology by integrating sex and gender analysis into research. This talk focuses on the third approach. Gendered Innovations: 1) develops state-of-the-art methods of sex and gender analysis for scientists and engineers; and 2) provides 24 case studies as concrete illustrations of how sex and gender analysis leads to new ideas and excellence in research. Several case studies will be discussed, including stem cells, assistive technologies for the elderly, and osteoporosis in men. All case studies can be found at: http://genderedinnovations.stanford.edu/. To match the global reach of science and technology, this project was developed through a collaboration of over sixty experts from across the United States, Europe, and Canada (and has now extended to Asia). Gendered Innovations was funded by the National Science Foundation, the European Commission, and Stanford University.
Tuesday, June 9 2015

PL02.1 Innovation, Healthcare and the Future
Speaker(s): Jeff Immelt
Chairman and CEO of GE, Fairfield/CT/UNITED STATES OF AMERICA

Jeff Immelt, Chairman & CEO of GE, will talk about healthcare innovation and how GE has been repositioning its business to succeed in a market that is demanding more technology, more flexibility and more tailored solutions.

Wednesday, June 10 2015

PL03.1 The Changing Urban Environment and Health in a Future Earth
Speaker(s): Gordon McBean
Western University, London/ON/CANADA

Around our planet there have been increasing numbers of disasters due to floods, storms, earthquakes and other natural hazards. Although earthquakes are most horrific when they happen, climate-related events cause about three-quarters of all disasters and as the climate warms, these hazards are increasing. There is also the migration to people to major cities, often on coasts of the oceans or major rivers. The result is the intersection of the effects of the major issues of climate change, disaster risk reduction and sustainable development. In all cases we need to look to the future and take actions now to reduce losses in the future.

In 2015, nations will negotiate a revised framework on action on disaster risk reduction, a possible Paris-protocol on climate change and Sustainable Development Goals to be attained by all countries by 2030. The draft list of SDGs includes: end poverty and hunger; attain healthy life for all at all ages; secure water and sanitation; and build inclusive, safe and sustainable cities and human settlements. For the global science community, the challenge is providing the scientific basis for definitions and approaches, including how to achieve these goals and the criteria for measurement of progress.

This presentation will bring together these issues in the context of the new international research programs Future Earth: Research for Global Sustainability; Integrated Research on Disaster Risk; and Health and Wellbeing in the Changing Urban Environment: a Systems Analysis Approach; with a Canadian-funded project, Coastal Cities at Risk: Building Adaptive Capacity for Managing Climate Change in Coastal Megacities. The Future Earth program is adopting an approach to involve the stakeholder community in the research program from the beginning to co-design and co-produce the research based on the logic that this will make the research most directly relevant to societies needs to address these issues. The Coastal Cities research project is integrating across social-natural-economic-engineering and health sciences to develop a systems approach to quantifying urban resilience and then undertake “what if” experiments to identify the most effective approaches to improving resilience and reducing impacts, recognizing the complex interactions across these elements of society.
The International Council for Science is leading the Science and Technology Major Groups to input to these UN processes and will endeavour to bring these scientific principles to the negotiations. Working with UN agencies such as UNESCO, UNU and WMO, and non-governmental partners such as the Inter-Academy Medical Panel, the Council will continue in the coming decades to assert the importance of scientific bases for these international agreements and national actions. We need to have the full support of medical physicists and biomedical engineers engaged in supporting health care in diverse environments in order to achieve these societal objectives, consistent with the Council’s Mission to strengthen international science for the benefit of society - all societies and all people.

Thursday, June 11 2015

SESSION DATE: THURSDAY, JUNE 11 2015
SESSION TIME: 13:30 - 15:00
SESSION ROOM: PLENARY HALL (HALLS F&G)
SESSION TITLE: PL04 - EVIDENCE AND HEALTH INFORMATICS
SPEAKER(S): EDWARD SHORTLIFFE & VIMLA PATEL

PL03.2 Cancer: The Global Health Challenge
Speaker(s): Mary Gospodarowicz

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PL04.1 Academic Biomedical Informatics: Synergies and Challenges at the Interface with Industry
Speaker(s): Edward Shortliffe

Academic biomedical informatics has achieved great successes through research contributions and education of professional informaticians over several decades, now reflected in a thriving commercial marketplace for electronic health records and other informatics tools. That very success, coupled with changes in the ability of governments to support research at past levels, is forcing a reconsideration of the directions and emphases for faculty members in informatics academic units. In this presentation Dr. Shortliffe will discuss those forces and propose areas of emphasis that will strengthen the academic discipline as it continues to evolve. He will distinguish the roles of academic informaticians as practitioners of informatics, as researchers, and as educators. He will also stress the necessary synergies between academic informatics and the health information technology industry, arguing that both will be strengthened by more fertile relationships and joint efforts.
Given the complexities of modern medicine, delivery of safe and timely care is an ongoing and recognized challenge. Errors, misunderstandings, and inaccuracies—large and small—are routine occurrences in healthcare delivery. Health information technology (IT) has undoubtedly reduced the risk of serious injury for patients. However, its true potential for preventing medical errors remains only partially realized. Unfortunately, such systems may even give rise to hazards of their own. There is a growing recognition that many errors are attributable neither solely to lapses in human performance nor to flawed technology. Rather they develop as a product of the interaction between human beings and technology. In our view, errors are the product of cognitive activity in human adaptation to complex physical, social, and cultural environments. How well the design of health IT complements its intended setting and purpose is critically important for safe and effective performance. In this presentation, I will discuss the cognitive challenges we face in understanding human-computer interaction (HCI) that make the integration of computing and clinical practice a difficult task that, improperly addressed, can lead to threats to patient safety.
# SPECIAL SESSIONS

## Sunday, June 7 2015

**SESSION DATE:** Sunday, June 7 2015  
**SESSION TIME:** 08:00 - 17:15  
**SESSION ROOM:** 716  
**SESSION TITLE:** SS01 - USE OF AAPM TASK GROUP 100 RECOMMENDED RISK ASSESSMENT APPROACH TO DEVELOP A RISK BASED QUALITY MANAGEMENT PROGRAM IN RADIATION THERAPY  
**SESSION ORGANIZER(S):** SAIFUL HUQ

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<thead>
<tr>
<th>AGENDA</th>
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<tr>
<td>TG-100 overview and introduction</td>
<td>Saiful Huq</td>
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<td>Safety Guidance for Radiotherapy</td>
<td>Peter Dunscombe</td>
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<td>Incident learning systems: Structure, terminology and taxonomies</td>
<td>Peter Dunscombe</td>
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<td>Exercise 1: Event Classification</td>
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<td>Process mapping</td>
<td>Saiful Huq</td>
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<td>Systems and Culture</td>
<td>Jean-Pierre Bissonnette</td>
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<td>Peter Dunscombe</td>
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<td>Exercise 3: Fault Tree Analysis</td>
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<td>Design of QM from the Risk Assessment</td>
<td>Ellen Yorke</td>
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<td>Exercise 4: QM Layout</td>
<td>Jean-Pierre Bissonnette</td>
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<td>Change Management</td>
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<td>Wrap and final questions</td>
<td>Saiful Huq</td>
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**SESSION DATE:** Sunday, June 7 2015  
**SESSION TIME:** 08:00 - 13:30  
**SESSION ROOM:** 715B  
**SESSION TITLE:** SS02 - AUTOSEG 2015  
**SESSION ORGANIZER(S):** STEPHEN BREEN & VLADIMIR PEKAR

**Introduction to Session:**  
This program will focus on automated methods for medical image segmentation. Topics will include: clinical applications, algorithms, and computational implementation.

Medical physicists, biomedical engineers, imaging scientists, computer scientists and healthcare professionals who use autosegmentation methods will enhance their knowledge and skills by attending this one-day event.

Ten leaders in autosegmentation will be presenting their latest methods and results.

After this event, attendees will be able to describe several autosegmentation algorithms; compare and evaluate different autosegmentation techniques; and select amongst different algorithms for varied imaging modalities and tasks.

**SESSION DATE:** Sunday, June 7 2015  
**SESSION TIME:** 13:30 - 18:00  
**SESSION ROOM:** 718A  
**SESSION TITLE:** SS03 - RT RESEARCH SYSTEM DEVELOPMENT ON OPEN-SOURCE SLICERRT PLATFORM  
**SESSION ORGANIZER(S):** GABOR FICTINGER AND CSABA PINTER

**SESSION DATE:** Sunday, June 7 2015  
**SESSION TIME:** 08:00 - 13:30  
**SESSION ROOM:** 715A  
**SESSION TITLE:** SS03 - RT RESEARCH SYSTEM DEVELOPMENT ON OPEN-SOURCE SLICERRT PLATFORM  
**SESSION ORGANIZER(S):** GABOR FICTINGER AND CSABA PINTER

**SESSION DATE:** Sunday, June 7 2015  
**SESSION TIME:** 13:30 - 18:00  
**SESSION ROOM:** 718A  
**SESSION TITLE:** SS04 - YIS PRESENTATIONS – JOINT IOMP & IFMBE
### Monday, June 8 2015

**Session Details:**
- **Session Date:** Monday, June 8 2015
- **Session Time:** 15:00 - 16:30
- **Session Room:** 714B
- **Session Title:** SS05 - European Initiatives in Medical Radiation Protection
- **Session Organizer(s):** Eugene Lief and John Damilakis

**Agenda:**
- **PIDRL:** A European Commission project on Paediatric DRLs
  - **Professor John Damilakis, EFOMP President.**
- **Overview of EFOMP projects on Radiation Protection**
  - **Professor Virginia Tsapaki, EFOMP**
- **Collaboration of AAPM and EFOMP on Radiation Protection Projects**
  - **Dr. Eugene Lief, AAPM**
- **Question and Answer time**

### Tuesday, June 9 2015

**Session Details:**
- **Session Date:** Tuesday, June 9 2015
- **Session Time:** 08:00 - 10:00
- **Session Room:** PLENARY HALL (HALLS F&G)
- **Session Title:** SS10 - IFMBE Awardees Presentations

**The Awardees will include:**
- IFMBE Laura M.C. Bassi Award: Alison Noble
- IFMBE Otto Schmidt Award: Karin Wardell
- IFMBE Vladimir Zworykin Award: Chwee Teck Lim
- IFMBE John A. Hopps Distinguished Service Award: Robert M. Nerem

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**Session Details:**
- **Session Date:** Monday, June 8 2015
- **Session Time:** 16:00 - 18:00
- **Session Room:** PLENARY HALL (HALLS F&G)
- **Session Title:** SS07.1 - Presentation of 2021 Bids

**Session Details:**
- **Session Date:** Monday, June 8 2015
- **Session Time:** 18:00 - 19:00
- **Session Room:** PLENARY HALL (HALLS F&G)
- **Session Title:** SS07.2 - IUPESM Awardees Presentations

**The Awardees will include:**
- IUPESM Award of Merit - IFMBE recipient: Fumihiko Kajiya
- IUPESM Award of Merit - Medical Physics: Peter Smith
Introduction to Session:
For years, in-house clinical engineering (CE) departments and independent service organizations have faced several challenges. These relate to obtaining the supports required to service and maintain medical equipment in the field. To the CE community, providing safe, cost-effective, and expedient service depends on ability to obtain spare parts, service manuals, technical training, software, and access pass codes. It is becoming increasingly difficult to obtain these items. Manufacturers are placing conditions on servicing their products. Either no supports are provided or they charge very high prices to acquire them. Some companies will not allow servicing in the field unless expensive training is acquired. They create proprietary manuals and information separately for OEM eyes only and may charge even more to acquire this. Manufacturers contribute to the issue citing risks to the reliable support of their product. Purchasing agents are easily swayed by vendor claims of complexity that they and only they can service it (not field serviceable) and various other unfounded risks like “FDA won’t allow it.” Manufacturers and CE need to develop an understanding and common ground that will serve both sides so only the patient benefits.

Objectives
To discuss with Biomedical and Clinical Engineers, Physicists, Scientists, Academics, Healthcare Technology Managers, Healthcare Institutions, Manufacturers, Vendors, Independent Service, Organizations, Regulatory Agencies, Independent Research Organizations the issue of serviceability of Medical Devices.

The summit focus will be on questions below:
1. Is there a problem?
2. If so, how do we articulate it?
3. Define ‘Supportability’
4. Provide perspective from both sides

Impact on the Medical Device Industry
Medical equipment manufacturers may find a competitive edge when they fully support service of equipment in the field. When customers compare a vendor’s product, field supportability can be grounds for decision-making. Today’s devices and systems are becoming more and more similar from both hardware and software perspectives. The level of distinction among competing products and vendors is shrinking. Correspondingly, characteristics around the purchasing aspect have become increasingly apparent. From an in-house clinical engineering perspective, the vendor’s support for field supportability could make acquisition more efficient for in-house CE departments (less haggling). In-house service is known to reduce equipment cost of ownership in hospitals. This apply to all patient related technologies.

Supportability Defined
The level of ease to which a specific medical device or system is serviced by entities other than representatives or direct agents of the original equipment manufacturer (OEM).

AGENDA:

| REGULATION OF MEDICAL DEVICES | Nicolas PalliKarakis, University of Patras, Greece, and Chair HTA Division of IFMBE |
| Pre-market HTA of Medical Devices: an overview | Leandro Pecchia, University of Warwick, UK, and Treasurer of HTA Division of the IFMBE |
| From Monitoring the European Innovation Partnership on Active and Healthy Ageing (EIP on AHA) to early technology assessment | Christian Boehler, Joint Research Centre, European Commission, Seville, Spain |
| Multi-criteria decision analysis as a tool for medical devices assessment: a case study on R&D portfolio decision for new robotics in healthcare | Marjan Hummel, University of Twenty, The Nederlands |
### Session Title:

**Session Organizer(s):** Jake Van Dyk and Cari Borrás

**AGENDA:**

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<th>Time</th>
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<td>13:30-13:35</td>
<td>Introduction</td>
<td>Cari Borrás, Chair, IUPESM-Health Technology Task Group (HTTG), Washington DC, United States</td>
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<td>13:35-14:00</td>
<td>The Global Cancer Burden and WHO’s Response</td>
<td>Adriana Velazquez, World Health Organization (WHO), Geneva, Switzerland</td>
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<td>14:00-14:25</td>
<td>Biomedical Engineering Research for Cancer Diagnostics and Therapeutics</td>
<td>Ratko Magjarević, University of Zagreb, Zagreb, Croatia</td>
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<td>14:25-14:50</td>
<td>Appropriate Technologies for Cancer Diagnostics and Therapeutics</td>
<td>Cari Borrás, HTTG, Washington DC, United States</td>
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<td>14:50-15:15</td>
<td>IAEA Activities in Support of Radiation Therapy Services</td>
<td>Joanna Izewska, International Atomic Energy Agency (IAEA), Vienna, Austria</td>
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<td>15:15-15:40</td>
<td>Initiatives of Expertise Mobilization</td>
<td>Jacob Van Dyk, Western University, London, Ontario, Canada</td>
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<tr>
<td>15:40-16:05</td>
<td>Equal Access to Radiation Therapy by 2035</td>
<td>David Jaffray, Global Task Force on Radiotherapy for Cancer Control (GTFRCC), Ontario Cancer Institute, Toronto, Canada</td>
</tr>
<tr>
<td>16:05-16:30</td>
<td>Discussion and Summary</td>
<td>Jacob Van Dyk, Western University, London, Ontario, Canada</td>
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</tbody>
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### Session Title:
**SS15 - Methods and Tools for Pre-Market HTA of Medical Devices (Health Technology Assessment for Biomedical Engineers Workshop)**

**Session Organizer(s):** Nicolas Pallikarakis and Leandro Pecchia

**AGENDA:**

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Presenter(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:30-13:50</td>
<td>Multi-criteria decision analysis for medical devices assessment</td>
<td>Marjan Hummell, University of Twenty, the Netherlands</td>
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<tr>
<td></td>
<td>A tool to monitor the European Innovation Partnership on Active and Healthy Ageing: development, implementation and potential use for pre-market HTA</td>
<td>Christian Boehler, Joint Research Centre, European Commission, Seville, Spain</td>
</tr>
<tr>
<td>14:00-14:25</td>
<td>AHP for user need elicitation: method and available tools</td>
<td>Leandro Pecchia, University of Warwick and Treasurer of HTA Division of the IFMBE</td>
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</tbody>
</table>

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### Special Session: SS16 - Addressing Global Challenges

**Introduction to Session:**
This Special Session “Addressing Global Challenges” will be presented by the past and current Chairs of the International Academy of Medical and Biological Engineering of the IFMBE.

The Opening Presentation by Robert Nerem is on “Bioengineering in the 21st Century”, followed by presentations on a variety of topics addressing global challenges from different perspectives including device technologies, information technologies, and innovative uses of physiological modeling.

#### Agenda:

<table>
<thead>
<tr>
<th>Topic</th>
<th>Presenter</th>
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<tbody>
<tr>
<td>Bioengineering in the 21st Century</td>
<td>Robert Nerem (Georgia Technological Institute, USA)</td>
</tr>
<tr>
<td>Contribution of medical and biological engineering to medical care in coming super-aging society - collaboration among academia, industry and government</td>
<td>Ueno Shoogo (Dept of Applied Quantum Physics, Graduate School of Engineering, Kyushu University, Japan)</td>
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<td>Fumihiko Kajiya (Kawasaki University of Medical Welfare and Kawasaki Medical School, Japan)</td>
</tr>
<tr>
<td>ICT for Prevention of Non-Communicable Diseases</td>
<td>Niilo Saranummi (VTT Technical Research Centre of Finland, Finland)</td>
</tr>
<tr>
<td>The Future Potential for Living, Multicellular Machines</td>
<td>Roger Kamm (Massachusetts Institute of Technology, USA)</td>
</tr>
</tbody>
</table>

### Special Session: SS17 - Spreading and Integrating Human Factors Expertise in Healthcare An International Panel Discussion

**Introduction to Session:**
Over the past decade, improving patient safety has been a priority for many healthcare organizations, but progress in the reduction of preventable patient harm has been slow. Human factors (HF) is recognized as an important scientific approach to improve health technology safety when applied to both pre-market (e.g., improved technology design), and post-market (e.g., improved practices, training and technology configuration/implementation) activities. HF is a discipline focused on improving safety by recognizing that humans are fallible, despite good intentions and hard work. It aims to build system resilience by focusing on the conditions under which people work and building defenses to minimize errors and their impacts.

While the potential for HF to improve healthcare safety is well established, it is not integrated and embedded in most safety initiatives. A possible explanation for this unfulfilled potential is that there are limited HF experts working in healthcare. Most HF-related work to date is done at a few organizations in a few countries (i.e., organizational silos). In addition, there has been a lack of formal professional collaboration between HF experts, patient safety leaders, regulators, clinicians, and health technology managers and designers, resulting in disparate expertise (i.e., professional/expertise silos). As such, there is a need to spread HF expertise internationally and across healthcare-related professions (e.g., clinical engineers, biomedical technicians, designers) so they can be empowered to take more active roles in initiating and leading safety projects that incorporate HF.

HumanEra, an HF team based at the University Health Network in Toronto, Canada, has been teaching HF to various healthcare sectors and stakeholders for almost 10 years. Teaching tactics have included:

- Introductory HF workshops
- HF method courses
- Partnering with healthcare organizations to build in-house HF teams/expertise (multi-year contracts focused on project-based collaborations)
- An introductory HF book (expected publication late 2015)

This session will consist of a panel of HumanEra teachers and past international students to share our combined experiences in teaching, learning, and applying HF for the first time to a safety initiative. The panel will include representatives from different sectors (e.g., academics, clinical engineers, regulators, designers/vendors) and countries (e.g., Canada, Brazil, Spain).
By attending this session you will:

- Discover how HF can improve healthcare safety
- Learn from the panel's experience about applying HF in their different roles/professions, organizations, and/or jurisdictions
- Contribute to meaningful discussions about how you can become an HF champion and help to accelerate the adoption of HF in your organization
- Meet international professionals interested in HF collaboration to contribute to the cross-fertilization of this important field

**AGENDA:**

**Overview:**
A brief introduction to HF will be provided (e.g., define HF for the healthcare context)

**Presentations:**
Each panel member will present a short summary of their experience in promoting and applying HF to healthcare, focusing on their successes and barriers.

**Interactive discussion:**
The presentations will serve as a springboard for an interactive discussion between panel members and the audience.

*Moderated by Dr. Patricia Trbovich*

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**SESSION DATE:** THURSDAY, JUNE 11 2015  
**SESSION TIME:** 12:00 - 13:30  
**SESSION ROOM:** 713B  
**SESSION TITLE:** SS18 - MEDICAL PHYSICISTS WITHOUT BORDERS  
**SESSION ORGANIZER(S):** JAKE VAN DYK

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**SESSION DATE:** THURSDAY, JUNE 11 2015  
**SESSION TIME:** 12:00 - 13:30  
**SESSION ROOM:** 717B  
**SESSION TITLE:** SS19 - SOCIAL IMPLICATIONS OF TECHNOLOGY WORKSHOP (IN HONOR OF OUR FRIEND & COLLEAGUE; DR LODEWIJK BOS)  
**SESSION ORGANIZER(S):** LUIS KUN

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**SESSION DATE:** THURSDAY, JUNE 11 2015  
**SESSION TIME:** 12:00 - 13:30  
**SESSION ROOM:** 716B  
**SESSION TITLE:** SS20 - EMBEDDED SENSOR SYSTEMS FOR HEALTH WORKSHOP  
**SESSION ORGANIZER(S):** MARIA LINDEN
Introduction to Session:

The World Biomedical Engineering and Medical Physics Leaders’ Summit is the inaugural tri-annual high-level policy meeting dedicated exclusively to furthering the role of biomedical engineering and medical physics in medicine. This unique event brings together key decision makers, academics, and practicing engineers and physicists from around the globe and encourages timely debate on emerging issues related to the development and sustainability of the role and impact of medical physicists and biomedical engineers in medicine and healthcare. The Summit provides a unique and important forum to secure a coordinated, multileveled global response to the need, demand, and importance of creating and supporting strong academic and clinical teams of biomedical engineers and medical physicists for the benefit of human health.

Key Objectives of the Leaders’ Summit:

- Raising awareness among leading decision makers to ensure the role of biomedical engineering and medical physics is recognized as a local, regional, and global health priority.
- Providing a forum to exchange information and innovative ideas on how to create and sustain academic and clinical programs in medical physics and biomedical engineering.
- Creating a force that galvanizes the leadership and decision-makers in academia, industry, and medicine to assure the role of these two translational and impactful disciplines expand their impact on human health.
- Defining compelling messages to support the critical role that biomedical engineers and medical physics play in supporting and advancing human health.

AGENDA:

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>13:00 pm</td>
<td>Introduction</td>
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<tr>
<td>13:05 pm</td>
<td>Setting the Stage</td>
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<tr>
<td>13:15 pm</td>
<td>Panelist Commentary</td>
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<td>13:45 pm</td>
<td>Panel Discussion</td>
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<td>14:15 pm</td>
<td>Last Word</td>
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<td>14:25 pm</td>
<td>Closing Comments</td>
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### AGENDA:

<table>
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<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>15.00-15.15</td>
<td>Welcome Remarks; Objectives of the Workshop</td>
<td>Cari Borrás, IUPESM- HTTG Chair, Washington DC, USA</td>
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<tr>
<td>15.15-16.00</td>
<td>General Overview (The state of TeleHealth, TeleMedicine, and mHealth)</td>
<td>Kwan-Hoong Ng, Department of Biomedical Imaging, University of Malaya, Kuala Lumpur, Malaysia</td>
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<td>Implementation, Barriers and Policy Issues:</td>
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<td>16.00-16.25</td>
<td>Industrialized Areas</td>
<td>Yadin David, Biomedical Engineering Consultants, LLC., Houston, USA</td>
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<tr>
<td>16.25-16.50</td>
<td>Resource-limited Regions</td>
<td>K. Siddique-e Rabbani, Department of Biomedical Physics &amp; Technology, University of Dhaka, Bangladesh</td>
</tr>
<tr>
<td>16.50-17.05</td>
<td>Development of Healthcare Applications using Facilities and Functions available in Modern Mobile Devices</td>
<td>Marlen Perez-Diaz, Center for Studies on Electronic and Information Technologies. Central University of Las Villas, Santa Clara, Villa Clara, Cuba</td>
</tr>
<tr>
<td>17.05-17.20</td>
<td>Quality of Service Assessment, Maintenance and Sustainability Issues</td>
<td>J. Tobey Clark, Instrumentation and Technical Services, University of Vermont, Burlington, Vermont, USA</td>
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<td>Point of Care Solutions:</td>
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<tr>
<td>17.20-17.55</td>
<td>Demonstration</td>
<td>K. Siddique-e Rabbani, Department of Biomedical Physics &amp; Technology, University of Dhaka, Bangladesh</td>
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<tr>
<td>17.55-18.30</td>
<td>Demonstration</td>
<td>Kwan Hoong Ng, Department of Biomedical Imaging, University of Malaya, Kuala Lumpur, Malaysia</td>
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<tr>
<td>18.30-18.50</td>
<td>Discussion</td>
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<tr>
<td>18.50-19.00</td>
<td>Summary and Recommendations</td>
<td>Colin Orton, Wayne University, Detroit, Michigan, USA</td>
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## CONTINUING EDUCATION SESSIONS

### Monday, June 8 2015

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<thead>
<tr>
<th>Session Time</th>
<th>Session Room</th>
<th>Session Name</th>
<th>Session Details</th>
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</table>
| **08:00** | **802A** | **BMEE01 - GENERAL BME EDUCATION** | *08:00* BMEE01.1 Biomaterials - Cell-Material Interactions: Biochemistry & Physics  
*Dennis Discher, United States*  
*09:00* BMEE01.2: Radiology 101: Intro to X-Ray tubes / BME Technical/Service Courses (manufacture & maintenance)  
*Phillip Bogolub, United States* |
| **08:00** | **801A + 801B** | **JT01 - IMAGING** | *08:00* JT01.1: SPECT and Gamma Camera State-Of-The-Art Technology and Current Research  
*R Glenn Wells*  
*09:00* JT01.2: Magnetic Resonance Imaging State-Of-The-Art Technology and Current Research  
*Richard Frayne, Canada* |
| **08:00** | **802B** | **MPS01 - RADIATION THERAPY** | *08:00* MPS01.1: Radiobiology applications for clinicians - Isoeffective dose calculations, Hypofractionation, TCP/NTCP  
*Beatriz Sánchez, Chile* |
| **15:00** | **801A** | **BMEE02 - MEDICAL DEVICE DEVELOPMENT AND COMMERCIALIZATION** | *15:00* BMEE02.1: Med-Tech Commercialization – A Research Hospital’s Perspective  
*Mark Taylor, Canada* |
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<tr>
<th>Time</th>
<th>Session Time</th>
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<th>Session Name</th>
<th>Presentations</th>
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</table>
| 15:00  | 15:00 – 16:30| 801B         | MPE01 - MEDICAL PHYSICS EDUCATION & PROFESSIONAL ISSUES | MPE01.1: Workforce Models for Medical Physicists  
Julian Malicki, Poland  
MPE01.2: International Educational Standards: Can We Define a Common Medical Physics Curriculum?  
Colin Orton, United States  
Raymond Wu, United States  
Tomas Kron, Australia |
| 15:00  | 15:00 – 16:30| 803B         | MPF02 - SYSTÈMES INFORMATISÉS                     | MPF02.1: Éléments de base: réseaux informatiques, serveurs, et standards de communication  
Stefan Michalowski, Canada |
| 15:00  | 15:00 – 16:00| 802B         | MPE02 - RADIATION THERAPY                         | MPE02.1: Adaptive Radiotherapy  
Jan-Jakob Sonke, The Netherlands |
| 15:00  | 15:00 – 16:00| 803B         | MPS02 - COMPUTERIZED SYSTEMS                      | MPS02.1: Radiation Treatment Planning Systems and Dose Computation Algorithms (including Monte Carlo)  
Antonio Leal Plaza, Spain |
| 17:00  | 17:00 – 19:00| 801B         | MPE03 - RADIATION THERAPY                         | MPE03.1: Image-Guided Radiotherapy, Including Commissioning, QC, and Imaging Dose  
Douglas Moseley, Canada  
MPE03.2: In Vivo Dosimetry  
Ben Mijnheer, The Netherlands |
| 17:00  | 17:00 – 19:00| 802B         | MPF03 - RADIOTHÉRAPIE                             | MPF03.1: Appareils spécialisés: Tomotherapy, CyberKnife, Brainlab, Gamma Knife  
Veronique Vallet  
MPF03.2: Curiethérapie guidée par l'image  
Luc Beauregard, Canada |
| 17:00  | 17:00 – 19:00| 803B         | BMEF02 - GESTION EN GÉNIE BIOMÉDICAL/CLINIQUE    | BMEF02.1: Clinical Engineering Standards of Practice – Normes de praticité en génie clinique- Nouvelle édition canadienne en français  
Mocine El Garch, Canada  
Bill Gentles, Canada |
| 17:00  | 17:00 – 19:00| 803A         | BMEF03 - GESTION EN GÉNIE BIOMÉDICAL/CLINIQUE    | BMEF03.1: Impacts de la Technologie Médicale sur la Santé de la Mère et de l’Enfant  
Gnahoua Zoabli, Canada |
| 18:00  | 18:00 – 19:00| 801A         | BMEE03 - BIOINFORMATICS, TELEMEDICINE AND HOSPITAL| BMEE03.1: DICOM & PACS: Managing Digital Imaging Networks Information Systems  
Marvin Mitchell, Canada |
| 18:00  | 18:00 – 19:00| 801A         | BMEE03 - BIOINFORMATICS, TELEMEDICINE AND HOSPITAL| BMEE03.1: DICOM & PACS: Managing Digital Imaging Networks Information Systems  
Marvin Mitchell, Canada |
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<tbody>
<tr>
<td>08:00</td>
<td>JT02.1</td>
<td>UNICEF’s Approach to Medical Device Selection and Procurement for Low-Resource Setting</td>
<td>Shauna Mullally, Denmark</td>
<td>801A + 801B</td>
</tr>
<tr>
<td>09:00</td>
<td>JT02.2</td>
<td>Equipment Donation and Disposal - Goodwill vs. Risk</td>
<td>Mario Ramirez, Canada</td>
<td>801A + 801B</td>
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<tbody>
<tr>
<td>08:00</td>
<td>MPF04.1</td>
<td>Les Standards Professionnels et la Certification des Physiciens Médicaux</td>
<td>Clément Arsenault, Canada</td>
<td>802B</td>
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<tr>
<td>09:00</td>
<td>MPF04.2</td>
<td>Nanoparticles and Radiotherapy</td>
<td>Yolanda Prezado, France</td>
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<tr>
<td>08:00</td>
<td>MPS03.1</td>
<td>Protontherapy</td>
<td>Alejandro Mazal</td>
<td>803A</td>
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<td>09:00</td>
<td>MPS03.2</td>
<td>Nanoparticles and Radiotherapy</td>
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<tr>
<td>08:00</td>
<td>MPF05.1</td>
<td>Le Partenariat Canadien pour la Qualité en Radiothérapie</td>
<td>Normand Frenière, Canada</td>
<td>803B</td>
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<tr>
<td>09:00</td>
<td>MPF05.2</td>
<td>L’ingénierie des facteurs humains</td>
<td>Jean-Yves Fiset, Canada</td>
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<tr>
<td>08:00</td>
<td>BMES01.1</td>
<td>Healthcare Continuum</td>
<td>Vladimir Quintero, Columbia</td>
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<td>09:00</td>
<td>MPS04.1</td>
<td>CT Basics</td>
<td>Caridad Borrás, United States</td>
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<tbody>
<tr>
<td>08:00</td>
<td>MPF06.1</td>
<td>La Boîte à Outils du Physicien Moderne: Instruments de Contrôle de Qualité</td>
<td>Alain Gauvin, Canada</td>
<td>803B</td>
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<tr>
<td>09:00</td>
<td>MPF06.2</td>
<td>La Radiologie Interventionnelle, Incluant un Survol des Nouvelles Technologies et Approches</td>
<td>Cécile Salvat, France</td>
<td>803B</td>
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<td>15:00</td>
<td>MPE04.1: Quality Framework: The Canadian Partnership for Quality Radiotherapy</td>
<td>15:00 – 16:30</td>
<td>BMEE02 - INTEROPERABILITY IN HEALTH TECHNOLOGY</td>
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<tr>
<td>15:00</td>
<td>BMES02.1: Business Opportunities</td>
<td>15:00 – 16:30</td>
<td>MPS05 - COMPUTERIZED SYSTEM</td>
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<td>15:00</td>
<td>MPS05.1: Managing Respiratory Motion, Including 4D and Gating Techniques; QC</td>
<td>15:00 – 16:30</td>
<td>BMEE04 - GENERAL BME EDUCATION</td>
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<td>15:00</td>
<td>BMEE04.1: Biomaterials - Polymer/Organic Coatings</td>
<td>15:00 – 16:30</td>
<td>MPS06 - COMPUTERIZED SYSTEM</td>
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<td>BMEF05 - GESTION EN GÉNIE BIOMÉDICAL/CLINIQUE</td>
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<td>17:00</td>
<td>BMEF05.1: Implantation du Guide des Bonnes Pratiques de l'Ingénierie Biomédicale en Etablissement de Santé</td>
<td>17:00 – 19:00</td>
<td>BMEF05 - GESTION EN GÉNIE BIOMÉDICAL/CLINIQUE</td>
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<tr>
<td>17:00</td>
<td>BMEE05.1: Introduction to Medical Technology Management (Clinical Engineering Practice)</td>
<td>17:00 – 19:00</td>
<td>MPF07 - RADIOThÉAPIE</td>
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<td>17:00</td>
<td>MPF07.1: Nouvelles Technologies et Approches en Curiethérapie</td>
<td>17:00 – 19:00</td>
<td>MPF07 - RADIOThÉAPIE</td>
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<td>17:00</td>
<td>MPF07.2: Protontherapy</td>
<td>17:00 – 18:30</td>
<td>MPS06 - COMPUTERIZED SYSTEM</td>
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<tr>
<td>17:00</td>
<td>MPS06.1: Optimization: IMRT and VMAT</td>
<td>17:00 – 19:00</td>
<td>BMEF05 - GESTION EN GÉNIE BIOMÉDICAL/CLINIQUE</td>
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<td>17:00</td>
<td>MPS06.2: Automated Contouring</td>
<td>17:00 – 18:30</td>
<td>MPS07 - RADIATION THERAPY</td>
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<td>17:00</td>
<td>MPS07.1: Image-Guided Radiotherapy, Including QC and Imaging Dose; Adapative Radiotherapy</td>
<td>17:00 – 18:30</td>
<td>MPS06 - COMPUTERIZED SYSTEM</td>
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Wednesday, June 10 2015

10:30  JT04.1: Ethics for Biomedical Engineers and Medical Physicists Workshop
       Jean-Pierre Bissonnette, Canada
       Monique Frize, Canada

10:30  MPS09.1: Peripheral Neutron and Photon Doses
       Beatriz Sanchez Nieto, Chile

10:30  MPS08.1: Curriculum Design: How to Train the Next Generation of Physicists?
       Maria Ester Brandan, Mexico

10:30  BMEE06.1: Regulatory Issues in Biocompatibility
       Paul Santerre, Canada

10:30  MPF08.1: Algorithmes de Calcul de Dose, Incluant Monte Carlo
       Raphaelle Moekli, Switzerland

11:30  MPF08.2: Utilisation de la Maîtrise Statistique des Processus en Milieu Hospitalier
       Karine Herlevin (Gérard), France

13:30  BMEE07.1: E-medicine and Remote Medical Consultations
       Gilad Epstein, Canada

13:30  MPS09.1: The Modern Physicist Tool Box: How to Choose Between Current Dosimeters
       Faustino Gómez, Spain

13:30  MPS08.1: Curriculum Design: How to Train the Next Generation of Physicists?
       Maria Ester Brandan, Mexico

13:30  BMEE06.1: Regulatory Issues in Biocompatibility
       Paul Santerre, Canada

13:30  MPF08.1: Algorithmes de Calcul de Dose, Incluant Monte Carlo
       Raphaelle Moekli, Switzerland

11:30  MPF08.2: Utilisation de la Maîtrise Statistique des Processus en Milieu Hospitalier
       Karine Herlevin (Gérard), France

15:00  BMEE08.1: Biomechanics - Implant design
       Cheng-Kung (Richard) Cheng, Chinese Taipei

13:30  MPS10.1: The Modern Physicist Tool Box: How to Choose Between Current Dosimeters
       Faustino Gómez, Spain

13:30  MPS10.1: The Modern Physicist Tool Box: How to Choose Between Current Dosimeters
       Faustino Gómez, Spain

14:30  MPS10.2: Dosimétrie et Radioprotection en Radiologie
       Sylvain Deschênes, Canada

15:00  BMEE08.1: Biomechanics - Implant design
       Cheng-Kung (Richard) Cheng, Chinese Taipei

13:30  MPS09.1: The Modern Physicist Tool Box: How to Choose Between Current Dosimeters
       Faustino Gómez, Spain

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       Sylvain Deschênes, Canada

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       Maria Ester Brandan, Mexico

14:30  MPS08.2: Utilisation de la Maîtrise Statistique des Processus en Milieu Hospitalier
       Karine Herlevin (Gérard), France

15:00  BMEE08.1: Biomechanics - Implant design
       Cheng-Kung (Richard) Cheng, Chinese Taipei

13:30  MPS07.1: What can IAEA do for the Clinical Medical Physicist?
       Joanna Izewksa, Austria

14:20  MPS07.2: Safety Learning and Safety Management to Prevent Radiotherapy Incidents
       Ola Holmberg, Austria

15:20  MPS07.3: Equipment Standards and Performance Measurements for Radiotherapy
       Jean Moran, United States
15:00  BMEE09.1: Medical Device Network Connectivity  
      Ryan Forde, United States

15:00  MPE08.1: Quality Systems in Radiotherapy  
      Mary Coffey, Ireland

15:00  MPS11.1: Dosimetry Under Non-Reference Conditions  
      Faustino Gómez, Spain

15:00  MPF10.1: La Radiothérapie Guidée par L’image,  
      Incluant Doses et CQ  
      Myriam Ayadi-Zahra, France

15:00  BMEE10.1: Multiscale Biomechanics in Deep Tissue  
      Injuries  
      Arthur Mak, Hong Kong

17:00  BMEE11.1: Trends in Medical Device Certification and  
      improving Patient Safety through Evolving Standards  
      Dale Morgan, Canada

17:00  MPE09.1: The Modern Physicist Tool Box:  
      How to Choose Between Current Dosimeters  
      Jan Seuntjens, Canada

17:30  MPE09.2: Radiobiology Applications for Clinical  
      Physicists: Isoeffective dose calculations;  
      Hypofractionation; TCP/NTCP; Peripheral doses  
      and secondary cancers  
      Michael Joiner, United States

18:00  BMEE12.1: Clinical Engineers & Biomedical Engineering  
      Technologists Certification - International Perspective  
      Larry Boyce, Canada  
      Petr Kresta, Canada
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<th>Time</th>
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| 08:00 – 10:00 | JT05 - Leadership | 801A + 801B | 08:00 | JT05.1: What is Leadership? A Roundtable from Recognized Leaders | Kin-Yin Cheung, Hong Kong | Tony Easty, Canada 
David Jaffray, Canada 
Ratko Magjarevic, Croatia 
Herbert F. Voigt, United States |
| 09:30 | JT05.2: Meet the Leaders | 801A + 801B | 09:30 | | Kin-Yin Cheung, Hong Kong | Tony Easty, Canada 
David Jaffray, Canada 
Ratko Magjarevic, Croatia 
Herbert F. Voigt, United States |
| 08:00 – 10:00 | BMEE13 - Clinical Engineering | 803A | 08:00 | BMEE13.1: Patient safety and Optimal Performance: A Holistic Framework for Medical Devices | Saleh Altayyar, Saudi Arabia | Michael Cheng, Canada 
Hal Hifi, Canada 
Julie Polisena, Canada |
| 10:30 – 12:00 | MPE12 - Computerized Systems | 802B | 10:30 | MPE12.1: Image Registration | Mike Velec, Canada |
| 11:30 | MPE12.2: Automated Segmentation of Images for Treatment Planning Purposes | 802B | 11:30 | | Greg Sharp, United States |
| 08:00 – 10:00 | MPE10 - Computerized Systems | 802B | 08:00 | MPE10.1: Dose Computation Algorithms, Including Monte Carlo | Tommy Knoos, Sweden |
| 09:00 | MPE10.2: Treatment Planning Optimization: IMRT and VMAT | 802B | 09:00 | | Jan Unkelbach, United States |
| 08:00 – 10:00 | MPE11 - Radiation Therapy | 803B | 08:00 | MPE11.1: Linear Accelerator Technology | Malcolm McEwen, Canada |
| 09:00 | MPE11.2: Reference Dosimetry and its Uncertainties | 803B | 09:00 | | Malcolm McEwen, Canada 
David Rogers, Canada |
| 10:30 – 12:00 | BMEE14 - Neural & Rehabilitation Engineering | 802A | 10:30 | BMEE14.1: Neuro-robotics – Neuromodulated and Inspired Prosthesis | Nitish Thakor, Singapore |
| 11:30 | BMEE14.2: Automated Segmentation of Images for Treatment Planning Purposes | 802A | 11:30 | | Greg Sharp, United States |
| 08:00 – 10:00 | MPE13 - Medical Physics Education and Professional Issues | 803B | 08:00 | MPE13.1: Advocacy for Physicists and How to Deal with Government, Unions, Regulators, and Employers | Jerry Battista, Canada | Wayne Beckham, Canada |
| 10:30 | MPE13.2: Reference Dosimetry and its Uncertainties | 803B | 10:30 | | Malcolm McEwen, Canada 
David Rogers, Canada |
<p>| 11:15 | MPE13.3: Social Media in Science and Medicine | 803B | 11:15 | | Parminder Basran, Canada |
| 10:30 – 12:00 | JT06 - Leadership | 801A + 801B | 10:30 | JT06.1: Hosting and Organizing an International Meeting | Mathias Posch, Canada |
| 11:15 | JT06.2: Social Media in Science and Medicine | 801A + 801B | 11:15 | | Parminder Basran, Canada |
| 10:30 – 12:30 | BMEE15 - Clinical Engineering/Technology Management/General BME Education | 803A | 10:30 | BMEE15.1: Introduction to Root Cause Analysis (RCA) and Failure Modes and Effects Analysis (FMEA) to Support Medication Safety Initiatives | Julie Greenall, Canada |
| 11:30 | BMEE15.2: Biomechanics - Computational Modeling and Analysis | 803A | 11:30 | | Yubo Fan, People’s Republic of China |</p>
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| 15:00 – 16:30 | 8031B | MPE14 - RADIATION THERAPY | MPE14.1: Radiotherapy Units: Cobalt-60 Units and Gamma Knife Units  
*Steve Goetsch, United States*  
MPE14.2: Brachytherapy: Overview of State-Of-The-Art and New Developments  
*Nicole Nesvacil, Austria* |
| 15:00 – 16:30 | 803B | MPE15 - COMPUTERIZED SYSTEMS | MPE15.1: Managing Respiratory Motion in Radiation Oncology  
*Paul Keall, Australia*  
MPE15.2: RadOnc Treatment Management Systems and the Paperless Treatment Process  
*Benedick Fraass, United States* |
| 15:00 – 16:30 | 801B | BMEE16 - BME TECHNICAL/SERVICE COURSES | BMEE16.1: Surgical Laser: Technology and Safety Issues  
*Murray Greenwood, Canada* |
| 15:00 – 16:00 | 802A | BMEE17 - MEDICAL DEVICE DEVELOPMENT & COMMERCIALIZATION | BMEE17.1: Technology Commercialization - Road Map and Precautions  
*Thomas Rock Mackie, United States* |
| 15:00 – 16:00 | 803A | BMEE18 - GENERAL BME EDUCATION | BMEE18.1: BioMEMS - Microsensors; Microactuators; Microfluidics; Micro-Total Analysis Systems (e.g., Genomics and Proteomics)  
*David Weitz, Canada* |
| 17:00 – 19:00 | 801A | BMEE19 - BME TECHNICAL/SERVICE COURSES | BMEE19.1: Rechargeable Batteries: Characteristics, Performance, and Maintenance  
*Isidor Buchmann, Canada* |
| 17:00 – 19:00 | 803B | MPE16 - RADIATION THERAPY | MPE16.1: Specialized Units: Tomotherapy and CyberKnife Systems  
*Martina Descovich, United States*  
*Robert Staton, United States*  
MPE16.2: Heavy Particle / Light Ion Therapy  
*Oliver Jäkel, Germany* |
| 17:00 – 19:00 | 803A | BMEE21 - GENERAL BME EDUCATION | BMEE21.1: Biomaterials - Cell-surface Interaction  
*Caroline Loy, Canada*  
BMEE21.2: Biomaterials - Plasma Medicine  
*Michael Keidar, United States* |
| 17:00 – 18:00 | 802A | BMEE20 - HUMAN FACTORS & MEDICAL DEVICE SAFETY | BMEE20.1: Clinical Alarms Management (incl. IHE Alarm Communication Mgt)  
*Tobey Clark, United States*  
*Yadin David, United States*  
*Marjorie Funk, Germany* |
Friday, June 12 2015

**SESSION TIME:** 08:00 – 10:00  
**SESSION ROOM:** 801A + 801B  
**SESSION NAME:** JT07 - HUMAN FACTORS & MEDICAL DEVICE SAFETY

08:00  JT07.1: FMEA and Root Cause Analysis  
Eric Ford, United States

09:00  JT07.2: Human Factors and United Statesability Assessment  
Patricia Trbovich, Canada

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**SESSION TIME:** 08:00 – 10:00  
**SESSION ROOM:** 802A  
**SESSION NAME:** BMEE22 - GENERAL BME EDUCATION

08:00  BMEE22.1: Biosensors and Signal Processing - Signal Analysis and Processing  
Sri Krishnan, Canada

09:00  BMEE22.2: Cellular and Biomolecular Engineering - Nanoparticles in Diagnostic Therapy  
Mukesh Harisinghani, United States

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**SESSION TIME:** 08:00 – 10:00  
**SESSION ROOM:** 802B  
**SESSION NAME:** MPE18 - MEDICAL PHYSICS EDUCATION AND PROFESSIONAL ISSUES

08:00  MPE18.1: Curriculum Design: How to Train the Next Generation of Physicists?  
John Damilakis, Greece

09:00  MPE18.2: Professional Standards and Certification of Qualified Individuals  
Geoff Ibbott, United States  
Matthew Schmid, Canada

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**SESSION TIME:** 08:00 – 10:00  
**SESSION ROOM:** 803A  
**SESSION NAME:** BMEE23 - CLINICAL ENGINEERING/TECHNOLOGY MANAGEMENT

08:00  BMEE23.1: Clinical Engineering Standards of Practice - Canadian New Edition and Other Countries  
Anthony Chan, Canada  
Bill Gentles, Canada

09:00  BMEE23.2: Emerging Medical Technologies - What to Expect, How to Prepare for it  
Jim Keller, United States

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**SESSION TIME:** 08:00 – 10:00  
**SESSION ROOM:** 803B  
**SESSION NAME:** MPE19 - RADIATION THERAPY

08:00  MPE19.1: Commissioning, Clinical Implementation and Quality Assurance for Stereotactic Body Radiation Therapy  
Timothy Solberg, United States

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**SESSION TIME:** 10:30 – 12:00  
**SESSION ROOM:** 802A  
**SESSION NAME:** BMEE24 - MEDICAL DEVICE DEVELOPMENT AND COMMERCIALIZATION

10:30  BMEE24.1: The Product Development Cycle  
Lahav Gill, Canada

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**SESSION TIME:** 10:30 – 12:00  
**SESSION ROOM:** 801A + 801B  
**SESSION NAME:** JT08 - SCIENCES & RESEARCH

10:30  JT08.1: How to get Grants: Tips for Success  
Aaron Foster, United Kingdom

11:30  JT08.2: How to Write and Review Research Articles  
David Rogers, Canada  
David Thwaites, Australia

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**SESSION TIME:** 10:30 – 12:00  
**SESSION ROOM:** 803A  
**SESSION NAME:** BMEE25 - CLINICAL ENGINEERING/TECHNOLOGY MANAGEMENT

10:30  BMEE25.1: Clinical Engineering Best Practice and Bench-marking  
Binseng Wang, China

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**SESSION TIME:** 10:30 – 12:00  
**SESSION ROOM:** 802B  
**SESSION NAME:** BMEE26 - CLINICAL ENGINEERING

10:30  BMEE26.1: Collaboration on Health Care Decision-Making  
Michael Cheng, Canada  
Julie Polisena, Canada  
Hal Hilti, Canada
ADVANCING RADIATION THERAPY THROUGH SOFTWARE INNOVATION

Monday, June 8, 2015
At 12:15 to 13:15
Metro Toronto Convention Centre, South Building
Room 718A
Lunch will be provided

12:15 - 12:35
Considerations for implementing adaptive therapy using RayStation
Bon Mzenda, Chief Physicist
Auckland Radiation Oncology, Auckland, New Zealand

12:35 - 12:55
Deformable Image Registration and Dose Accumulation
Jean-Pierre Bissonnette & Vicky Kong
Radiation Medicine Program
Princess Margaret Cancer Center, Toronto Canada

12:55 - 13:15
Advancing radiation therapy through software innovation
Johan Löf, CEO
RaySearch Laboratories AB, Stockholm, Sweden

Moderator: Marc Mlyn, CEO, RaySearch Americas Inc.

www.raysearchlabs.com
## SCIENTIFIC PROGRAM
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<td>SP001 Image Processing and Visualization: Part 1</td>
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<td>15:00 – 16:00</td>
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<td>SP013 MRI: Methods</td>
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<td>17:00 – 18:00</td>
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<td>SP023 Quantitative Imaging: Part 1</td>
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<td>17:00 – 18:45</td>
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<td>SP024 Breast CAD and New Breast Imaging Techniques</td>
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<td><strong>TUESDAY, JUNE 9, 2015</strong></td>
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<td>SP034 CT: New Techniques</td>
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<td>SP035 Imaging Detector Technology</td>
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<td>SP044 Bio-Impedance and Imaging (Other)</td>
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<td>SP065 Conebeam CT</td>
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<td>SP070 Molecular Imaging PET/SPECT: Part 2</td>
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<td>SP088 Computer Aided Diagnosis</td>
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<td>SP096 Optical Imaging: Applications</td>
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<td>SP097 Quantitative Imaging: Part 2</td>
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<td>SP104 Phantoms</td>
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<td>SP105 MRI: Novel Approaches and Molecular Imaging &amp; Applications</td>
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<td><strong>THURSDAY, JUNE 11, 2015</strong></td>
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<td>SP128 Multimodality Imaging</td>
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<td>SP115 CT Image Quality and Dose Optimization</td>
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<td>SP129 Image Quality Assessment (Mammography and Other)</td>
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<td>SP139 Optical Imaging: Methods</td>
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<td>SP149 Iterative Reconstruction</td>
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<td>SP150 X-Ray Phase Contrast &amp; Scatter Imaging</td>
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<td>SP161 Angiography / X-ray Imaging</td>
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<td>SP162 Ultrasound and OCT: Applications</td>
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<td>SP172 Mammography and Tomosynthesis</td>
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<td>SP173 Ultrasound and OCT: Methods</td>
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**TRACK 02: BIOMATERIALS AND REGENERATIVE MEDICINE**

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<td>SP002 Stem Cells in Tissue Engineering and Regeneration</td>
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<td>TUESDAY, JUNE 9, 2015</td>
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<td>SP071 Scaffolds in Tissue Engineering</td>
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<td>SP098 Biomaterials and Regenerative Medicine</td>
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**TRACK 03: BIOMECHANICS AND ARTIFICIAL ORGANS**

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<td>SP089 Tissue Modelling</td>
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<td>THURSDAY, JUNE 11, 2015</td>
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<td>SP151 Cardio Mechanics &amp; Organs</td>
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**TRACK 04: RADIATION ONCOLOGY**

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<td>SP003 Brachy Therapy: Part 1</td>
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<td>SP004 Quality Assurance: Part 1</td>
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<td>SP015 Other Radiation Oncology: Part 1</td>
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<td>SP016 Image Guided RT: Part 1</td>
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<td>SP025 Dose Calculation: Part 1</td>
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<td>SP036 Treatment Planning – Motion and Robustness</td>
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<td>SP107 Beam Delivery</td>
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<td>SP078 Brachy Therapy: Part 2</td>
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<td>10:30 – 12:00</td>
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<td>SP079 Motion Management: Part 1</td>
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<td>SP081 Validation and Verification of Therapy Dose Delivery: Part 1</td>
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<td>SP100 Dose Optimization: Focus on DRLs</td>
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<td>SP108 Patient and Occupational Dose Assessment</td>
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<td>SP154 Developments in Radiation Protection</td>
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## TRACK 06: NEW TECHNOLOGIES IN CANCER RESEARCH AND TREATMENT

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<td>Nanotechnology in Radiation Therapy and Imaging: Part 1</td>
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## TRACK 07: SURGERY, COMPUTER AIDED SURGERY, MINIMAL INVASIVE INTERVENTIONS, ENDOSCOPY AND IMAGE-GUIDED THERAPY, MODELLING AND SIMULATION

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<td>Robotics and Virtual Reality in Surgery</td>
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<td>Radiotherapy and Guidance</td>
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## TRACK 08: BIOSENSOR, NANOTECHNOLOGY, BIOMEMS AND BIOPHOTONICS

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<td>Lab-on-chip, BioMEMS and Microfluidics</td>
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### TRACK 09: BIOSIGNAL PROCESSING

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<td>ECG</td>
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### TRACK 10: REHABILITATION MEDICINE, SPORTS MEDICINE, REHABILITATION ENGINEERING AND PROSTHETICS

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<td>Spinal Cord / Brain Injury &amp; Upper Limb Measurement and Treatments</td>
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<td>Ergonomics, Wearable Sensors and Virtual Reality</td>
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<td>Lower Limb Injury Assessment and Treatment &amp; Prosthetics and Assistive Devices</td>
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<td>Developing Tools for Successful Aging: Independent Mobility &amp; Visual Impairment</td>
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### TRACK 11: NEUROENGINEERING, NEURAL SYSTEMS

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<td>Brain Computer/Machine Interfaces</td>
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<td>Functional Neuroimaging and Neuronavigation</td>
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<td>Deep Brain Stimulation</td>
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## TRACK 12: MEDICAL DEVICES

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<td>SP053 Cardiovascular Instrumentation</td>
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<td>SP060 Special Session: UNESCO International Year of Light</td>
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<td>SP061 Improvement of Diagnosis and Therapies</td>
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<td>SP084 New Designing Ideas</td>
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<td>SP169 Self Engagement, Patient Empowerment and mHealth</td>
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## TRACK 14: INFORMATION TECHNOLOGIES IN HEALTHCARE DELIVERY AND MANAGEMENT

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<td>SP113 Information Technologies in Healthcare Delivery and Management: Part 1</td>
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## TRACK 15: BIOINFORMATICS

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### TRACK 16: CLINICAL ENGINEERING, CLINICAL PHYSICS, AND PATIENT SAFETY

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<td>SP009 Patient Safety, Medical Errors and Adverse Events Prevention Related to Health Technologies and Incident Analysis and Management</td>
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<td>701A</td>
<td>SP042 Technology Management Programmes and Equipment Management Systems</td>
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<td>SP062 Clinical Process Analysis, Optimization, Productivity and Benchmarking</td>
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<td>SP093 Health Technology Assessment and Cost Effective Technologies for Developing Countries and Usability and Human Factors Engineering for Medical Devices and System Design: Part 1</td>
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<td>SP103 Health Technology Assessment and Cost Effective Technologies for Developing Countries and Usability and Human Factors Engineering for Medical Devices and System Design: Part 2</td>
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### TRACK 17: EDUCATIONAL AND PROFESSIONAL ACTIVITIES

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<td>SP063 Accreditation, Certification and Licensure Issues</td>
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<td>SP075 Special Session: Appropriate Technology in Imaging and Radiotherapy – Functionality and Safety Aspects</td>
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<td>10:30 – 12:00</td>
<td>714A</td>
<td>SP137 Special Session: Building Medical Physics Capacity in Developing Countries</td>
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### TRACK 18: GENDER, SCIENCE AND TECHNOLOGY

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<tbody>
<tr>
<td>MONDAY, JUNE 8, 2015</td>
<td>08:00 – 09:30</td>
<td>717A</td>
<td>SP011 Overview of Gender Roles in Medical Physics in North America</td>
</tr>
<tr>
<td>TUESDAY, JUNE 9, 2015</td>
<td>08:00 – 09:30</td>
<td>717A</td>
<td>SP043 Women in BioMedical Engineering</td>
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<tr>
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<td>10:30 – 12:00</td>
<td>717A</td>
<td>SP054 Women in Medical Physics: Current Status</td>
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<tr>
<td>WEDNESDAY, JUNE 10, 2015</td>
<td>10:30 – 11:45</td>
<td>717A</td>
<td>SP085 Women in Medical Physics: Current Status</td>
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<tr>
<td>SESSION DATE</td>
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<tr>
<td>TUESDAY, JUNE 9, 2015</td>
<td>17:15 – 19:00</td>
<td>717A</td>
<td>Radiobiological Modelling</td>
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<tr>
<td></td>
<td>10:30 – 11:45</td>
<td>715A</td>
<td>Biological Effects of Ionizing Radiation</td>
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<td>13:30 – 14:15</td>
<td>715A</td>
<td>Biological Modelling</td>
</tr>
<tr>
<td>THURSDAY, JUNE 11, 2015</td>
<td>08:00 – 09:45</td>
<td>715A</td>
<td>Computational Biology &amp; Hemodynamics</td>
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<tr>
<td></td>
<td>17:00 – 18:15</td>
<td>716B</td>
<td>Transport and Physiological Modelling</td>
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<tr>
<th>SESSION DATE</th>
<th>TIME</th>
<th>ROOM</th>
<th>SESSION TITLE</th>
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<tbody>
<tr>
<td>MONDAY, JUNE 8, 2015</td>
<td>15:00 – 16:30</td>
<td>713B</td>
<td>Educational and Professional Activities: Part 1</td>
</tr>
<tr>
<td></td>
<td>17:00 – 18:15</td>
<td>713B</td>
<td>Imaging: Part 1</td>
</tr>
<tr>
<td>TUESDAY, JUNE 9, 2015</td>
<td>15:00 – 16:15</td>
<td>713B</td>
<td>Biomechanics and Artificial Organs</td>
</tr>
<tr>
<td></td>
<td>17:00 – 18:45</td>
<td>713B</td>
<td>Radiation Oncology</td>
</tr>
<tr>
<td>WEDNESDAY, JUNE 10, 2015</td>
<td>10:30 – 12:15</td>
<td>713B</td>
<td>Educational and Professional Activities: Part 2</td>
</tr>
<tr>
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<td>13:30 – 15:15</td>
<td>713B</td>
<td>Biosignal Processing &amp; Pulmonary &amp; Respiratory</td>
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<tr>
<td></td>
<td>17:00 – 18:00</td>
<td>713B</td>
<td>Dosimetry and Radiation Protection</td>
</tr>
<tr>
<td>THURSDAY, JUNE 11, 2015</td>
<td>08:00 – 09:30</td>
<td>713B</td>
<td>Informatics In Health Care And Public Health / Biosensor, Nanotechnology, Biomems And Biophotonics</td>
</tr>
<tr>
<td></td>
<td>10:30 – 11:45</td>
<td>713B</td>
<td>Biosensor, Nanotechnology, Biomems And Biophotonics / New Technologies In Cancer Research And Treatment</td>
</tr>
<tr>
<td></td>
<td>15:00 – 16:30</td>
<td>713B</td>
<td>Medical Devices / Surgery, Computer Aided Surgery, Minimal Invasive Interventions, Endoscopy And Image-Guided Therapy, Modeling And Simulation</td>
</tr>
<tr>
<td></td>
<td>17:00 – 18:15</td>
<td>713B</td>
<td>Neuroengineering, Neural Systems / Biophysics And Modelling</td>
</tr>
<tr>
<td>FRIDAY, JUNE 12, 2015</td>
<td>08:00 – 10:00</td>
<td>714A</td>
<td>Clinical Engineering / Physics, Patient Safety &amp; Imaging</td>
</tr>
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</table>

SCI. PROGRAM BY TRACK
Monday, June 8 2015

SESSION TIME: 08:00 - 09:30
SESSION ROOM: 718A
SESSION TRACK: TRACK 01: IMAGING
SESSION NAME: SP001 - IMAGE PROCESSING AND VISUALIZATION: PART 1
SESSION CHAIR(S): MARLEN PEREZ-DIAZ, CUBA

08:00 SP001.1 - The Use of Wavelet Filters for Reducing Noise in Posterior Fossa Computed Tomography Images
*Marlen Perez-Diaz, Cuba*

08:15 SP001.2 - Automatic Liver Localization based on Classification Random Forest with KNN for Prediction
*Fucang Jia, People’s Republic of China*

08:30 SP001.3 - Brain Tumor Target Volume Segmentation: Local Region Based Approach
*Hossein Aslian, Italy*

08:45 SP001.4 - A Novel Automatic White Balance Algorithm for the 3D Image of Stereoscopic Endoscopy
*Ling Li, People’s Republic of China*

09:00 SP001.5 - A new log-compression rule for B-mode ultrasound imaging adjusted to the human visual system
*Ramon Fernandes, Brazil*

09:15 SP001.6 - Comparison of Independent Component Analysis (ICA) Algorithm for Heart Rate Measurement Based on Facial Imaging
*Septiana, Indonesia*

SESSION TIME: 08:00 - 09:45
SESSION ROOM: 701A
SESSION TRACK: TRACK 02: BIOMATERIALS AND REGENERATIVE MEDICINE
SESSION NAME: SP002 - STEM CELLS IN TISSUE ENGINEERING AND REGENERATION
SESSION CHAIR(S): GILDA BARABINO, UNITED STATES

08:00 SP002.1 - KEYNOTE: Biomaterials and Regenerative Medicine: Micro-environmental Modulation for Controlled Cell Differentiation and Tissue Development
*Gilda Barabino, United States*

08:30 SP002.2 - KEYNOTE: Defining the regulatory metrics for regenerative medicine using novel biomaterial tagging strategies
*Alicia El Haj, United Kingdom*

09:00 SP002.3 - The role of electric fields in promoting precursor cell migration to enhance wound repair
*Stephanie Iwasa, Canada*

09:15 SP002.4 - The role of niche architecture on muscle stem cell division orientation
*Richard Cheng, Canada*

09:30 SP002.5 - Mapping the Stem Cell’s Mechanome using Paired Live Cell Multiplexed Imaging and Modeling
*Melissa Knothe Tate, Australia*

SESSION TIME: 08:00 - 09:45
SESSION ROOM: 701B
SESSION TRACK: TRACK 04: RADIATION ONCOLOGY
SESSION NAME: SP003 - BRACHY THERAPY: PART 1
SESSION CHAIR(S): SIJI PAUL, INDIA

08:00 SP003.1 - The impact of in-homogeneity corrected dose calculations for various clinical HDR brachytherapy sites.
*Siji Paul, India*

08:15 SP003.2 - A novel QA device for brachytherapy applicator QA
*Sook Kien Ng, United States*

08:30 SP003.3 - Electromagnetic tracking for catheter reconstruction in ultrasound-guided high-dose-rate brachytherapy of the prostate
*Alexandru Nicolae, Canada*

08:45 SP003.4 - Dosimetric and radiobiological comparison of volumetric modulated arc therapy, high-dose-rate brachytherapy and low-dose-rate permanent seeds implant for localized prostate cancer
*Ruijie Yang, People’s Republic of China*

09:00 SP003.5 - A novel system for real-time planning and guidance of breast HDR brachytherapy
*Eric Poulin, Canada*
09:15  SP003.6 - Investigation of electromagnetic catheter tracking approach for spatial reconstruction of implant geometry in high dose rate brachytherapy of prostate cancer

Gabor Fichtinger, Canada

09:30  SP003.7 - Endoscopic Tracking for improved Applicator Insertion in Esophagus and Lung HDR Brachytherapy

Robert Weersink, Canada

08:00  SP004.1 - In Vivo EPID Dosimetry Detects Interfraction Errors in 3D-CRT of Rectal Cancer

Stefano Peca, Canada

08:15  SP004.2 - Establishing action thresholds for patient anatomy changes and machine errors during complex treatment using EPID and gamma analysis

Ophélie Piron, Canada

08:30  SP004.3 - Dosimetrical characteristics of amorphous silicon electronic portal imager for flattening filter free (FFF) photon beam of upgraded C-series Linear accelerator

Vellian Subramani, India

08:45  SP004.4 - Radiation field size, junction and MLC QA using amorphous silicon electronic portal imaging device, an efficient approach to improve routine accuracy

Dany Simard, Canada

09:00  SP004.6 - Real-time detection of deviations in radiotherapy beam delivery using a head-mounted detector

Richard Canters, Netherlands

08:15  SP005.2 - Influence of Jaw Tracking in Intensity Modulated and Volumetric Modulated Arc Radiotherapy for Head and Neck Cancers? A Dosimetric Study

Kh Anamul Haque, Bangladesh

08:30  SP005.3 - Evaluation of the eye lens dose according to patient setup errors in pediatric head CT examination

Rumi Gotanda, Japan

08:45  SP005.4 - Multi-Point Sources on Skin to Assess the Annual Effective Dose by Usage of TENORM added Pillow

Do hyeon Yoo, Republic of Korea

09:00  SP005.5 - Patient-Specific Quality Assurance of Respiratory-Gated VMAT Using a Programmable Cylindrical Respiratory Motion Insert for the ArcCHECK™ Phantom

Heather Young, Canada

08:00  SP006.1 - KEYNOTE: Dosimetry and Radiation Protection

Virginia Tsapakis, Greece

08:30  SP006.2 - Organ dose reduction while using in-house CBCT patient-specific protocols based on OSL dosimetry

Étienne Létourneau, Canada

08:45  SP006.3 - A novel tool for in vivo dosimetry in diagnostic and interventional radiology using plastic scintillation detectors

Jonathan Boivin, Canada

09:00  SP006.5 - Assessment of patient’s eye lens dose using a custom made anthropomorphic head phantom

Kwan Hoong Ng, Malaysia

09:15  SP006.6 - Dose Profile and Equilibrium Doses in CT

Ricardo Terini, Brazil

08:00  SP0005.1 - Verifying dynamic planning in gamma knife radiosurgery using gel dosimetry

Gopishankar Natanasabapathi, India
08:00  SP007.1 - **KEYNOTE**: Biosignal Processing  
*Adrian Chan, Canada*

08:30  SP007.2 - Adaptive filter for eliminating baseline wander of pulse wave signals  
*Anna Akulova, Russian Federation*

08:45  SP007.3 - Efficacy of DWT denoising in the removal of power line interference and the effect on morphological distortion of underlying atrial fibrillatory waves in AF-ECG  
*Omar Escalona, United Kingdom*

09:00  SP007.4 - Quantifying Blood-Oxygen Saturation Measurement Error in Motion Contaminated Pulse Oximetry Signals  
*Geoffrey Clarke, Canada*

09:15  SP007.5 - Signal Quality Indices for Ambulatory Electrocardiograms used in Myocardial Ischemia Monitoring  
*Mohamed Abdelazez, Canada*

09:30  SP007.6 - A simple algorithm for identifying artifact beats in long ECG recordings  
*Nini Rao, People’s Republic of China*

09:45  SP007.7 - Automatic Detection of Low-Quality Seismocardiogram Cycles Using the Outlier Approach  
*Vahid Zakeri, Canada*

08:00  SP008.1 - A Validation Test of a Simple Method of Stride Length Measurement Only with Inertial Sensors and a Preliminary Test in FES-assisted Hemiplegic Gait  
*Takashi Watanabe, Japan*

08:15  SP008.2 - A novel Treadmill Body Weight Support system using Pneumatic Artificial Muscle actuators: a comparison between active Body Weight Support system and counter weight system  
*Thuc Tran, Japan*

08:30  SP008.3 - A Serious Game for Training and Evaluating the Balance of Hemiparetic Stroke Patients  
*Pedro Bertemes-Filho, Brazil*

08:45  SP008.4 - fNIRS-based analysis of brain activation with knee extension induced by functional electrical stimulation  
*Misato Ohdaira, Japan*

09:00  SP008.5 - Muscle fatigability of isometric and isokinetic knee-extension generated by single-electrode- and spatially-distributed-sequential-stimulation  
*Austin Bergquist, Canada*

09:15  SP008.6 - External modulation of electrical stimulated spinal reflexes - a control modality for human lumbosacral networks in injury induced disconnection from brain control  
*Winfried Mayr, Austria*

09:30  SP008.7 - Motor Control Assessment using Leap Motion: Filtering Methods and Performance in Indoor and Outdoor Environments  
*Jone Kim, Canada*

09:45  SP008.8 - Biceps brachii EMG signals: estimation of dipole sources  
*Peyman Aghajamaliaval, Canada*

10:00  SP008.9 - Validating a Solid-Static Single-Armed Male Prototype Tasked to Produce Dynamic Movement from the Shoulder Through the Preparation Phase  
*Alicia Gal, Canada*
**SESSION TIME:** 08:00 – 09:45  
**SESSION ROOM:** 715A  
**SESSION TRACK:** TRACK 17: EDUCATIONAL AND PROFESSIONAL ACTIVITIES  
**SESSION NAME:** SP010 – EDUCATION AND TRAINING IN BIOMEDICAL ENGINEERING  
**SESSION CHAIR(S):** SHANKAR KRISHNAN, UNITED STATES  
MLADEN POLUTA, SOUTH AFRICA

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<tr>
<th>Time</th>
<th>Session</th>
<th>Title</th>
<th>Speaker(s)</th>
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<tr>
<td>08:00</td>
<td>SP010.1</td>
<td>Biomedical Engineering in Nigeria: A Developmental Overview</td>
<td>Kenneth Nkuma-Udah, Nigeria</td>
</tr>
<tr>
<td>08:15</td>
<td>SP010.2</td>
<td>Biomedical Engineering Education in Peru in 2015: A Unique and Innovative Collaboration in Latin America</td>
<td>Rossana Rivas, Peru</td>
</tr>
<tr>
<td>08:30</td>
<td>SP010.3</td>
<td>Improving Biomedical Engineering in Uganda through education, benchmarking and mentorship</td>
<td>Robert Ssekitoleko, Uganda</td>
</tr>
<tr>
<td>08:45</td>
<td>SP010.4</td>
<td>Designing Biomedical Engineering Programs to Prepare for Medtech Industry</td>
<td>Shankar Krishnan, United States</td>
</tr>
<tr>
<td>09:00</td>
<td>SP010.5</td>
<td>BME vs CE vs HTM vs HbHTA vs EAM. What’s in a Name and does it matter?</td>
<td>Mladen Poluta, South Africa</td>
</tr>
<tr>
<td>09:15</td>
<td>SP010.6</td>
<td>Clinical Engineering Certification Program in the Americas</td>
<td>Frank Painter, United States</td>
</tr>
<tr>
<td>09:30</td>
<td>SP010.7</td>
<td>Biomedical Technology Online Courses for the Americas</td>
<td>Tobey Clark, United States</td>
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**SESSION TIME:** 08:00 – 09:30  
**SESSION ROOM:** 717A  
**SESSION TRACK:** TRACK 18: GENDER, SCIENCE AND TECHNOLOGY  
**SESSION NAME:** SP011 – OVERVIEW OF GENDER ROLES IN MEDICAL PHYSICS IN NORTH AMERICA  
**SESSION CHAIR(S):** PATRICIA TRBOVICH, CANADA  
KRISTY BROCK, UNITED STATES

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<th>Time</th>
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<tr>
<td>08:00</td>
<td>SP011.1</td>
<td>KEYNOTE: Gender, Science and Technology: The Role of Women in Medical Physics</td>
<td>Kristy Brock, United States</td>
</tr>
<tr>
<td>08:30</td>
<td>SP011.2</td>
<td>Biography of Women in Medical Physics: Maryellen Giger, Ph.D.</td>
<td>Maryellen Giger, United States</td>
</tr>
<tr>
<td>08:45</td>
<td>SP011.3</td>
<td>My STEM story: from Martinique in the Caribbean to Quebec City, through France and Vietnam</td>
<td>Nadia Octave, Canada</td>
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**SESSION TIME:** 15:00 – 16:00  
**SESSION ROOM:** 718A  
**SESSION TRACK:** TRACK 01: IMAGING  
**SESSION NAME:** SP013 – MRI: METHODS  
**SESSION CHAIR(S):** ZOFIA DRZAZGA, POLAND  
CHEMSEDDINE FATNASSI, SWITZERLAND

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<tr>
<td>15:00</td>
<td>SP013.1</td>
<td>Numerical Simpson’s Rule for Real Time and Accurate T2* maps generation Using 3D Quantitative GRE</td>
<td>Chemseddine Fatnassi, Switzerland</td>
</tr>
<tr>
<td>15:15</td>
<td>SP013.2</td>
<td>Optimization of Pulse-Triggered fMRI Measurement Delay with Acoustic Stimulation</td>
<td>Zofia Drzazga, Poland</td>
</tr>
<tr>
<td>15:30</td>
<td>SP013.3</td>
<td>Improvement of Pseudo Multispectral Classification of Brain MR Images</td>
<td>Chemseddine Fatnassi, Switzerland</td>
</tr>
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<td>15:45</td>
<td>SP013.4</td>
<td>Image reconstruction of RF encoded MRI signals in an inhomogeneous B0 field</td>
<td>Somaie Salajeghe, Canada</td>
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**SESSION TIME:** 15:00 – 16:15  
**SESSION ROOM:** 701B  
**SESSION TRACK:** TRACK 03: BIOMECHANICS AND ARTIFICIAL ORGANS  
**SESSION NAME:** SP014 – BONE MECHANICS  
**SESSION CHAIR(S):** JIE YAO, PEOPLE’S REPUBLIC OF CHINA

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<th>Speaker(s)</th>
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<tr>
<td>15:00</td>
<td>SP014.1</td>
<td>KEYNOTE: Biomechanics and Artificial Organs</td>
<td>Yubo Fan, People’s Republic of China</td>
</tr>
<tr>
<td>15:30</td>
<td>SP014.2</td>
<td>Improved Semi-automated 3D Kinematic Measurement of Total Knee Arthroplasty Using X-ray Fluoroscopic Images</td>
<td>Takaharu Yamazaki, Japan</td>
</tr>
<tr>
<td>15:45</td>
<td>SP014.3</td>
<td>The influence of screw length and stiffness on the tibial mechanical environment in ACL reconstruction</td>
<td>Jie Yao, People’s Republic of China</td>
</tr>
<tr>
<td>16:00</td>
<td>SP014.4</td>
<td>A new method for determining the effect of follower load on the range of motions in the lumbar spine</td>
<td>Cheng-fei Du, People’s Republic of China</td>
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<td>Session Time</td>
<td>Session Name</td>
<td>Session Chair(s)</td>
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<tr>
<td>15:00 - 16:15</td>
<td>SP015.1 - Beta Enhancers: towards a local dose enhancer device for Boron Neutron Capture Therapy (BNCT) on superficial tumors</td>
<td>Esteban Boggio, Argentina</td>
<td></td>
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<tr>
<td>15:15</td>
<td>SP015.2 - Nanoparticle Enhanced Radiation Therapies: Is There a Synergy with Chemotherapies?</td>
<td>Linda Rogers, Australia</td>
<td></td>
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<tr>
<td>15:30</td>
<td>SP015.3 - Change in Hounsfield Units due to lung expansion as a predictor of LAD and heart displacement in patients undergoing deep inspiration breath hold for left sided breast cancer</td>
<td>Peta Lonski, Australia</td>
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<tr>
<td>15:45</td>
<td>SP016.4 - Samarium-153 Labelled Microparticles for Targeted Radionuclide Therapy of Liver Tumor</td>
<td>Chai Hong Yeong, Malaysia</td>
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<tr>
<td>16:00</td>
<td>SP016.5 - Anatomical Modelling of the Pregnant Radiotherapy Patient</td>
<td>Tanya Kairn, Australia</td>
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<tr>
<td>15:00 - 16:30</td>
<td>SP016.1 - 18F-NaF PET/CT-directed dose escalation in stereotactic body radiotherapy for spine oligometastases from prostate cancer</td>
<td>James Chow, Canada</td>
</tr>
<tr>
<td>15:15</td>
<td>SP016.2 - Evaluation of a lung tumor autocontouring algorithm for intrafractional tumor tracking using 0.5T linac-MR: phantom and in-vivo study</td>
<td>Manuel Rodriguez, Canada</td>
</tr>
<tr>
<td>15:30</td>
<td>SP016.3 - Multi-modal image registration for MR-guided radiotherapy workflow based on detection of features in a customized stereotactic body frame</td>
<td>Nelson Miksys, Canada</td>
</tr>
<tr>
<td>15:45</td>
<td>SP016.4 - A phantom study of impact of probe metal artifact in planning dose for ultrasound-guided radiotherapy</td>
<td>Mohamad Mohamad Alabdoaburas, France</td>
</tr>
<tr>
<td>16:00</td>
<td>SP016.5 - Software development for image guidance on the magnetic resonance-guided radiation therapy (MRgRTTM) system</td>
<td>Donna Murrell, Canada</td>
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<tr>
<td>15:00 - 16:30</td>
<td>SP017.1 - Dosimetric Effect of Beam Angle on the Unflattened and Flattened Photon Beams: A Monte Carlo study</td>
<td>Hassan Ali Nedaie, Iran</td>
</tr>
<tr>
<td>15:15</td>
<td>SP017.2 - Monte Carlo calculations and measurements of the TG-43U1 recommended dosimetric parameters for the 125I (Model IR-Seed2) brachytherapy source</td>
<td>Nelson Miksys, Canada</td>
</tr>
<tr>
<td>15:30</td>
<td>SP017.3 - Assessment of RayStation treatment planning algorithm to calculate dose in the presence of lung tissue</td>
<td>Johann Riehl, Norway</td>
</tr>
<tr>
<td>15:45</td>
<td>SP017.4 - Improving the efficiency of charged particle transport in magnetic fields in EGSnrc</td>
<td>Victor Malkov, Canada</td>
</tr>
<tr>
<td>16:00</td>
<td>SP017.5 - Accurate Monte Carlo dose calculations for permanent implant prostate brachytherapy: first results from a large scale retrospective study</td>
<td>Victor Malkov, Canada</td>
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<tr>
<td>15:00 - 16:30</td>
<td>SP018.1 - KEYNOTE: New Technologies in Cancer Research and Treatment</td>
<td>Frank Verhaegen, Netherlands</td>
</tr>
<tr>
<td>15:15</td>
<td>SP018.2 - Longitudinal MRI evaluation of whole brain radiotherapy on brain metastasis development and dormancy in a mouse model</td>
<td>Donna Murrell, Canada</td>
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</table>
15:45  SP018.3 - Dual energy micro-CT determination of effective atomic number and electron density  
*Michael Jensen, Canada*

16:00  SP018.4 - Tissue characterization using dual energy cone beam CT imaging with a dedicated small animal radiotherapy platform  
*Patrick Granton, Canada*

16:15  SP018.5 - Low-dose prostate cancer brachytherapy by injections of radioactive gold nanoparticles (103Pd:Pd@Au NPs)  
*Myriam Laprise-Pelletier, Canada*

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**SESSION TIME:**  15:00 – 16:30  
**SESSION ROOM:**  717B  
**SESSION TRACK:**  TRACK 08: BIOSENSOR, NANOTECHNOLOGY, BIOMEMS AND BIOPHOTONICS  
**SESSION NAME:**  SP019 - NANOBIOSENSORS AND NANOTHERANOSTICS  
**SESSION CHAIR(S):**  KWANG OH, UNITED STATES  
WALTER H. CHANG, CHINESE TAIPEI

15:00  SP019.1 - Synthesis and evaluation of C595 mAb-conjugated SPIONs nanoprobe for specific detection of Prostate cancer  
*Mohammad Abdollahi, Iran*

15:15  SP019.2 - Magnetic Resonance Nanotheranostics of Guerin's Carcinoma  
*Valerii Orel, Ukraine*

15:30  SP019.3 - Effects of Fluorescence Gold Nanoclusters on Anti-oxidation and Anti-aging by Cell Model  
*Walter H. Chang, Chinese Taipei*

15:45  SP019.4 - Nanoparticle-aided Radiotherapy for Retinoblastoma and Choroidal Melanoma  
*Wilfred Ngwa, United States*

16:00  SP019.5 - Nanoparticle enhancement of radiation dose: experimental confirmation using scintillation dosimetry  
*Natalka Suchowerska, Australia*

16:15  SP019.6 - Graphene Plasmonics as Promising Platform for Highly Sensitive Plasmonic Sensing  
*Dong Ha Kim, Republic of Korea*

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**SESSION TIME:**  15:00 – 16:45  
**SESSION ROOM:**  715B  
**SESSION TRACK:**  TRACK 09: BIOSIGNAL PROCESSING  
**SESSION NAME:**  SP020 – BIOMEDICAL MODELING  
**SESSION CHAIR(S):**  RUI FONSECA-PINTO, PORTUGAL  
KYUICHI NIIZEKI, JAPAN

15:00  SP020.1 - Respiratory parameters have different patterns in imposed-inspiration and imposed-expiration within a closed pneumatic circuit in rats  
*Fabio Aoki, Brazil*

15:15  SP020.2 - Autonomic and cardiovascular responses to food ingestion and gum chewing in healthy young subjects  
*Kyuichi Niizeki, Japan*

15:30  SP020.3 - Characteristic Analysis and Modeling for Signals of Auditory Propagation Pathway  
*Qin Gong, People's Republic of China*

15:45  SP020.4 - Numerical Optimization Performance of a Perfusion Kinetic Modelling Algorithm using Volumetric DCE CT  
*Igor Svistoun, Canada*

16:00  SP020.5 - Validation of a Sympathovagal Balance Model to Evaluate Autonomic Function in Rats Using Time-Frequency Analysis  
*Rui Fonseca-Pinto, Portugal*

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**SESSION TIME:**  15:00 – 16:15  
**SESSION ROOM:**  716B  
**SESSION TRACK:**  TRACK 13: INFORMATICS IN HEALTH CARE AND PUBLIC HEALTH  
**SESSION NAME:**  SP021 – PUBLIC HEALTH, ACTIVE AND HEALTHY AGING  
**SESSION CHAIR(S):**  ELINA KALDOUDI, GREECE  
CHRISTIAN BOEHLER, SPAIN

15:00  SP021.1 - KEYNOTE: Informatics in Health Care and Public Health  
*Leandro Pecchia, United Kingdom*

15:30  SP021.2 - Monitoring Information System of Aedes Aegypti Reproduction  
*Lourdes Brasil, Brazil*

15:45  SP021.3 - Design and Functionality of a Meta-Reporting Tool within a Medical Devices Vigilance System  
*Aris Dermitzakis, Greece*

16:00  SP021.4 - Evaluation of the Impact in the Physical Condition of School Age Children Exposed to an Intervention of Exergaming in Montemorelos Mexico  
*Gerardo Romo-Cardenas, Mexico*

16:15  SP021.5 - Using the EIP on AHA monitoring tool for the early technology assessment of a planned device to predict in-hospital falls in the elderly  
*Christian Boehler, Spain*

16:30  SP021.6 - An innovative Decision Support System (DSS) for patients with Inflammatory Bowel Disease (IBD)  
*Vasileios Tsianos, Greece*
15:00  SP022.1 - Biomedical Engineering in Nigeria: A Developmental Overview  
*Kenneth Nkuma-Udah, Nigeria*

15:15  SP022.2 - Modernising Scientific Careers? A new scheme for the education and training of physicists, engineers and other scientific staff in the UK National Health Service  
*Keith Ison, United Kingdom*

15:30  SP022.3 - Medical Physics Residency Program in Developing Countries: Lessons, Challenges and Solutions Learned from a Regional Pilot Training Program  
*Belal Moftah, Saudi Arabia*

15:45  SP022.4 - International Union of Biological Sciences  
*Nils Chr. Stenseth, France*

16:00  SP022.5 - Promoting the public image of Medical Physicists and Biomedical Engineers  
*Micah Cheng, Canada*

16:15  SP022.6 - The Utilization and Design of Doorless Mazes for Medical Linear Accelerator Rooms In Ontario, Canada  
*Joseph Szabo, Canada*

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17:00  SP023.1 - Improving quantitative functional imaging with dynamic contrast enhanced studies using a linearized Johnson-Wilson model approach  
*Fiona Li, Canada*

17:15  SP023.2 - Early tumor Response assessment using volumetric DCE-CT and DCE-MRI in Metastatic Brain Cancer Patients  
*Catherine Coolens, Canada*

17:30  SP023.3 - Diffusion tensor imaging is correlated with quantitative histology in surgically-rectested hippocampi of epilepsy patients  
*Terry Peters, Canada*

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17:45  SP023.4 - Evaluation of fully automatic volumetric GBM segmentation in the TCGA-GBM dataset: Prognosis and correlation with VASARI features  
*Emmanuel Rios Velazquez, United States*
17:30 SP025.3 - A Geant4 Helical Tomotherapy model as a tool for 3D dose distribution evaluation
   Alessandro Esposito, Portugal

17:45 SP025.4 - Development of 4D actual delivered dose calculation system for dynamic tumor-tracking irradiation with a gimballed linac
   Yoshitomo Ishihara, Japan

18:00 SP025.5 - Organ Doses from Hepatic Radioembolization with Y-90, Sm-153, Ho-166 and Lu-177: A GEANT4 Monte Carlo Simulation Study
   Chai Hong Yeong, Malaysia

18:15 SP025.6 - Stereotactic Ablative Radiotherapy (SABR) for lung cancer using Volumetric Modulated Arc Therapy (VMAT) with a 10x Flattening Filter Free (FFF) beam: validation of the calculated dose distribution using Monte Carlo
   Tony Mestrovic, Canada

18:30 SP025.7 - Performance of the ACUROS® dose calculation algorithm for 6 MV FFF beams in inhomogeneous media
   Matthew Schmid, Canada

18:45 SP025.8 - Ray Tracing Algorithm for Virtual Source Modelling based on Evaluation of Rounded Leaf End Effect of Multileaf Collimator
   Dong Zhou, People’s Republic of China

17:00 SP026.1 - The Development of a Device for the Fricke Dosimetry for HDR Brachytherapy
   Camila Salata, Brazil

17:15 SP026.2 - A New Methodology for the Determination of the G-value for Fricke Dosimetry
   Camila Salata, Brazil

17:30 SP026.3 - The Use of Fricke Dosimetry as a Primary Standard for the Absorbed Dose to Water for 192Ir HDR-BT Sources: Determination of the G-value
   Camila Salata, Brazil

17:45 SP026.4 - IAEA Dosimetry Laboratory support to the IAEA/WHO SSDL Network
   Joanna Izewska, Austria

18:00 SP026.5 - Measurement of Wair in high energy electron beams
   Claudiu Cojocaru, Canada

18:15 SP026.6 - Monte Carlo corrections for a Fricke-based standard of absorbed dose to water for Ir-192 HDR brachytherapy.
   Ernesto Mainegra-Hing, Canada

18:30 SP026.7 - Changes in absorbed dose to water caused by dose standard shift for ionization chamber calibration in Japan
   Hidetoshi Saitoh, Japan

18:45 SP026.8 - A calibration system of therapy-level dosimeter in Japan organized by ANTM
   Suoh Sakata, Japan
17:00 SP028.1 - On Understanding of the Limiting Factors in Radiofrequency Ablation on Target Tissue Necrosis Volume
Bing Zhang, People’s Republic of China

17:15 SP028.2 - Thermal Dose Based Monitoring of Thermal Therapy for Prostate Cancer
Joseph Kumaradas, Canada

17:30 SP028.3 - Nanodrug Delivery and Anti-tumor Efficacy for Brain Metastasis of Breast Cancer Enhanced by Short-time Low-dose Ultrasound Hyperthermia
Sheng-Kai Wu, Chinese Taipei

17:45 SP028.4 - Evaluating breast cancer surgical margins using high-frequency ultrasound: Statistical analysis of a 17-patient pilot study
Robyn Omer, United States

18:00 SP028.5 - The Intraoperative Detection of Breast Cancer in Surgical Margins Using High-Frequency Ultrasound: Studies Using Histology Mimicking Phantoms
Zachary Coffman, United States

18:15 SP028.6 - Rapid Molecular Subtyping of Breast Cancer Using High-Frequency Ultrasound (10-120 MHz) and Principal Component Analysis
Caitlin Carter, United States

18:30 SP028.7 - Inverse treatment planning using radiofrequency ablation in cancer therapy
Shefali Kulkarni-Thaker, Canada

17:15 SP029.2 - Seymour Shield? An Operative Adjunct Device for Maintaining Visualization during Laparoscopic Surgery
Karthik Kannan, Singapore

17:30 SP029.3 - Optimizing MRI-targeted fusion prostate biopsy: the effect of systematic error and anisotropy on tumour sampling
Peter Martin, Canada

17:45 SP029.4 - Is hemolysis influenced by the dynamic calibration method of CPB roller pumps?
Eduardo Costa, Brazil

18:00 SP029.5 - A Fiducial Apparatus for 6DOF Pose Estimation of an External Echo Probe from a Single X-ray Projection: Initial Simulation Studies on Design Requirements
Charles Hatt, United States

18:15 SP029.6 - Mechanism design a flexible endoscope with USB adaptation to training.
Francisco Perez Reynoso, Mexico

18:30 SP030.1 - KEYNOTE: Drop-based microfluidics for diagnostic applications
David Weitz, United States

17:00 SP030.2 - Enhanced multielectrode configurations in miniaturized 3D electrical impedance spectroscopy and tomography? Monitoring the overall process of tissue engineering with spatial sensing for future challenges in microfluidics
Chiara Canali, Denmark

17:45 SP030.3 - On-line monitoring of 2D and 3D cell cultures: electrode configurations for impedance based sensors
Chiara Canali, Denmark

18:00 SP030.4 - Development of Microfluidic Paper-Based Electrochemical Immunoassays for the Detection of Prostate Cancer
Sean Rawlinson, United Kingdom

18:15 SP030.5 - Investigating chip design for a Raman microfluidic system with clinical radiobiological applications.
Samantha Harder, Canada
18:30 SP030.6 - A lab-on-a-chip system for hypoxic investigations on single biological cells
   Ahmed Alrifaiy, Sweden

18:45 SP030.7 - Gas Sensors with ZnO Quantum Dots Synthesized by Sol-Gel Methods
   Lourdes Brasil, Brazil

17:00 SP031.1 - The Recognition of Pinch-to-Zoom Gesture Based on Surface EMG
   Jongin Kim, Republic of Korea

17:15 SP031.2 - Feature extraction trends for biomedical signals
   Yashodhan Athavale, Canada

17:30 SP031.3 - A Hybrid Model for Diagnosing Sever Aortic Stenosis in Asymptomatic Patients using Phonocardiogram
   Maria Lindén, Sweden

17:45 SP031.4 - Classification of Load in Hands Based on Upper Limb SEMG
   Illya Seagal, Canada

18:00 SP031.5 - An Intelligent Method for Discrimination between Aortic and Pulmonary Stenosis using Phonocardiogram
   Amir Sepehri, Belgium

17:00 SP032.1 - KEYNOTE: Neuroprosthetic Systems for Enhancement of Neuroplasticity Following Stroke and Spinal Cord Injury
   Milos Popovic, Canada

17:30 SP032.2 - Demonstration of Graphene Microelectrodes as a Bioelectronic Interface
   Michael Horn, United States

17:45 SP032.3 - Development of a planar microelectrode array offering long-term, high-resolution neuronal recordings
   Pierre Wijdenes, Canada

18:00 SP032.4 - Morphological changes in photoreceptors due to DC electric field
   Juliana Guerra, Brazil

18:15 SP032.5 - Accelerating Neurite Outgrowth Through Electric Field Manipulation
   Michael Purdy, Canada
## Tuesday, June 9 2015

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<tr>
<th>SESSION TIME</th>
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<th>SESSION TRACK</th>
<th>SESSION NAME</th>
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<td>08:00 – 09:30</td>
<td>701B</td>
<td>TRACK 01: IMAGING</td>
<td>SP035 – IMAGING DETECTOR TECHNOLOGY</td>
<td>FRANCIS LOIGNON-HOULE, CANADA ÉMILIE GAUDIN, CANADA</td>
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### SP035.1 - Detectability in SPECT Myocardial Perfusion Imaging: Comparison between a Conventional and a Semiconductor Detector System

**Ana Marques Da Silva, Brazil**

08:00

### SP035.6 - An alternate mathematical modeling of image formation, and framework for performance analysis of positioning algorithms in the scintillation camera

**Mohammad Reza Ay, Iran**

08:15

### SP035.3 - Apodized-Aperture Pixel Design of an X-Ray Detector with Enhanced High-Frequency DE and Reduced Noise Aliasing

**Elina Ismailova, Canada**

08:30

### SP035.4 - Geant4 Simulations of Scintillation Light Collection and Extraction in PET/CT Detectors

**Francis Loignon-Houle, Canada**

08:45

### SP035.5 - LabPETII.5: APD-based Detector Characterization for Pre-clinical PET Imaging

**Émilie Gaudin, Canada**

09:00

### SP035.2 - The performance of the CMOS APS detector for dual energy contrast enhanced digital mammography

**Ilias Billas, United Kingdom**

09:15

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**SESSION TIME:** 08:00 – 10:00

**SESSION ROOM:** 718A

**SESSION TRACK:** TRACK 01: IMAGING

**SESSION NAME:** SP034 – CT: NEW TECHNIQUES

**SESSION CHAIR(S):** MOHAMMAD REZA AY, IRAN

### SP034.1 - Design, modeling and performance evaluation of a small animal Micro-CT scanner: A Monte Carlo study

**Mohammad Reza Ay, Iran**

08:00

### SP034.2 - An imaging method by using electron mode of linear accelerator for soft tissue emphasis

**Atsushi Myojoyama, Japan**

08:15

### SP034.3 - Anatomical noise model for CT head images: preliminary results

**Marlen Perez-Díaz, Cuba**

08:30

### SP034.4 - The potential of spectral-CT for material decomposition with gold-nanoparticle and iodine contrast

**Byungdu Jo, Republic of Korea**

08:45

### SP034.5 - Spatial Resolution Studies for a Prototype Proton CT Scanner

**Tia Plautz, United States**

09:00

### SP034.6 - Influences of object size and tube potential pairing on the accuracy of iodine quantification using dual energy CT

**Josh Grimes, United States**

09:15

### SP034.7 - Characterization of Vulnerable Plaque with Dual-Energy during CT Coronary Angiography: A Phantom Study

**Ali Ursani, Canada**

09:30

### SP034.8 - The combination of a custom vascular perfusion contrast agent and dual-energy micro-CT to characterize bone-related vasculature

**Justin Tse, Canada**

09:45

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**SESSION TIME:** 08:00 – 10:00

**SESSION ROOM:** 718B

**SESSION TRACK:** TRACK 04: RADIATION ONCOLOGY

**SESSION NAME:** SP036 – TREATMENT PLANNING – MOTION AND ROBUSTNESS

**SESSION CHAIR(S):** JAN UNKELBACH, UNITED STATES ALBIN FREDRIKSSON, SWEDEN

### SP036.1 - Robust optimization with independent beams produces robustly matched fields for intensity-modulated proton therapy treatments

**Albin Fredriksson, Sweden**

08:00
08:15  SP036.2 - Rotational tolerance in lung cancer image-guided radiation therapy
        Peter Hoang, Canada

08:30  SP036.3 - Robustness Assessment of a Novel 4D Optimization Approach for Lung Cancer Radiotherapy
        Shahad Al-Ward, Canada

08:45  SP036.4 - The role of VMAT interplay effects for liver stereotactic body radiation therapy
        Gillian Ecclestone, Canada

09:00  SP036.5 - Interplay of MLC, gantry and respiratory motion during DCAT delivery
        Tanya Kairn, Australia

09:15  SP036.6 - Impact of deep inspiration breath hold (DIBH) in lymphoma’s radiation therapy treatment
        Daniel Venencia, Argentina

09:30  SP036.7 - Cardiac sparing in left-sided breast IMRT using robust optimization
        Houra Mahmoudzadeh, Canada

09:45  SP036.8 - Real Time Tumor Position Control During VMAT Hypofractioned Treatment
        Chemseddine Fatnassi, Switzerland

SESSION TIME: 08:00 – 09:45
SESSION ROOM: 716A
SESSION TRACK: TRACK 05: DOSIMETRY AND RADIATION PROTECTION
SESSION NAME: SP037 – DOSIMETRY IN NUCLEAR MEDICINE
SESSION CHAIR(S): ALEXANDRA ZVEREVA, GERMANY

08:00  SP037.1 - Comparative Evaluation of Radiation Dose Rates in Cancer Thyroid Patients Treated with Variable Doses of Radioiodine
        Ajai Kumar Shukla, India

08:15  SP037.2 - Estimation of the influence of other organs of the body in the determination of the gamma fraction energy emitted by iodine 131 deposited within the thyroid gland
        Abderrahim Betka, DZ

08:30  SP037.3 - Personalized compartmental biokinetic modelling and internal dosimetry of two novel radiopharmaceuticals
        Alexandra Zvereva, Germany

08:45  SP037.4 - TLD Measurement of Absorbed Dose of Workers in PET/CT Department
        Pardis Ghafarian, Iran

09:00  SP037.5 - Renewing the radiopharmaceutical accuracy check service for Canadian dose calibrators
        Malcolm McEwen, Canada

09:15  SP037.6 - Radiation Dose Assessment of 99mTc-labeled Tetrofosmin in Patients Undergoing Rest-Stress Myocardial Perfusion Scintigraphy
        Stella Veloza, Colombia

09:30  SP037.8 - Biological Excretion and Half - Life of Remnant Radioactive Iodine 131I in Post Treated Hyperthyroidism Patients.
        Shuaa Al-Sadoon, Jo

SESSION TIME: 08:00 – 09:15
SESSION ROOM: 715B
SESSION TRACK: TRACK 05: DOSIMETRY AND RADIATION PROTECTION
SESSION NAME: SP038 – DOSIMETRY OF NON-STANDARD FIELDS
SESSION CHAIR(S): HUGO BOUCHARD, UNITED KINGDOM
        SJI PAUL, INDIA

08:00  SP038.1 - Determination of small photon field quality correction factors using EBT3 radiochromic film
        Ilias Billas, United Kingdom

08:15  SP038.2 - On the physics of megavoltage small photon field dosimetry
        Hugo Bouchard, United Kingdom

08:30  SP038.3 - Comparison of AAPM TG 148 and UK code of practice of Reference dosimetry in Helical Tomotherapy.
        Siji Paul, India

08:45  SP038.4 - A new facility to support the adaptation of reference dosimetry in the presence of strong magnetic fields
        Simon Duane, United Kingdom

09:00  SP038.5 - The use of ionization chambers and Gafchromic films to determine the reference absorbed dose rate and output factors in a CyberKnife® unit small radiation fields
        Guerda Massillon-Jl, Mexico

SESSION TIME: 08:00 – 09:45
SESSION ROOM: 716B
SESSION TRACK: TRACK 09: BIOSIGNAL PROCESSING
SESSION NAME: SP039 – ECG
SESSION CHAIR(S): ADRIAN CHAN, CANADA
        PHILIP WARRICK, CANADA

08:00  SP039.1 - Improved T-wave Alternans Detection in ECG Signals
        Guangyi Chen, Canada

08:15  SP039.2 - Electrical Left Atrial Conduction Delay with Focused Transthoracic Electrocardiography in Cardiac Resynchronization Therapy
        Matthias Heinke, Germany
08:30 SP039.3 - Electrical Interatrial to Interventricular Conduction Delay Ratio with Focused Transesophageal Electrocardiography in Cardiac Resynchronization Therapy
Matthias Heinke, Germany

08:45 SP039.4 - Analytical geometry based parameters for studying repolarization variability in patients with myocardial infarction
Muhammad Hasan, Canada

09:00 SP039.5 - Acute Mental Stress Detection via Ultra-short term HRV Analysis
Rossana Castaldo, United Kingdom

09:15 SP039.6 - Classification of Abdominal Fetal Electrocardiogram Recordings using Karhunen-Loève Decomposition
Philip Warrick, Canada

09:30 SP039.7 - Dictionary Learning Algorithms For The Application Of Ventricular Arrhythmia Classification.
Iman Kalaji, Canada

SESSION TIME: 08:00 – 09:30
SESSION ROOM: 715A
SESSION TRACK: TRACK 10: REHABILITATION MEDICINE, SPORTS MEDICINE, REHABILITATION ENGINEERING AND PROSTHETICS
SESSION NAME: SP040 – ERGONOMICS, WEARABLE SENSORS AND VIRTUAL REALITY
SESSION CHAIR(S): MICHELE OLIVER, CANADA

08:00 SP040.1 - KEYNOTE: Working to live: The use of field studies and simulations to make workplaces safer
Michele Oliver, Canada

08:30 SP040.2 - Pitch movement acceleration measures during the practice of virtual games in adolescents with Down syndrome
Paulo Lopes, Brazil

08:45 SP040.3 - Movement Training and Assessment with 3D Virtual Reality for Parkinson’s Disease Patient
Chien-An Chen, Chinese Taipei

09:00 SP040.4 - Arm angle detection in egocentric video of upper extremity tasks
Jirapat Likitlersuang, Canada

09:15 SP040.5 - Development of an image-based calibration technique for use with non-ideal postures in the assessment of kinematics using wearable sensors
Monica Gomez, Canada

SESSION TIME: 08:00 – 09:45
SESSION ROOM: 714A
SESSION TRACK: TRACK 11: NEUROENGINEERING, NEURAL SYSTEMS
SESSION NAME: SP041 – BRAIN COMPUTER/MACHINE INTERFACES
SESSION CHAIR(S): BAO-LIANG LU, PEOPLE’S REPUBLIC OF CHINA

08:00 SP041.1 - Cross-subject and Cross-gender Emotion Classification from EEG
Bao-Liang Lu, People’s Republic of China

08:15 SP041.2 - Comparison of Classification Methods for EEG-based Emotion Recognition
Bao-Liang Lu, People’s Republic of China

08:30 SP041.3 - A Brain Computer Interface (BCI) based on intermittent photic-stimulation using multiple coherence to command detection
Antonio Infantisori, Brazil

08:45 SP041.4 - Volitional modulation of neural activity to control a 2 degree-of-freedom brain-machine interface in a rat model
Martha Garcia, Canada

09:00 SP041.5 - Electroencephalography-Based Off-Line Prediction of Specific Grasping Actions Performed with the Same Hand: Towards Integration of Brain-Computer Interfaces and Functional Electrical Stimulation Therapy
Cesar Marquez-Chin, Canada

09:15 SP041.6 - Wireless Distributed Intracortical Neural Interfacing: A New Approach for Brain Machine Interfaces
Alireza Zabihian, Canada

09:30 SP041.7 - Design and construction of a brain-computer interface for applications in neuro robotics
Alma Méndez Gordillo, Mexico

SESSION TIME: 08:00 – 09:45
SESSION ROOM: 701A
SESSION TRACK: TRACK 16: CLINICAL ENGINEERING, CLINICAL PHYSICS, AND PATIENT SAFETY
SESSION NAME: SP042 – TECHNOLOGY MANAGEMENT PROGRAMMES AND EQUIPMENT MANAGEMENT SYSTEMS
SESSION CHAIR(S): JOHN KILDEA, CANADA, TOM JUDD, UNITED STATES

08:00 SP042.1 - KEYNOTE: Medical device systems Health Technology Management (HTM) strategies and best practices
Tom Judd, United States
08:30  SP042.3 - Development of a scoring system to support medical equipment replacement prioritization using the Analytical Hierarchy Process (AHP)
Paul Prowse, Canada

08:45  SP042.4 - Multi-criteria decision analysis to redesign an Italian Clinical Engineering Service under specific needs and regulation requirements
Irene Lasorsa, Italy

09:00  SP042.5 - Developing a system to support equipment repair versus replacement decision making
Sarah Kelso, Canada

Philip Anyango, Kenya

09:30  SP042.7 - Mathematical Model for Reliable Maintenance of Medical Equipment
Abdelbaset Khalaf, South Africa

08:00  SP043.1 - KEYNOTE: One thousand years of women in science
Monique Frize, Canada

08:30  SP043.2 - Creating the Memories and Celebrating the Legacy of Women in Science and Engineering
Ruby Heap, Canada

08:45  SP043.3 - Women In Bio-Medical Engineering In Kenya
Salome Mwaura, Kenya

09:00  SP043.4 - Physics is a waste of your intelligence
Shada Wadi-Ramahi, Saudi Arabia

09:15  SP043.5 - Medical physics? or how a change in career path becomes a passion
Loredana Marcu, Romania

10:00  SP044.1 - Personal Time-Varying Magnetic Fields Evaluation During Activities in MRI Sites
Giuseppe Acri, Italy

10:45  SP044.2 - ECG Imaging of Ventricular Extrasystoles
Olaf Doessel, Germany

11:00  SP044.3 - Experimental Study on Amplitude Frequency of Acoustic Signal Excited by Coupling Magneto-Acoustic Field
Zhongpeng Liu, People’s Republic of China

11:15  SP044.4 - In vivo electric conductivity values of cervical cancer patients reconstructed with a 3T MR system for improved SAR determination
Edmond Balidemaj, Netherlands

11:30  SP044.5 - Focus Tunable Gel Lens Using Annular Dielectric Elastomer Actuator
Thanh Giang La, Singapore

11:45  SP044.6 - Ultra-low-field MRI for improving spatial accuracy of bioelectric source imaging
Koos Zevenhoven, Finlandia

10:30  SP045.1 - Quantitative accuracy of SPECT imaging with a dedicated cardiac camera: Physical phantom experiments
Amir Pourmoghaddas, Canada

10:45  SP045.2 - The Impact of time of flight algorithm and PSF modeling on standard uptake value in clinical PET/CT imaging
Mohammad Reza Ay, Iran

11:00  SP045.3 - Can Pacemaker and ICD degrade CT-Based Attenuation Corrected cardiac SPECT images?
Mohammad Reza Ay, Iran

11:15  SP045.4 - Impact of Point spread function modeling on tumor quantification in clinical PET/CT imaging
Mohammad Reza Ay, Iran

11:30  SP045.5 - Incidental Thyroid Cancer Identified on 18FDG- PET/CT for Ovarian Cancer Evaluation-Case Study.
Shuaa Al-Sadoon, Jordan

11:45  SP045.6 - Zinc material filter for scatter correction in Tc-99m myocardial SPECT imaging: Heart thorax phantom study
Nazifah Abdullah, Malaysia
### Session 046 - Assessment of Radiotherapy Response

#### Time: 10:30 – 12:00

**Session Room:** 718B  
**Session Track:** TRACK 04: RADIATION ONCOLOGY  
**Session Name:** SP046 – ASSESSMENT OF RADIOTHERAPY RESPONSE  
**Session Chair(s):** Issam El Naqa, Canada  
Sarah Mattonen, Canada  

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<td>10:30</td>
<td><strong>SP046.1</strong> - Early prediction of lung cancer recurrence after stereotactic radiotherapy using texture analysis of automatic graph cuts segmentations</td>
<td>Sarah Mattonen, Canada</td>
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<td>10:45</td>
<td><strong>SP046.2</strong> - Can parameteric response maps predict voxel-wise treatment response? Implications for locally adaptive radiotherapy.</td>
<td>Anthony Lausch, Canada</td>
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<td>11:00</td>
<td><strong>SP046.3</strong> - Using Magnetic Resonance Imaging Radiomics to Personalize Brain Metastases Treatment</td>
<td>Sarah Mattonen, Canada</td>
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<td>11:15</td>
<td><strong>SP046.4</strong> - Raman spectroscopy for assessment of radiation therapy response: Pre-clinical animal study results for lung cancer</td>
<td>Suneetha Devpura, United States</td>
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<td>11:45</td>
<td><strong>SP046.6</strong> - Evaluation and Visualization of Radiogenomic Modeling Frameworks for the Prediction of Normal Tissue Toxicities</td>
<td>Issam El Naqa, Canada</td>
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### Session 047 - Dose Calculation, Part 2

#### Time: 10:30 – 12:00

**Session Room:** 716A  
**Session Track:** TRACK 05: DOSIMETRY AND RADIATION PROTECTION  
**Session Name:** SP048 – DOSIMETRY OF PROTONS AND HEAVY IONS  
**Session Chair(s):** Heidi Nettelbeck, Germany  
Giulia Arico, Germany  

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<td><strong>SP048.1</strong> - An Attempt to Predict the Proton Relative Biological Effectiveness using Radical Recombination</td>
<td>Kiyofumi Haneda, Japan</td>
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<td>10:45</td>
<td><strong>SP048.2</strong> - A correction method for absorbed dose estimation using TEP-TLSD/SR1 in therapeutic carbon beam</td>
<td>Weishan Chang, Japan</td>
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<td>11:00</td>
<td><strong>SP048.3</strong> - Biologically-weighted dosimetric quantities based on a multiscale approach</td>
<td>Heidi Nettelbeck, Germany</td>
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<td>11:15</td>
<td><strong>SP048.4</strong> - Studies of Helium and Carbon Ion Fragmentation processes in Water and in PMMA, using versatile Semiconductor Detectors</td>
<td>Giulia Arico, Germany</td>
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<td>11:30</td>
<td><strong>SP048.5</strong> - Monte Carlo study of secondary neutron dose for multipurpose nozzle in proton therapy</td>
<td>Sungkoo Cho, Republic of Korea</td>
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<td>11:45</td>
<td><strong>SP048.6</strong> - Investigation of the uncertainties involved in the low energy proton interaction in different MC-codes for proton therapy application</td>
<td>Lalageh Mirzakhanian, Canada</td>
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### Session 048 - Nanotechnology in Radiation Therapy and Imaging, Part 1

#### Time: 10:30 – 12:00

**Session Room:** 717B  
**Session Track:** TRACK 06: NEW TECHNOLOGIES IN CANCER RESEARCH AND TREATMENT  
**Session Name:** SP049 – NANOTECHNOLOGY IN RADIATION THERAPY AND IMAGING: PART 1  
**Session Chair(s):** Luc Beauleiu, Canada  
Michael Antosh, United States  

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<td>10:30</td>
<td><strong>SP047.4</strong> - 4D Monte Carlo simulation for verification of delivered dose to deforming anatomy</td>
<td>Sara Gholampourkashi, Canada</td>
</tr>
<tr>
<td>11:00</td>
<td><strong>SP047.5</strong> - Clinical implementation of an EPID-based in vivo dose verification system for SBRT-VMAT delivery; catching errors</td>
<td>Peter McCowan, Canada</td>
</tr>
<tr>
<td>11:45</td>
<td><strong>SP047.6</strong> - pGPUMCD, a GPU-based Monte Carlo proton transport code</td>
<td>Daniel Maneval, Canada</td>
</tr>
<tr>
<td>10:30</td>
<td><strong>SP047.1</strong> - Non-Standard IOERT Dose Distributions Scenarios by Monte Carlo Studies</td>
<td>Alessandro Esposito, Portugal</td>
</tr>
<tr>
<td>10:45</td>
<td><strong>SP047.2</strong> - Validation of a Commercial GPU-Based Monte Carlo Dose Calculation Algorithm for use with an Elekta MRI-Linear Accelerator</td>
<td>Moti Paudel, Canada</td>
</tr>
<tr>
<td>11:00</td>
<td><strong>SP047.3</strong> - A Dosimetric Evaluation of Interface Effects Using Two Commercial Electron Treatment Planning Algorithms</td>
<td>Mark Yudelev, United States</td>
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<tr>
<td>10:30</td>
<td>SP049.1 - A plasma electrochemistry reactor enabling the rapid, efficient, automatic and on-site synthesis of radioactive gold nanoparticles for brachytherapy treatments. <em>Mathieu Bouchard, Canada</em></td>
<td></td>
</tr>
<tr>
<td>10:45</td>
<td>SP049.2 - Dose Enhancement in Radiotherapy by Novel Application Of Gadolinium Based MRI Contrast Agent Nanomagnetic Particles in Gel Dosimetry <em>Nader Riyahi Alam, Iran</em></td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td>SP049.3 - Monte Carlo simulation of the radiosensitizing effect by gold nanoparticles: comparison between proton and X-ray irradiation <em>Jihun Kwon, Japan</em></td>
<td></td>
</tr>
<tr>
<td>11:15</td>
<td>SP049.4 - Colloidal quantum dots: radiation resistant nano-scintillators for radiation-based applications <em>Marie-Ève Delage, Canada</em></td>
<td></td>
</tr>
<tr>
<td>11:30</td>
<td>SP049.5 - Use of gold nanoparticles and pH-LIP (pH Low Insertion Peptide) to increase radiation effectiveness in cancer cells. <em>Michael Antosh, United States</em></td>
<td></td>
</tr>
<tr>
<td>11:45</td>
<td>SP049.6 - The use of nanoparticles to improve hadrontherapy <em>Marta Bolsa-Ferruz, France</em></td>
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<tbody>
<tr>
<td>10:30</td>
<td>SP050.1 - KEYNOTE: Frontiers of Neuroengineering <em>Nitish Thakor, Singapore</em></td>
</tr>
<tr>
<td>11:00</td>
<td>SP050.2 - Neural responses to hearing own names comparing with repeated/non-repeated unfamiliar stimuli <em>Kaori Tamura, Japan</em></td>
</tr>
<tr>
<td>11:15</td>
<td>SP050.3 - MRS data deconvolution through KBDM with multiple signal truncation and clustering: circumventing noise effects <em>Danilo Da Silva, Brazil</em></td>
</tr>
<tr>
<td>11:30</td>
<td>SP050.4 - Quantification of Wavelet Band Metrics for Assessing Heart Rate Variability <em>Mark Wachowiak, Canada</em></td>
</tr>
<tr>
<td>11:45</td>
<td>SP050.5 - Effect of Coffee on EEG Spectral Asymmetry <em>Maie Bachmann, Estonia</em></td>
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<tr>
<td>12:00</td>
<td>SP050.6 - Effects of Changing in the Neck Fluid Volume, Neck Circumference and Upper Airway during Sleep on Snoring Sound Characteristics <em>Zahra Moussavi, Canada</em></td>
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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>10:30</td>
<td>SP051.1 - Biomechanical Simulation of Upper Extremities Exoskeleton to Aid Stroke Patients <em>Yahia Al-Smadi, United States</em></td>
</tr>
<tr>
<td>10:45</td>
<td>SP051.2 - Testing a mobile robot toy for children with disabilities <em>William Rodriguez, Colombia</em></td>
</tr>
<tr>
<td>11:00</td>
<td>SP051.3 - Pilot study of a soft metal hydride actuator for a wearable rehabilitation system <em>Minako Hosono, Japan</em></td>
</tr>
<tr>
<td>11:15</td>
<td>SP051.4 - Robotic Spasticity Quantification: Velocity Dependent Component of Biomechanical Resistance <em>Nitin Seth, Canada</em></td>
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<tr>
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<tbody>
<tr>
<td>10:30</td>
<td>SP052.1 - KEYNOTE: From human neuron to human brain: Neurosurgical contributions to understanding the brain <em>Taufik Valiante, Canada</em></td>
</tr>
<tr>
<td>11:00</td>
<td>SP052.2 - Modulation of event-related desynchronization and synchronization during right finger flexion in patients with Amyotrophic Lateral Sclerosis <em>Natasa Bizovicar, Slovenia</em></td>
</tr>
<tr>
<td>11:15</td>
<td>SP052.3 - Functional connectivity patterns associated with swallowing of fluids with various viscosity <em>Ervin Sejdic, United States</em></td>
</tr>
<tr>
<td>11:30</td>
<td>SP052.4 - Distribution of F-Latency (DFL) - a new nerve conduction parameter for early detection of radiculomyelopathy <em>K Siddique Rabbani, Bangladesh</em></td>
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</table>
## SESSION TIME: 10:30 – 11:45
### SESSION ROOM: 715B
### SESSION TRACK: TRACK 12: MEDICAL DEVICES
### SESSION NAME: SP053 – CARDIOVASCULAR INSTRUMENTATION
### SESSION CHAIR(S): MARIE KEAYS, IRELAND
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<thead>
<tr>
<th>Time</th>
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<th>Speaker(s)</th>
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<tbody>
<tr>
<td>10:30</td>
<td>SP053.1 - A Microfluidic cell culture Instrument for individual testing of therapeutics.</td>
<td>Marie Keays, Ireland</td>
</tr>
<tr>
<td>10:45</td>
<td>SP053.2 - A Bioinspired Catheter Harnessing Gecko Adhesion and Inchworm?Like Locomotion for Targeted Drug Delivery</td>
<td>Jonathan Wolfe, Singapore</td>
</tr>
<tr>
<td>11:00</td>
<td>SP053.3 - Covered stent with perforated membrane for treatment of peripheral atheroembolic disease</td>
<td>Foad Kabinejadzian, Singapore</td>
</tr>
<tr>
<td>11:15</td>
<td>SP053.4 - Nanostructuring Carbon Fibre Probes for Use in Central Venous Catheters</td>
<td>Jolene McHugh, United Kingdom</td>
</tr>
<tr>
<td>11:30</td>
<td>SP053.5 - Denoising RF defibrillator waveforms for intracardiac atrial substrate impedance characterisation using digital filtering techniques</td>
<td>Omar Escalona, United Kingdom</td>
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</table>

## SESSION TIME: 10:30 – 12:00
### SESSION ROOM: 717A
### SESSION TRACK: TRACK 18: GENDER, SCIENCE AND TECHNOLOGY
### SESSION NAME: SP054 – WOMEN IN MEDICAL PHYSICS: CURRENT STATUS
### SESSION CHAIR(S): PATRICIA TRBOVICH, CANADA
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<tr>
<td>10:30</td>
<td>SP054.1 - Experiences as a Women in the Biomedical Engineering Field</td>
<td>Molly Shoichet, Canada</td>
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<tr>
<td>11:00</td>
<td>SP054.2 - The Historical Role of Women in Medical Physics</td>
<td>Magdalena Stoeva, United Kingdom</td>
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<tr>
<td>11:10</td>
<td>SP054.3 - Women in Medical Physics</td>
<td>Simone Koduliovitch, Brazil</td>
</tr>
<tr>
<td>11:20</td>
<td>SP054.4 - Women in Medical Physics; current status in Australia and New Zealand.</td>
<td>Eva Bezak, Australia</td>
</tr>
<tr>
<td>11:30</td>
<td>SP054.5 - Women in medical physics; Current status</td>
<td>Nicole Ranger, United States</td>
</tr>
<tr>
<td>11:40</td>
<td>SP054.6 - Women in Medical Physics</td>
<td>Jamila Salem Al Suwaidi, United Arab Emirates</td>
</tr>
</tbody>
</table>

## SESSION TIME: 15:00 – 16:30
### SESSION ROOM: 715A
### SESSION TRACK: TRACK 03: BIOMECHANICS AND ARTIFICIAL ORGANS
### SESSION NAME: SP055 – CELLULAR & MOLECULAR MECHANICS
### SESSION CHAIR(S): ANDREW QUIGLEY, CANADA
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<th>Speaker(s)</th>
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</thead>
<tbody>
<tr>
<td>15:00</td>
<td>SP055.1 - Neurite outgrowth induced by shock waves</td>
<td>Youn Kihwan, Japan</td>
</tr>
<tr>
<td>15:15</td>
<td>SP055.2 - Investigating mechanical behavior and structural response to strain of bovine tendon collagen fibrils using atomic force microscopy</td>
<td>Andrew Quigley, Canada</td>
</tr>
<tr>
<td>15:30</td>
<td>SP055.3 - Collagen fibrils from overloaded tendons show sites of discrete plasticity and overall perturbation in molecular packing</td>
<td>Samuel Baldwin, Canada</td>
</tr>
<tr>
<td>15:45</td>
<td>SP055.4 - Mechanobiology of Hepatic Cells and Engineered Construction of Liver</td>
<td>Mian Long, People's Republic of China</td>
</tr>
<tr>
<td>16:00</td>
<td>SP055.5 - Modelling and Understanding Normal Pressure Hydrocephalus</td>
<td>Christine Goffin, Germany</td>
</tr>
<tr>
<td>16:15</td>
<td>SP055.6 - Osteolytic tumour involvement modifies characteristics of Collagen-I within the vertebral bone matrix impacting mechanical behaviour</td>
<td>Mikhail Burke, Canada</td>
</tr>
</tbody>
</table>

## SESSION TIME: 15:00 – 16:15
### SESSION ROOM: 701A
### SESSION TRACK: TRACK 04: RADIATION ONCOLOGY
### SESSION NAME: SP056 – IMAGE GUIDED RT: PART 2
### SESSION CHAIR(S): LI ZHOU, PEOPLE'S REPUBLIC OF CHINA
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<tr>
<td>15:00</td>
<td>SP056.1 - Imaging Dose and Dose Pattern in Image-guided Radiotherapy of Cancers</td>
<td>Li Zhou, People's Republic of China</td>
</tr>
<tr>
<td>15:15</td>
<td>SP056.2 - Residual errors and dosimetric consequences related to the spinal cord in head and neck radiotherapy</td>
<td>Jinkoo Kim, United States</td>
</tr>
<tr>
<td>15:30</td>
<td>SP056.3 - An automatic dosimetric and geometric tracking system for head and neck adaptive radiotherapy</td>
<td>Jinkoo Kim, United States</td>
</tr>
<tr>
<td>15:45</td>
<td>SP056.4 - Morphological Analysis of Tumor Regression and Its Impact on Deformable Image Registration for Adaptive Radiotherapy of Lung Cancer Patients</td>
<td>Hualiang Zhong, United States</td>
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</tbody>
</table>
16:00 SP056.5 - Assessment of a 4D-CBCT system for managing respiratory motion in Radiotherapy
Yudy Ascencion, Cuba

15:00 SP057.1 - Sensitivity of VMAT patient specific QC devices to linac calibration errors
Eduard Gershkevitsh, Estonia

15:15 SP057.2 - Clinical implementation of a novel transmission detector for 3D quality assurance during radiation therapy
Greg Sharp, United States

15:30 SP057.3 - Development of a Radiochromic Film Dosimetry Imaging System
Kevin Alexander, Canada

15:45 SP057.4 - Implementation of MOSFET detectors for in-vivo radiotherapy dosimetry,
Yi Wah Eva Cheung, United Kingdom

16:00 SP057.5 - 3D in vivo dose verification at The Netherlands Cancer Institute
Ben Mijnheer, Netherlands

15:00 SP058.1 - Destructive backscatter-based readout of polymer gel dosimeters: proof of principle
Warren Campbell, Canada

15:15 SP058.2 - New Detector Systems for the Dosimetry in Radiation Therapy
Viktor Iakovenko, Ukraine

15:30 SP058.3 - Dose response evaluation of lung equivalent gel dosimeters by use of a new fitting algorithm
Hassan Ali Nedaie, Iran

15:45 SP058.4 - Photoluminescence response of pure LiF crystals to clinical proton and carbon ions: a preliminary assessment for dose to water evaluations
Jose Villarreal-Barajas, Canada

16:00 SP058.5 - Evaluation of Accuracy and Precision in X-ray Computed Tomography Polymer Gel Dosimetry.
Evan Maynard, Canada
## SESSION 1: TRACK 12: MEDICAL DEVICES

**SESSION TIME:** 15:00 – 16:30
**SESSION ROOM:** 715B
**SESSION TRACK:** TRACK 12: MEDICAL DEVICES
**SESSION NAME:** SP061 – IMPROVEMENT OF DIAGNOSIS AND THERAPIES
**SESSION CHAIR(S):** FERNANDO INFANTOSI, BRAZIL, ROMAIN ESPAGNET, CANADA

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<tr>
<td>15:00</td>
<td>SP061.1 - Development of heart sparing device for Left Breast Radiotherapy with deep breath-holding <em>Shanmugam Senthilkumar, India</em></td>
</tr>
<tr>
<td>15:15</td>
<td>SP061.2 - HTA for Medical Devices: Multiple-Criteria Decision Making as an Outcome Evaluation Tool <em>Ivana Jurickova, Czech Republic</em></td>
</tr>
<tr>
<td>15:45</td>
<td>SP061.3 - Developing Smart Bandage Materials for the Management of Chronic Wounds in Diabetic Patients <em>Jolene McHugh, United Kingdom</em></td>
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<tr>
<td>16:00</td>
<td>SP061.4 - A CdZnTe-based automated Blood Counter for Quantitative Molecular Imaging <em>Romain Espagnet, Canada</em></td>
</tr>
<tr>
<td>16:15</td>
<td>SP061.5 - A Portable Free-Hand 3D SPECT System <em>Harley Chan, Canada</em></td>
</tr>
<tr>
<td>16:30</td>
<td>SP061.6 - Probing the Biomechanical Properties of Cells using High-Frequency Ultrasound and Acoustic Levitation <em>Natalie Sullivan, United States</em></td>
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</table>

## SESSION 2: TRACK 17: EDUCATIONAL AND PROFESSIONAL ACTIVITIES

**SESSION TIME:** 15:00 – 17:15
**SESSION ROOM:** 717A
**SESSION TRACK:** TRACK 17: EDUCATIONAL AND PROFESSIONAL ACTIVITIES
**SESSION NAME:** SP063 – ACCREDITATION, CERTIFICATION AND LICENSURE ISSUES
**SESSION CHAIR(S):** ADRIANA VELAZQUEZ BERUMEN, SWITZERLAND, RAYMUND WU, UNITED STATES

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<tr>
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<tbody>
<tr>
<td>15:00</td>
<td>SP063.1 - KEYNOTE: The Current State of Clinical Engineering Education and Career <em>Yadin David, United States</em></td>
</tr>
<tr>
<td>15:30</td>
<td>SP063.2 - The Pursuit of Regulated Health Profession Status for Medical Physicists in Alberta <em>Charles Kirkby, Canada</em></td>
</tr>
<tr>
<td>15:45</td>
<td>SP063.3 - The International Medical Physics Certification Board <em>Colin Orton, United States</em></td>
</tr>
<tr>
<td>16:00</td>
<td>SP063.4 - Radiation protection continued training program evaluation: return on a 7-year experience <em>Nadia Octave, Canada</em></td>
</tr>
<tr>
<td>16:15</td>
<td>SP063.5 - Where to find biomedical engineers worldwide? Mapping biomedical engineers around the world <em>Adriana Velazquez Berumen, Switzerland</em></td>
</tr>
<tr>
<td>16:30</td>
<td>SP063.6 - Oh dear medical physicist and biomedical engineer, why is it difficult to pioneer your specialist career? <em>Mario Medvedec, Croatia</em></td>
</tr>
<tr>
<td>16:45</td>
<td>SP063.7 - Biomedical Engineering Education and Training and Accreditation of Bachelor-degree Biomedical Engineering Programmes <em>Min Wang, Hong Kong</em></td>
</tr>
<tr>
<td>17:00</td>
<td>SP063.8 - IOMP initiative for Validation and Accreditation of MSc courses <em>Slavik Tabakov, United Kingdom</em></td>
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</table>
15:00 SP064.1 - Biomechanical Analysis of Optimal Orientation and Stress Shielding for Short and Long Stem Hip Implants  
*Peter Goshulak, Canada*

15:15 SP064.2 - Biomechanical Analysis of Acute Total Hip Replacements after Acetabular Fracture: Plate vs Cable Repair  
*Mina Aziz, Canada*

15:30 SP064.3 - Biomechanical Validation of the Radiographic Union Score for Tibial fractures (RUST) as a Predictor for Fracture Healing  
*Sandra Fiset, Canada*

15:45 SP064.4 - Patient-specific multi-scaling simulation of blood flow and fractional flow reserve in a coronary artery  
*Kyung Lee, Republic of Korea*

16:00 SP064.5 - A Modified PID Algorithm with Fuzzy Control for Closed-loop Artificial Pancreas  
*Jin Hao Yu, People’s Republic of China*

17:00 SP065.1 - Fingertip touch adjust postural orientation during perturbed stance  
*Alireena Azaman, Japan*

17:15 SP065.2 - Design and Evaluation of a Prosthetic Knee Joint based on Automatic Stance-Phase Lock (ASPL) Technology for Children with Transfemoral Amputations  
*Calvin Ngan, Canada*

17:30 SP065.3 - Frontal plane gait during cross-slope walking for able-bodied and transtibial amputees  
*Emily Sinitski, Canada*

17:45 SP065.4 - Impact of gait modifications on hip joint loads during level walking  
*Masaru Higa, Japan*

18:00 SP065.5 - The influence of the aquatic environment on the control of gait initiation  
*Andresa Marinho Buzelli, Canada*

17:00 SP066.1 - Towards Functional C-arm CT Imaging in the Interventional Suite: Progress and challenges  
*Rebecca Fahrig, United States*

17:30 SP066.2 - 2D/3D Registration for Motion Compensated Reconstruction in Cone-Beam CT of Knees Under Weight-Bearing Condition  
*Martin Berger, Germany*

17:45 SP066.3 - Direct Scatter Estimation and Separation for Cone-beam CT Images Utilizing Monte Carlo Simulation  
*Yu Wang, People’s Republic of China*

18:00 SP066.4 - Automatic Motion Estimation and Compensation Framework for Weight-bearing C-arm CT scans using Fiducial Markers  
*Kerstin Mueller, United States*
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<tr>
<td>17:00</td>
<td>SP068</td>
<td>A Farmer ion chamber as reference to the calibration of CT chambers</td>
<td>Ricardo Terini, Brazil</td>
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<tr>
<td>17:15</td>
<td>SP068</td>
<td>Determination of the Uncertainty in the Cross-calibration of an Ionization Chamber Used in Radiation Therapy</td>
<td>Pedro Cardoso, Brazil</td>
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<tr>
<td>17:30</td>
<td>SP068</td>
<td>A study of uncertainties in the half-value layer measurement of a miniature kV x-ray source</td>
<td>Peter Watson, Canada</td>
</tr>
<tr>
<td>17:45</td>
<td>SP068</td>
<td>Low Energy Therapeutic X-Ray Calibration Methods</td>
<td>Mehran Zaini, United States</td>
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<tr>
<td>18:00</td>
<td>SP068</td>
<td>Energy response of a thimble-type ionization chamber for Ir-192 and Co-60 radiation beams</td>
<td>Cecilia Kessler, France</td>
</tr>
<tr>
<td>18:15</td>
<td>SP068</td>
<td>Kilo-voltage X-Ray tube dosimetry Correction factors for in-water measurement in TG-61</td>
<td>Nima Sherafati, Canada</td>
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<tr>
<td>17:00</td>
<td>SP069</td>
<td>Synergistic Action of Ionizing Radiation with Platinum-based Chemotherapeutic Drugs: Soft X-rays and Low-Energy Electrons</td>
<td>Elahe Alizadeh, Canada</td>
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<td>17:15</td>
<td>SP069</td>
<td>Cherenkov emission dosimetry for electron beam radiotherapy: a Monte Carlo feasibility study of absolute dose prediction</td>
<td>Yana Zlateva, Canada</td>
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<td>17:30</td>
<td>SP069</td>
<td>Detection of melanoma through image recognition and artificial neural networks</td>
<td>Cristofer Marin, Mexico</td>
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<tr>
<td>17:45</td>
<td>SP069</td>
<td>Clinical Implementation of an Intraoperative Radiotherapy Program</td>
<td>Muthana Al-Ghazi, United States</td>
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<td>18:00</td>
<td>SP070</td>
<td>Performance of a Back-etched Silicon Detector Array Designed to Monitor Each Synchrotron Generated X-ray Beam in Microbeam Radiation Therapy</td>
<td>Michael Lerch, Australia</td>
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<td>18:15</td>
<td>SP070</td>
<td>Dynamic Mechanical Characterization of a Poly(vinyl alcohol) Breast Palpation Phantom</td>
<td>Gabriel Rodriguez, United States</td>
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<tr>
<td>17:00</td>
<td>SP070</td>
<td>Optimal Pixelated Crystal for a Molecular SPECT Scanner: A GATE Monte Carlo Study</td>
<td>Mohammad Reza Ay, Iran</td>
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<tr>
<td>17:15</td>
<td>SP070</td>
<td>Spinning Knife-Edge Slit-Hole: a Novel Collimation for High-Sensitivity Molecular SPECT</td>
<td>Mohammad Reza Ay, Iran</td>
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<tr>
<td>17:30</td>
<td>SP070</td>
<td>Simultaneous estimation of the radioactivity distribution and electron density map from scattered coincidences in PET: A project overview</td>
<td>Hongyan Sun, Canada</td>
</tr>
<tr>
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<td>Title</td>
<td>Speaker, Location</td>
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<tr>
<td>17:45</td>
<td>SP070.4</td>
<td>Generating a four-class attenuation map for MR-based attenuation correction of PET data in pelvis region using an automatic segmentation protocol</td>
<td>Hamidreza Saligheh Rad, Iran</td>
</tr>
<tr>
<td>18:00</td>
<td>SP070.5</td>
<td>Extracting PET activity distribution from scattered coincidences for non-ideal energy resolutions by modeling the probabilities of annihilation positions within a generalized scattering reconstruction algorithm</td>
<td>Hongyan Sun, Canada</td>
</tr>
<tr>
<td>18:15</td>
<td>SP070.6</td>
<td>Quantitative Functional Imaging with Hybrid PET-CT Via Improved Kinetics Modeling: Application to 18F-Fluorocholine PET Imaging of Prostate Cancer</td>
<td>Adam Blais, Canada</td>
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<tr>
<td>18:30</td>
<td>SP070.7</td>
<td>Simultaneous Measurement of Perfusion and Hypoxia in Pancreatic Cancers with Dynamic PET-FAZA Imaging</td>
<td>Ivan Yeung, Canada</td>
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<tr>
<td>17:00</td>
<td>SP071.1</td>
<td>Optimization of Crosslinking Parameters for Biosynthetic Poly(vinyl-alcohol)-Tyramine Hydrogels</td>
<td>Penny Martens, Australia</td>
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<tr>
<td>17:15</td>
<td>SP071.2</td>
<td>A synchrotron radiation microtomography study of wettability and swelling of nanocomposite Alginite/Hydroxyapatite scaffolds for bone tissue engineering</td>
<td>Francesco Brun, Italy</td>
</tr>
<tr>
<td>17:30</td>
<td>SP071.3</td>
<td>ECM production and distribution in regenerated cartilage tissue cultured under traction loading</td>
<td>Yoshinori Sawae, Japan</td>
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<tr>
<td>17:45</td>
<td>SP071.4</td>
<td>Alginate encapsulation: a solution for controlled infiltration of cells within artificial fiber constructs</td>
<td>Birgit Glasmacher, Germany</td>
</tr>
<tr>
<td>18:00</td>
<td>SP071.5</td>
<td>Biominalization and In vivo-Compatibility of LnPO4 Nanorods with Enhanced MR and Luminescence Imaging</td>
<td>Zhongbing Huang, People’s Republic of China</td>
</tr>
<tr>
<td>18:15</td>
<td>SP071.6</td>
<td>Additive Manufacturing for Creating Multifunctional Tissue Engineering Scaffolds</td>
<td>Min Wang, Hong Kong</td>
</tr>
<tr>
<td>18:30</td>
<td>SP071.7</td>
<td>Comparison of different dosage of ion implantation on electrospun collagen fibers to improve aqueous stability</td>
<td>Nisha Sharma, Canada</td>
</tr>
<tr>
<td>17:00</td>
<td>SP072.1</td>
<td>Variations in geometric distortion using static and moving table acquisition for radiotherapy treatment planning applications</td>
<td>Amy Walker, Australia</td>
</tr>
<tr>
<td>17:15</td>
<td>SP072.2</td>
<td>Translation of biomechanical deformable image registration (MORFEUS) to the RayStation radiotherapy treatment planning system</td>
<td>Michael Velec, Canada</td>
</tr>
<tr>
<td>17:30</td>
<td>SP072.3</td>
<td>Phantom Validation of a Point-Set Deformable Registration Method using Pig Bladder</td>
<td>Roja Zakariaee, Canada</td>
</tr>
<tr>
<td>17:45</td>
<td>SP072.4</td>
<td>Automatic bone and air segmentation during generation of synthetic CT from MR data in the brain</td>
<td>Joshua Kim, United States</td>
</tr>
<tr>
<td>18:00</td>
<td>SP072.5</td>
<td>Effect of Deformable Registration Accuracy Uncertainty on Lung Dose Accumulation</td>
<td>Navid Samavati, Canada</td>
</tr>
<tr>
<td>18:15</td>
<td>SP072.6</td>
<td>Development of a Multi-Modality 4D biomechanical Phantom for Evaluation of Simultaneous Registration/Segmentation Algorithms</td>
<td>Daniel Markel, Canada</td>
</tr>
<tr>
<td>18:30</td>
<td>SP072.7</td>
<td>Using Magnetic Resonance Image (MRI) alone in Treatment Planning and Treatment Localization</td>
<td>Shupeng Chen, United States</td>
</tr>
<tr>
<td>17:00</td>
<td>SP073.1</td>
<td>KEYNOTE: Augmented Reality in Image-guided Cardiac Interventions.</td>
<td>Terry Peters, Canada</td>
</tr>
<tr>
<td>17:30</td>
<td>SP073.2</td>
<td>Assistant Laparoscopic Postural: Kinematic Behavior</td>
<td>Daniel Lorias-Espinoza, Mexico</td>
</tr>
<tr>
<td>17:45</td>
<td>SP073.3</td>
<td>Workspace optimization of a surgical instrument for single port access surgery</td>
<td>Bastian Blase, Germany</td>
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</table>
18:00  SP073.4  -  High-Dexterity Telemanipulation Robot for Minimally Invasive Surgery  
**Sebastian Schlegel, Germany**  

18:15  SP073.5  -  Integrated Sensors for a Single-Incision Laparoscopic Instrument  
**Simon Albrecht, Germany**  

18:30  SP073.6  -  Development and Evaluation of an Open-Source 3D Virtual Simulator with Integrated Motion-Tracking as a Teaching Tool for Pedicle Screw Insertion  
**Stewart McLachlin, Canada**  

18:45  SP073.7  -  A Robotic System with Ultrasound Imaging for Patient Setup and Monitoring during Fractionated Radiotherapy  
**Kai Ding, United States**  

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**SESSION TIME:**  17:00 – 19:00  
**SESSION ROOM:**  716B  
**SESSION TRACK:**  TRACK 09: BIOSIGNAL PROCESSING  
**SESSION NAME:**  SP074 – BIOMEDICAL MONITORING & BIOELECTROMAGNETISM  
**SESSION CHAIR(S):**  MILOS POPVIC, CANADA  
MALCOLM LATORRE, SWEDEN  

17:00  SP074.1  -  Towards Dual Respiratory and Cardiac Gated Radiotherapy  
**Kirpal Kohli, Canada**  

17:15  SP074.2  -  A mobile terminal to follow-up the evolution of chronic diseases  
**Hector Torres, Cuba**  

17:30  SP074.3  -  Relationship between the tuning characteristics of stimulus frequency otoacoustic emissions and behavioral tests at moderate levels  
**Qin Gong, People's Republic of China**  

17:45  SP074.4  -  An Axon Mimic for Medical Electrode Tests  
**Malcolm Latorre, Sweden**  

18:00  SP074.5  -  Evaluation the Accuracy of Oscillometric Blood Pressure Measurement According to the AAMI SP10  
**Haiyan Xiang, People's Republic of China**  

18:15  SP074.6  -  PEMF effects on chondrocyte cellularity and gene expression of the rat distal femoral metaphyseal articular cartilage.  
**Fernando Sotelo-Barroso, Mexico**  

18:30  SP074.7  -  Classification of responders versus non-responders to TDCS by analyzing voltage between anode and cathode during treatment session  
**Isar Nejadgholi, Canada**  

18:45  SP074.8  -  Matlab toolbox for bioelectric cardiac images analysis  
**Juan Alberto Cruz, Brazil**
18:45 SP076.7 - The stochastic extension of the Linear Quadratic model: Taking into account the uncertainty of radiobiological parameters. 
Moises Saez-Beltran, Spain

17:30 SP077.3 - Dosimetric evaluation of the interplay effect for non-gated VMAT treatment of moving targets with high dose rate FFF beams
Ashley Smith, United States

17:45 SP077.4 - In vivo Image Guided Brachytherapy Verification (IGBV) in high dose rate prostate brachytherapy. Initial Clinical Experience
Ryan Smith, Australia

18:00 SP077.5 - Electronic Portal Imaging Device Dosimetry for IMRT: a Review on Commercially Available Solutions
Omemh Bawazeer, Australia

18:15 SP077.6 - The Nano-X Radiotherapy Machine: Lean Innovation Transforming Global Access to Cancer Care
Paul Keall, Australia

18:30 SP077.7 - Development of an MR and CT compatible non-invasive temperature based optical fiber respiration sensor for use in radiotherapy
Ashley Smith, United States
### Wednesday, June 10 2015

**SESSION TIME:** 10:30 – 12:00  
**SESSION ROOM:** 701A  
**SESSION TRACK:** TRACK 04: RADIATION ONCOLOGY  
**SESSION NAME:** SP078 – BRACHY THERAPY: PART 2  
**SESSION CHAIR(S):** JUSTIN SUTHERLAND, CANADA  
MICHELLE HILTS, CANADA

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<th>Speaker(s)</th>
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<tr>
<td>10:30</td>
<td>SP078.1 - The Effect of Bladder Preparation on Motion of Organs at Risk in High Dose Rate Gynecological Brachytherapy</td>
<td>Parisa Sadeghi, Canada</td>
</tr>
<tr>
<td>10:45</td>
<td>SP078.2 - Retrospective Monte Carlo dose calculations for permanent implant prostate brachytherapy using 125I</td>
<td>Justin Sutherland, Canada</td>
</tr>
<tr>
<td>11:00</td>
<td>SP078.3 - Combining doses for prostate cancer patients receiving external beam radiotherapy and a HDR brachytherapy boost: Dosimetric parameters and dose-surface maps for patients with and without late rectal bleeding</td>
<td>Calyn Moulton, Australia</td>
</tr>
<tr>
<td>11:15</td>
<td>SP078.4 - Implementation of Permanent Breast Seed Implants in British Columbia: Innovation and Early Results</td>
<td>Michelle Hilts, Canada</td>
</tr>
<tr>
<td>11:30</td>
<td>SP078.5 - Estimation of α/β for late rectal bleeding via minimum dosimetric differences for prostate cancer patients treated with external beam radiotherapy versus a HDR brachytherapy boost after external beam radiotherapy</td>
<td>Calyn Moulton, Australia</td>
</tr>
<tr>
<td>11:45</td>
<td>SP078.6 - Failure Mode and Effects Analysis (FMEA) for improving quality assurance for Image-Guided High Dose Rate (HDR) brachytherapy</td>
<td>Shada Wadi-Ramahi, Saudi Arabia</td>
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### Wednesday, June 10 2015

**SESSION TIME:** 10:30 – 11:45  
**SESSION ROOM:** 701B  
**SESSION TRACK:** TRACK 04: RADIATION ONCOLOGY  
**SESSION NAME:** SP079 – MOTION MANAGEMENT: PART 1  
**SESSION CHAIR(S):** AMIT SAWANT, UNITED STATES  
TAE SUK SUH, REPUBLIC OF KOREA

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<td>SP079.1 - Feasibility of respiratory gated radiotherapy using real-time positron emission tracking</td>
<td>Marc Chamberland, Canada</td>
</tr>
<tr>
<td>10:45</td>
<td>SP079.2 - The first kilovoltage intrafraction monitoring trial for gated prostate radiotherapy: Accuracy and dosimetric results</td>
<td>Prabhjot Juneja, Australia</td>
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<tr>
<td>11:00</td>
<td>SP079.3 - The impact of audio-visual biofeedback with a patient-specific guiding waveform on respiratory motion management: Comparison of two different respiratory management systems</td>
<td>Yuiiro Nakajima, Japan</td>
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<tr>
<td>11:15</td>
<td>SP079.4 - Tracking Accuracy for Robotic Radiosurgery in the Liver</td>
<td>Jeff Winter, Canada</td>
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<td>11:30</td>
<td>SP079.5 - Deep Inspiration breath hold lung SBRT-Can Flattening Filter Free beam based VMAT combined with gated CBCT facilitate precise treatment delivery with sufficient dosimetric accuracy?</td>
<td>Vallinayagam shanmuga subramanian, India</td>
</tr>
<tr>
<td>11:45</td>
<td>SP079.6 - Feasibility of markerless tumor tracking by sequential dual-energy fluoroscopy on a clinical tumor tracking system</td>
<td>Jennifer Dhont, Belgium</td>
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### Wednesday, June 10 2015

**SESSION TIME:** 10:30 – 12:00  
**SESSION ROOM:** 718B  
**SESSION TRACK:** TRACK 04: RADIATION ONCOLOGY  
**SESSION NAME:** SP079 – MOTION MANAGEMENT: PART 1  
**SESSION CHAIR(S):** AMIT SAWANT, UNITED STATES  
TAE SUK SUH, REPUBLIC OF KOREA

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<td>Jennifer Dhont, Belgium</td>
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<tr>
<td>10:45</td>
<td>SP080.2</td>
<td>3D Slicer Gel Dosimetry Analysis: Validation of the Calibration Process</td>
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<td>11:00</td>
<td>SP080.3</td>
<td>Whole body interactive 3D visualisation of both the benefits and risks of radiotherapy for common cancers: a tool to guide decision making</td>
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<tr>
<td>11:15</td>
<td>SP080.4</td>
<td>A Software App for Radiotherapy with In-situ Dose-painting using high Z nanoparticles</td>
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<tr>
<td>11:30</td>
<td>SP080.5</td>
<td>Performing radiation therapy research using the open-source SlicerRT toolkit</td>
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**SESSION TIME:** 10:30 – 11:45  
**SESSION ROOM:** 716A  
**SESSION TRACK:** TRACK 05: DOSIMETRY AND RADIATION PROTECTION  
**SESSION NAME:** SP081 – VALIDATION AND VERIFICATION OF THERAPY DOSE DELIVERY: PART 1  
**SESSION CHAIR(S):** GEOFFREY IBBOTT, UNITED STATES  
SAADAT ALI, PAKISTAN

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<th>Speaker &amp; Location</th>
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<tbody>
<tr>
<td>10:30</td>
<td>SP081.1</td>
<td>Validation of Eclipse Treatment planning system Commissioning using Octavius 4D</td>
<td>Paul Ravindran, BN</td>
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<tr>
<td>10:45</td>
<td>SP081.2</td>
<td>Evaluation of Electron Beam Algorithm of Prowess Panther Planning System for Customized Electron Cutouts of different Sizes</td>
<td>Saadat Ali, Pakistan</td>
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<tr>
<td>11:00</td>
<td>SP081.3</td>
<td>Standard Measurements and MU Calibrations for Carbon Beam Therapy of SAGA-HIMAT</td>
<td>Manabu Mizota, Japan</td>
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<td>11:15</td>
<td>SP081.4</td>
<td>3D 'Bridge' Silicon Microdosimeter for RBE Studies in 12C Radiation Therapy</td>
<td>Michael Lerch, Australia</td>
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<tr>
<td>11:30</td>
<td>SP081.5</td>
<td>Characterization of a ZnSe(Te) inorganic scintillator for scintillation dosimetry applications</td>
<td>Patricia Duguay-Drouin, Canada</td>
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<tr>
<td>11:45</td>
<td>SP081.6</td>
<td>Determination of correction factors for the use of ionization chambers in the presence of magnetic fields</td>
<td>Geoffrey Ibbott, United States</td>
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**SESSION TIME:** 10:30 – 12:00  
**SESSION ROOM:** 716A  
**SESSION TRACK:** TRACK 05: DOSIMETRY AND RADIATION PROTECTION  
**SESSION NAME:** SP081 – VALIDATION AND VERIFICATION OF THERAPY DOSE DELIVERY: PART 1  
**SESSION CHAIR(S):** GEOFFREY IBBOTT, UNITED STATES  
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<tr>
<td>10:30</td>
<td>SP082.1</td>
<td>Aging Process: Central Pressure Waveform Loss of Complexity</td>
<td>Ricardo Armentano, Argentina</td>
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<tr>
<td>10:45</td>
<td>SP082.2</td>
<td>Changes in COP scaling behaviour in quiet stance after mTBI</td>
<td>Coren Walters-Stewart, Canada</td>
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<tr>
<td>11:00</td>
<td>SP082.3</td>
<td>Tracking algorithm of spiral wave core in a cardiac tissue using Hilbert transform and phase variance analysis</td>
<td>Naoki Tomii, Japan</td>
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<tr>
<td>11:15</td>
<td>SP082.4</td>
<td>Mapping the Fractal Dimension of Arterial Pressure</td>
<td>Leandro Cymberknop, Argentina</td>
</tr>
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<td>11:30</td>
<td>SP082.5</td>
<td>Moving deterended fluctuation analysis for inspecting time evolution of scale invariant structures in biomedical signals</td>
<td>Hamidreza Saghir, Canada</td>
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**SESSION TIME:** 10:30 – 11:30  
**SESSION ROOM:** 715B  
**SESSION TRACK:** TRACK 09: BIOSIGNAL PROCESSING  
**SESSION NAME:** SP082 – NONLINEAR DYNAMIC ANALYSIS  
**SESSION CHAIR(S):** ZAHRA MOUSSAVI, CANADA  
RICARDO ARMENTANO, ARGENTINA

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<tr>
<td>10:30</td>
<td>SP083.1</td>
<td>Design of a braking simulator for the assessment of lower limb fracture recovery</td>
<td>Andrew O’Connell, Canada</td>
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<tr>
<td>10:45</td>
<td>SP083.2</td>
<td>Quantitative measurement of subtalar joint passive stiffness in children with cerebral palsy</td>
<td>Wei Chen, People’s Republic of China</td>
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<tr>
<td>11:00</td>
<td>SP083.3</td>
<td>Differences in the parameters of impedance between knees with and without meniscal injury in female athletes</td>
<td>Marysol Garcia-Pérez, Mexico</td>
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<tr>
<td>11:15</td>
<td>SP083.4</td>
<td>Development and evaluation of a mechanical stance controlled orthotic knee joint with stance flexion utilizing a timing based control strategy flexion</td>
<td>Hankyu Lee, Canada</td>
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**SESSION TIME:** 10:30 – 11:30  
**SESSION ROOM:** 715B  
**SESSION TRACK:** TRACK 10: REHABILITATION MEDICINE, SPORTS MEDICINE, REHABILITATION ENGINEERING AND PROSTHETICS  
**SESSION NAME:** SP083 – LOWER LIMB INJURY ASSESSMENT AND TREATMENT & PROSTHETICS AND ASSISTIVE DEVICES  
**SESSION CHAIR(S):** AMY HSIAO, CANADA
### SESSION TIME: 10:30 – 12:00
### SESSION ROOM: 717B
### SESSION TRACK: TRACK 12: MEDICAL DEVICES
### SESSION NAME: SP084 – NEW DESIGNING IDEAS
### SESSION CHAIR(S): ZIWEI HUANG, AUSTRALIA
**FRED HOSEA, UNITED STATES**

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<td>10:30</td>
<td>SP084.1 - Soprano - Nasogastric Tube Insertion Guide</td>
<td>Hwa Liang Leo, Singapore</td>
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<td>10:45</td>
<td>SP084.2 - High Output Impedance Current-Convoyer Oscillator for Electrical Bioimpedance Applications</td>
<td>Pedro Bertemes-Filho, Brazil</td>
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<td>11:00</td>
<td>SP084.3 - Healthcare Device for People Affected by Dementia</td>
<td>Sara Velez, Colombia</td>
<td>717B</td>
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<td>11:15</td>
<td>SP084.4 - Wide Field-of-View Fluorescence Imaging with Curved Sample Chamber for Point-of-Care CD4 Test</td>
<td>Kyung-hoon Kim, Republic of Korea</td>
<td>717B</td>
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<tr>
<td>11:30</td>
<td>SP084.5 - Moisture effect on antibody longevity on paper substrate and the role of hydroxyl groups in the concept of ‘bio-compatible paper’</td>
<td>Ziwei Huang, Australia</td>
<td>717B</td>
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<td>11:45</td>
<td>SP084.6 - An Interoperability Maturity Roadmap for Medical Device Design and Alignment with IT Systems</td>
<td>Fred Hosea, United States</td>
<td>717B</td>
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### SESSION TIME: 10:30 – 11:45
### SESSION ROOM: 715A
### SESSION TRACK: TRACK 18: GENDER, SCIENCE AND TECHNOLOGY
### SESSION NAME: SP085 – WOMEN IN MEDICAL PHYSICS: CURRENT STATUS
### SESSION CHAIR(S): KRISTY BROCK, UNITED STATES
**PAOLO RUSSO, ITALY**

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<td>10:30</td>
<td>SP085.1 - Women in medical physics: Current status Results from IOMP survey</td>
<td>Virginia Tsapakis, Greece</td>
<td>715A</td>
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<td>10:45</td>
<td>SP085.2 - Is there a ‘Leaky Pipeline’ for Women in Clinical Medical Physics in Canada?</td>
<td>Wendy Smith, Canada</td>
<td>715A</td>
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<tr>
<td>11:00</td>
<td>SP085.3 - Women in Medical field in Brazil: gender equality?</td>
<td>Simone Renha, Brazil</td>
<td>715A</td>
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<tr>
<td>11:15</td>
<td>SP085.4 - Women Biomedical Engineers as Consultants in Clinical Engineering Field in Latin American Countries: Case of Study</td>
<td>Claudia Cárdenas Alanís, Mexico</td>
<td>715A</td>
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### SESSION TIME: 10:30 – 12:15
### SESSION ROOM: 713B
### SESSION TRACK: PRESIDENT’S CALL
### SESSION NAME: SP087 – EDUCATIONAL AND PROFESSIONAL ACTIVITIES: PART 2
### SESSION CHAIR(S): FRANCO SIMINI, URUGUAY

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<td>10:30</td>
<td>SP087.1 - The potential role of IFMBE in improving the state of medical equipment in developing countries</td>
<td>Andrei Linnenbank, Netherlands</td>
<td>713B</td>
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<td>10:45</td>
<td>SP087.2 - Biomedical Engineering Education through Outreach Programs in Hospitals</td>
<td>Franco Simini, Uruguay</td>
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<td>11:00</td>
<td>SP087.3 - Clinical Engineer: a health professional to recognize</td>
<td>Paolo Lago, Italy</td>
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<td>11:15</td>
<td>SP087.4 - “Rehabilitation Engineering: Designing for Ability” - A summer outreach course for attracting talented high school students to the rehabilitation engineering field</td>
<td>Vicki Komisar, Canada</td>
<td>713B</td>
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<tr>
<td>11:30</td>
<td>SP087.5 - A Novel Approach to Train Biomedical Engineers in a Ugandan Setting</td>
<td>Robert Ssekitoleko, Uganda</td>
<td>713B</td>
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<td>Session Chair(S)</td>
<td>Session Track</td>
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<tr>
<td>11:45</td>
<td>SP087.6 - A Health Information Technology Management Course for Brazilian Clinical Engineers</td>
<td>Fernando Andrade, Brazil</td>
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<td>12:00</td>
<td>SP087.7 - A Successful High School Science Mentorship Program: Students on the Beamlines at the Canadian Light Source</td>
<td>Denise Miller, Canada</td>
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</tr>
<tr>
<td>11:45</td>
<td>SP087.6 - A Health Information Technology Management Course for Brazilian Clinical Engineers</td>
<td>Fernando Andrade, Brazil</td>
<td>13:30 - 14:45</td>
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<td>SP087.7 - A Successful High School Science Mentorship Program: Students on the Beamlines at the Canadian Light Source</td>
<td>Denise Miller, Canada</td>
<td>13:30 - 14:45</td>
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<td>13:30</td>
<td>SP088.1 - Automatic Analysis of Plantar Foot Thermal Images in at-Risk Type II Diabetes by Using an Infrared Camera</td>
<td>Luis Vilcahuaman, Peru</td>
<td>TRACK 01: IMAGING</td>
</tr>
<tr>
<td>13:45</td>
<td>SP088.2 - Computer Assisted Diagnosis of Sclerotic Bone Lesions from Dual Energy CT</td>
<td>Harini Veeraraghavan, United States</td>
<td>TRACK 01: IMAGING</td>
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<tr>
<td>14:00</td>
<td>SP088.3 - Mutual Information Based Template Matching Method for the Computer Aided Diagnosis of Alzheimer Disease</td>
<td>Albert Guvenis, Turkey</td>
<td>TRACK 01: IMAGING</td>
</tr>
<tr>
<td>14:15</td>
<td>SP088.4 - Development of an Anatomical Measurement and Data Analysis Tool Based on the Kinect Sensor for Physical Rehabilitation Applications.</td>
<td>David Duarte-Dyck, Mexico</td>
<td>TRACK 01: IMAGING</td>
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<tr>
<td>14:30</td>
<td>SP088.5 - Quantitative CT Assessment of Vertebral Fracture Severity</td>
<td>Curtis Caldwell, Canada</td>
<td>TRACK 01: IMAGING</td>
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<tr>
<td>13:30</td>
<td>SP089.1 - The protective effect of the eyelid on ocular injuries in blunt trauma</td>
<td>Xiaoyu Liu, People’s Republic of China</td>
<td>TRACK 03: BIOMECHANICS AND ARTIFICIAL ORGANS</td>
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<tr>
<td>13:45</td>
<td>SP089.2 - A Tale of Two Tendons: The Tradeoff between Strength and Fatigue Resistance</td>
<td>Samuel Veres, Canada</td>
<td>TRACK 03: BIOMECHANICS AND ARTIFICIAL ORGANS</td>
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<td>14:00</td>
<td>SP089.3 - Dynamic plantar pressure simulation integrated in case specific multibody gait simulations</td>
<td>Jos Vander Sloten, Belgium</td>
<td>TRACK 03: BIOMECHANICS AND ARTIFICIAL ORGANS</td>
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<td>13:30</td>
<td>SP090.1 - Response Characteristics of a Large-Area Ion Chamber with Various Radiotherapy Beams</td>
<td>Makan Farrokhkish, Canada</td>
<td>TRACK 05: DOSIMETRY AND RADIATION PROTECTION</td>
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<td>13:45</td>
<td>SP090.2 - Very small circular fields output factors: Comparison of MC calculations, EBT3 film and micro-diamond measurements</td>
<td>Eyad Alhakeem, Canada</td>
<td>TRACK 05: DOSIMETRY AND RADIATION PROTECTION</td>
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<td>14:00</td>
<td>SP090.3 - Investigation of pass rate variability in ArcCheck measurements</td>
<td>Harald Keller, Canada</td>
<td>TRACK 05: DOSIMETRY AND RADIATION PROTECTION</td>
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<td>14:15</td>
<td>SP090.4 - Characterization and image quality evaluation for a clinical 2.5 MV in-line portal imaging beam</td>
<td>Jose Villarreal-Barajas, Canada</td>
<td>TRACK 05: DOSIMETRY AND RADIATION PROTECTION</td>
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<td>14:30</td>
<td>SP090.5 - Usefulness of the commercialized EPID based dMLC QA tool for Elekta Agility MLC</td>
<td>Samju Cho, Republic of Korea</td>
<td>TRACK 05: DOSIMETRY AND RADIATION PROTECTION</td>
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<td>14:45</td>
<td>SP090.6 - In-vivo and pre-treatment quality assurance software validation and verification</td>
<td>Cinzia Talamonti, Italy</td>
<td>TRACK 05: DOSIMETRY AND RADIATION PROTECTION</td>
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<tr>
<td>13:30</td>
<td>SP091.1 - KEYNOTE: New Technologies in Cancer Research and Treatment</td>
<td>Eva Bezak, Australia</td>
<td>TRACK 06: NEW TECHNOLOGIES IN CANCER RESEARCH AND TREATMENT</td>
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<tr>
<td>13:30</td>
<td>SP091.2 - Keynote: New Technologies in Cancer Research and Treatment</td>
<td>Eva Bezak, Australia</td>
<td>TRACK 06: NEW TECHNOLOGIES IN CANCER RESEARCH AND TREATMENT</td>
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<td>14:00</td>
<td>SP091.2</td>
<td>Enhanced uptake of gold nanoparticles coated with polyethylene glycol</td>
<td>Charmaine Cruje, Canada</td>
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<td>14:15</td>
<td>SP091.3</td>
<td>Nuclear targeting of gold nanoparticles for improved therapeutics</td>
<td>Celina Yang, Canada</td>
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<td>13:30</td>
<td>SP092.1</td>
<td>Delta-Modulated High Frequency Oscillations Linked to Pathological Brain in Female Mecp2-Deficient Mice</td>
<td>Sinisa Colic, Canada</td>
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<td>13:45</td>
<td>SP092.2</td>
<td>Contrast between Spectral and Connectivity Features for Electroencephalography based Authentication</td>
<td>Chungmin Han, Republic of Korea</td>
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<td>14:00</td>
<td>SP092.3</td>
<td>EMG artifact removal using ICA-based dipole distribution from scalp EEG of epileptic patients</td>
<td>Chunsheng Li, Canada</td>
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<td>14:15</td>
<td>SP092.4</td>
<td>Power based features of epileptic iEEG rhythms to demarcate brain regions for resection</td>
<td>Joshua Dian, Canada</td>
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<td>14:30</td>
<td>SP092.5</td>
<td>The alpha rhythm in a rodent model of epilepsy is enhanced when adenosine receptors are blocked</td>
<td>Vanessa Breton, Canada</td>
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<td>13:30</td>
<td>SP093.1</td>
<td>The maintenance needs of oxygen concentrators in low-resource settings and implications for technician training: Experience from The Gambia</td>
<td>Beverly Bradley, Canada</td>
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<td>13:45</td>
<td>SP093.2</td>
<td>Global Medical Devices Pricing Survey</td>
<td>Adriana Velazquez Berumen, Switzerland</td>
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<td>14:00</td>
<td>SP093.3</td>
<td>Methodology to evaluate physical environment parameters in healthcare services</td>
<td>Saide Calli, Brazil</td>
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<td>14:15</td>
<td>SP093.4</td>
<td>HB-HTA method for the evaluation of exclusive Medical Devices</td>
<td>Paolo Lago, Italy</td>
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<td>14:30</td>
<td>SP093.5</td>
<td>Applying Heuristic Evaluation on Medical Devices User Manuals</td>
<td>Fernando Andrade, Brazil</td>
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<td>13:30</td>
<td>SP094.1</td>
<td>Finite Element Analysis of Dynamics of Two Microbubbles Under Ultrasonic Field</td>
<td>Xiao-hui Qiu, People's Republic of China</td>
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<td>13:45</td>
<td>SP094.2</td>
<td>The value of individual measurements for tumor control probability predictions in head and neck patients</td>
<td>Iuliana Toma-Dasu, Sweden</td>
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<td>14:00</td>
<td>SP094.3</td>
<td>A Novel Technique for Measuring Electrical Permittivity of Biological Tissues at Low Frequencies (100 KHz or lower)</td>
<td>Seyed Hesabgar, Canada</td>
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<td>13:30</td>
<td>SP095.1</td>
<td>Power Spectral Density Analysis of Tonic Electrodermal Activity for Sympathetic Arousal Assessment</td>
<td>Hugo Posada-Quintero, United States</td>
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<td>13:45</td>
<td>SP095.2</td>
<td>Multivariate Analysis Classification Based on Multi-Channel EMG Multisite Microelectrode Recording, Principal Component Analysis, and Hierarchical Clustering</td>
<td>Venkateshwarla Raju, India</td>
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<td>14:00</td>
<td>SP095.3</td>
<td>Blanket Fractal Dimension for Estimating Tidal Volume from the Smartphone Acquired Tracheal Sounds: Preliminary Results</td>
<td>Natasa Reljin, United States</td>
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</table>
14:15 SP095.4 - A Robust and Realistic Framework for Clinical Classification of Myocardial Infarction
Yasin Mamatjan, Canada

14:30 SP095.5 - A Mother Wavelet Selection Algorithm for Respiratory Rate Estimation from Photoplethysmogram
Dan Guo, People’s Republic of China

14:45 SP095.6 - Mathematical assessment of variability in respiratory airflow patterns
Saravana Raman, United States

15:00 SP095.7 - Spectral Analysis of Respiratory and Cardiac Signals Using Doppler Radar
Philip Tworzydlo, Canada

15:00 SP097.1 - Ischemia-time dependent CBF threshold for infarction determined in a porcine model of stroke using CT Perfusion and F-18 FFMZ PET imaging
Eric Wright, Canada

15:15 SP097.2 - Characterization of scatter factors in thyroid studies using a pinhole collimator by Monte Carlo Simulation.
Aley Palau, Cuba

15:30 SP097.3 - Fluid Quantification Using Temporal Subtraction: Comparing Single to Dual-Energy Digital Chest Radiography
Shailaja Sajja, Canada

15:45 SP097.4 - Quantitative low-kVp CT angiography in carotid artery imaging
Tianye Niu, People’s Republic of China

16:00 SP097.5 - Evaluation of the $\Delta V$ Ventilation Calculation Method Using In Vivo XeCT Ventilation Data
Geoffrey Zhang, United States

16:15 SP097.6 - Predicting Survival Outcomes of Post-Treatment Glioma Patients by Quantification of Viable Tumour Volume on CMET/FLT PET and MRI.
Christopher Leatherday, Australia

16:30 SP097.7 - A Novel Method for Lung’s Air Volume Estimation in Exhalation and Inhalation Phases From CT Imges
Elham Karami, Canada

16:45 SP097.8 - High-resolution micro-CT protocol for assessing lung ventilation and perfusion: image subtraction versus multi-energy analysis
Nancy Ford, Canada

15:00 SP098.1 - Finite Element Analysis of Abdominal Aortic Aneurysms to Predict Risk of Rupture - The Role of the Thrombosis Thicknesses.
Omar Altwijri, Saudi Arabia

15:15 SP098.2 - High-Frequency Ultrasonic Measurement of Ischemia and Revascularization in Mice with Ligated Femoral Arteries
Andrea Quiroz, United States

15:30 SP098.3 - Prevention of Thrombogenesis with a new Silane Based Adlayer on Commonly used Polymers in Medical Equipment Components
Kiril Fedorov, Canada

15:45 SP098.4 - Nature’s Own ‘Smart’ Biological Material to Inspire Next-Generation Biomaterials
Joanna Ng, Australia
16:00  SP098.5 - Vascular endothelial cell adhesion and hemocompatibility of biochemically- and topographically-modified poly(vinyl alcohol)
Evelyn Yim, Singapore

16:15  SP012.1 - Effects of PEMF on Neuroblastoma Cells Previously Exposed to Antidepressants
Teodoro Cordova-Fraga, Mexico

16:30  SP012.2 Porous bio-Sic ceramics from wood: approaching new medical implants
Birgit Glasmacher, Germany

SESSION TIME: 15:00 – 16:30
SESSION ROOM: 716A
SESSION TRACK: TRACK 05: DOSIMETRY AND RADIATION PROTECTION
SESSION NAME: SP099 – SPECIAL SESSION: CURRENT SITUATION OF DOSIMETRY IN RADIOLOGY AND RADIATION PROTECTION
SESSION CHAIR(S): MADAN REHANI, UNITED STATES

Speakers: SP099.1 - Madan Rehani, United States
SP099.2 - Pablo Jimenez, United States
SP099.3 - Joanna Izewska, Austria

SESSION TIME: 15:00 – 16:00
SESSION ROOM: 716B
SESSION TRACK: TRACK 05: DOSIMETRY AND RADIATION PROTECTION
SESSION NAME: SP100 – DOSE OPTIMIZATION: FOCUS ON DRLS
SESSION CHAIR(S): GRAEME WARDLAW, CANADA
JOSEP MARTI-CLIMENT, SPAIN

15:00  SP100.1 - A Contribution to the Establishment of Diagnostic Reference Levels in Computed Tomography in Brazil
Ana Marques Da Silva, Brazil

15:15  SP100.2 - Canada’s Computed Tomography (CT) Survey: Overview and Moving Toward Establishment of DRLs
Graeme Wardlaw, Canada

15:30  SP100.3 - Review UAE Dental Radiology Dosimetry Results for National DRLs Establishment
Fatima Al Kaabi, United Arab Emirates

15:45  SP100.4 - Should restrictions on the patients’ behavior during the radiopharmaceuticals incorporation and after 99mTc bone scans be imposed?
Josep Marti-Climent, Spain

SESSION TIME: 15:00 – 17:00
SESSION ROOM: 715A
SESSION TRACK: TRACK 13: INFORMATICS IN HEALTH CARE AND PUBLIC HEALTH
SESSION NAME: SP102 – CLINICAL INFORMATION SYSTEMS AND DECISION SUPPORT
SESSION CHAIR(S): LEANDRO PECCIA, UNITED KINGDOM
JORGE DOS SANTOS, GREECE

15:00  SP102.1 - A Multi-Attribute Decision Theory Approach to Radiation Dose De-escalation in Oropharyngeal Cancer
Wade Smith, United States

15:15  SP102.2 - Large-scale data of basic patient and treatment characteristics significantly improve predictions for post-radiotherapy dyspnea
Andre Dekker, Netherlands
15:30 SP102.3 - Substituting human MRI-observed tumor length with automated tumor length calculations for prediction model application
Johan Van Soest, Netherlands

15:45 SP102.4 - An Artifact Detection Framework for Clinical Decision Support Systems
Shermeen Nizami, Canada

16:00 SP102.5 - Design and implementation of an IT management system for a Medical Physics Department activity workflows
Massimiliano Paolucci, Italy

16:15 SP102.6 - Differential Feature Space in Mean Shift Clustering for Automated Melanoma Assessment
Javier Eslava, United States

16:30 SP102.7 - Fuzzy-state machine for Triage priority classifier in emergency room
Emmanuel Sánchez Velarde, Mexico

16:45 SP102.8 - An Australian mining boom: development of an Australian radiotherapy datamining network for rapid learning from clinical data to support improved clinical decisions
David Thwaites, Australia

17:00 SP104.1 - Monte Carlo simulation of interventional cardiac scenarios using a newborn hybrid phantom and MCNPX code
Fernanda Cavalcante, Brazil

17:15 SP104.2 - Computed tomography of a beating heart: High resolution simulator for the assessment of motion artifacts during CT scan of the heart
Dov Malonek, Israel

17:30 SP104.3 - Development of Dynamic Anthropomorphic Heart Phantom for Computed tomography
Ali Ursani, Canada

17:45 SP104.4 - Development of a PET/MR/CT Compatible Tumour Motion Phantom
John Patrick, Canada

17:00 SP105.1 - KEYNOTE: Advancing MRI for Non-invasive Physiological and Cellular Imaging
Hai-Ling Margaret Cheng, Canada

17:30 SP105.2 - Detection of Regional Radiation-Induced Lung Injury using Hyperpolarized 129Xe Localized Magnetic Resonance Spectroscopy
Brandon Zanette, Canada

17:42 SP105.3 - Conjugate-Mapped Compressed Sensing: a technique to mitigate the side effects of compressed sensing on MTF
Amr Heikal, Canada

17:54 SP105.4 - Gadolinium Labeled Glycosylated Nanomagnetic Particles as Metabolic Contrast Agents in Molecular Magnetic Resonance Imaging
Nader Riyahi-Alam, Iran

18:06 SP105.5 - Hyperpolarized 129Xe Magnetic Resonance Imaging of a Rat Model of Radiation-Induced Lung Injury Involving Single-Lung Radiation Therapy
Ozkan Doganay, Canada

18:18 SP105.6 - Ultra-short Echo Time (UTE) Magnetic Resonance Imaging of Cortical Bone: An Undersampled Acquisition Study
Yanchun Zhu, People's Republic of China
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<td>18:30</td>
<td>SP105.7 - Brain activation associated with working memory maintenance under anxiety-provoking distracter in patients with obsessive compulsive disorder</td>
<td>Gwang-Woo Jeong, Republic of Korea</td>
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<td>18:42</td>
<td>SP105.8 - Fractional Anisotropy, Voxel Wise Morphometry and Resting State in Patients with Lateral Amyotrophic Sclerosis</td>
<td>Maria Lopez-Titla, Mexico</td>
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<tr>
<td>17:00</td>
<td>SP106.1 - KEYNOTE: Proton therapy – close to becoming mainstream</td>
<td>Thomas Bortfeld, United States</td>
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<td>17:15</td>
<td>SP107.2 - The study of Total Marrow Irradiation Based on Rotational Intensity-modulated techniques</td>
<td>Shouping Xu, People’s Republic of China</td>
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<td>17:30</td>
<td>SP107.3 - IMRT and VMAT comparison for a case of bilateral breast carcinoma</td>
<td>Erick Montenegro, Guatemala</td>
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<td>17:45</td>
<td>SP107.4 - Measuring the Location and Dynamics of the Beam Spot and Field Centre on a Therapy Linear Accelerator in X-Ray Mode</td>
<td>David Spencer, Canada</td>
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<tr>
<td>18:00</td>
<td>SP107.5 - Monte Carlo based optimization of flattening filters for a cobalt-60 total body irradiation unit</td>
<td>Ingrid Lai, Canada</td>
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<tr>
<td>18:15</td>
<td>SP107.6 - Monte Carlo study for the design of a novel Gamma-Tomo SBRT system</td>
<td>Grisel Mora, Portugal</td>
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<tr>
<td>18:30</td>
<td>SP107.7 - A dosimetric evaluation of flattening filter-free volumetric modulated arc therapy for postoperative treatment of cervical cancer</td>
<td>Fuli Zhang, People’s Republic of China</td>
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**SESSION TIME:** 17:00 – 18:45  
**SESSION ROOM:** 701A  
**SESSION TRACK:** TRACK 04: RADIATION ONCOLOGY  
**SESSION NAME:** SP106 – PR: PROTON THERAPY  
**SESSION CHAIR(S):** DANIEL SANCHEZ-PARCERISA, UNITED STATES  
DEREK DOLNEY, UNITED STATES

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<td>17:00</td>
<td>SP106.2 - Monte Carlo-based Inverse Treatment Plan Optimization for Intensity Modulated Proton Therapy</td>
<td>Yongbao Li, People’s Republic of China</td>
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<td>17:30</td>
<td>SP106.3 - FoCa: a protontherapy treatment planning system written in object-oriented MATLAB</td>
<td>Daniel Sanchez-Parcerisa, United States</td>
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<td>17:45</td>
<td>SP106.4 - Assessment of the limitations of the dose calculation algorithm of a commercially-available treatment planning system for proton pencil beam scanning</td>
<td>Jessica Scholey, United States</td>
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<td>18:00</td>
<td>SP106.5 - Impact of the microdosimetric spread on cell survival data analysis</td>
<td>Shirin Enger, Canada</td>
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<td>18:15</td>
<td>SP106.6 - Magnetically scanned-beam proton radiography using Micromegas detectors</td>
<td>Derek Dolney, United States</td>
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<td>17:00</td>
<td>SP108.1 - Radiation dose to patients from cardiac interventions performed using image intensifier, flat detector and novel flat detector systems</td>
<td>Roshan Livingstone, India</td>
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<td>17:15</td>
<td>SP108.2 - First National Occupational Radiation Dose Registry in Ministry of Health and its Validation: An Oman Experience</td>
<td>Arun Kumar L S, Oman</td>
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<td>17:30</td>
<td>SP108.3 - Assessment of Patient and Staff Doses in Interventional Cerebral Angiography Using OSL</td>
<td>Chryzel Angelica Gonzales, Republic of the Philippines</td>
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<td>17:45</td>
<td>SP108.4 - A wireless personal dosimeter for Interventional Radiology medical personnel.</td>
<td>Massimiliano Paolucci, Italy</td>
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**SESSION TIME:** 17:00 – 18:00  
**SESSION ROOM:** 716A  
**SESSION TRACK:** TRACK 05: DOSIMETRY AND RADIATION PROTECTION  
**SESSION NAME:** SP108 – PATIENT AND OCCUPATIONAL DOSE ASSESSMENT  
**SESSION CHAIR(S):** ARUN KUMAR L S, OMAN

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<td>Grisel Mora, Portugal</td>
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<td>SP108.7 - A dosimetric evaluation of flattening filter-free volumetric modulated arc therapy for postoperative treatment of cervical cancer</td>
<td>Fuli Zhang, People’s Republic of China</td>
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**SESSION TIME:** 17:00 – 18:45  
**SESSION ROOM:** 718B  
**SESSION TRACK:** TRACK 04: RADIATION ONCOLOGY  
**SESSION NAME:** SP107 – BEAM DELIVERY  
**SESSION CHAIR(S):** NATALKA SUCHOWERSKA, AUSTRALIA  
RACHEL MCCARROLL, UNITED STATES

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<td>17:00</td>
<td>SP107.1 - A Quantitative Analysis of Teletherapy in Low Resource Settings: Cobalt or Linac?</td>
<td>Rachel McCarroll, United States</td>
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### SP099.1 - Development of a Thick Gas Electron Multiplier Based Multi-element Microdosimetric Detector

Soo Hyun Byun, Canada

### SP099.2 - Development of a 2-D THGEM Microdosimetric Detector

Sahar Darvish-Molla, Canada

### SP099.3 - Quantum versus classical trajectory Monte Carlo simulations of low energy electron transport in condensed media

Rowan Thomson, Canada

### SP099.4 - Investigation of the relations between absorbed dose to cellular targets and to bulk tissue for kilovoltage radiation using Monte Carlo simulations and cavity theory

Patricia Oliver, Canada

### SP099.5 - Development of transmitted alpha particle microdosimetry using Timepix: Investigation of A549 lung carcinoma cells exposed to alpha particles irradiated from Ra-223

Ruqaya Al Darwish, Australia

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### SP110.1 - KEYNOTE: Optical Navigation in Functional Neurosurgery

Karin Wårdell, Sweden

### SP110.2 - Endoscopic Electrospray: A minimal invasive tool for physical targeted gene delivery

David Hradetzky, Switzerland

### SP110.3 - Cone-Beam CT-Guided Fluorescence Tomography for Intraoperative 3D Imaging

Michael Daly, Canada

### SP110.4 - An Optimal Motion Profile for a Wireless Endoscopic Capsule Robot

Sina Mahmoudzadeh, Iran

### SP110.5 - Orthogonal IR System for Instrumental tracking in Minimally Invasive Spine Procedures for training using Wiimote Technology

Juana Martinez, Mexico

### SP110.6 - Use of a Patient-Specific Ventriculostomy Surgical Simulator to Develop a Model for Preoperative Risk Assessment Based on Measures of Anatomical Variation

Ryan Armstrong, Canada
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<td>17:00</td>
<td>SP112.1</td>
<td>SP112.1 - Adaptation of Surgical Instruments for the Removal of Bladder Tumours</td>
<td>Spencer Barnes, United Kingdom</td>
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<td>17:15</td>
<td>SP112.2</td>
<td>SP112.2 - A compact gantry based on pulse powered magnets for a laser-based proton radiotherapy</td>
<td>Leonhard Karsch, Germany</td>
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<td>17:30</td>
<td>SP112.3</td>
<td>SP112.3 - Developing a pH Responsive Mesh as a Smart Skin Wafer in Ostomy Appliances</td>
<td>Anna McLister, United Kingdom</td>
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<td>17:45</td>
<td>SP112.4</td>
<td>SP112.4 - Development of a smart needle integrated with a micro-structured impedance sensor for the detection of breast cancer</td>
<td>Niall Savage, Ireland</td>
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<td>18:00</td>
<td>SP112.5</td>
<td>SP112.5 - Towards development of a wearable, miniaturized, bioartificial lung</td>
<td>Esther Novosel, Germany</td>
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<td>18:15</td>
<td>SP112.6</td>
<td>SP112.6 - Development of a Low Cost Spectrometer for Studies of Diffuse Reflectance with Dermatological Science and Applications</td>
<td>Gerardo Romo-Cardenas, Mexico</td>
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<td>18:30</td>
<td>SP112.7</td>
<td>SP112.7 - Correctness of bioimpedance data for body composition obtained by BIA approach in various external conditions</td>
<td>Jan Hlubik, Czech Republic</td>
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<td>17:00</td>
<td>SP113.1</td>
<td>SP113.1 - KEYNOTE: Technologies for Patient Self-Care of Chronic Illness: Development and Evidence</td>
<td>Joseph Cafazzo, Canada</td>
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<td>17:30</td>
<td>SP113.2</td>
<td>SP113.2 - A mobile monitoring tool for the automatic activity recognition and its application for Parkinson's disease rehabilitation</td>
<td>Jorge Cancela, Spain</td>
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<td>SP113.3</td>
<td>SP113.3 - My Patient: An Electronic Patient Information Management System</td>
<td>Satish Jaywant, Kwaid</td>
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<td>18:00</td>
<td>SP113.4</td>
<td>SP113.4 - Hom-e-call? An enhanced fall detection system based on accelerometer and optical sensors applicable in domestic environment</td>
<td>Daniel Wohlrab, Germany</td>
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<td>18:15</td>
<td>SP113.5</td>
<td>SP113.5 - An Algorithm Based on Voice Description of Meal for Insulin Dose Calculation to Compensate Food Intake</td>
<td>Piotr Foltynski, Poland</td>
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<td>18:30</td>
<td>SP113.6</td>
<td>SP113.6 - Building neuroscientific evidence and best practices in active and healthy aging</td>
<td>Panagiotis Bamidis, Greece</td>
</tr>
<tr>
<td>18:45</td>
<td>SP113.7</td>
<td>SP113.7 - Intelligent System for Identification of patients in Healthcare</td>
<td>Giovanni Sagbay, Ecuador</td>
</tr>
</tbody>
</table>
Thursday, June 11 2015

SESSION TIME: 08:00 – 10:00
SESSION ROOM: 718A
SESSION TRACK: TRACK 01: IMAGING
SESSION NAME: SP115 – CT IMAGE QUALITY AND DOSE OPTIMIZATION
SESSION CHAIR(S): ANA MARIA MARQUES DA SILVA, BRAZIL

08:00 SP115.1 - Towards Image Quality Analysis of Small and Full Field of View Dental Cone Beam CT Systems
Ana Maria Marques Da Silva, Brazil

08:15 SP115.2 - Rapid non-invasive spatially varying HVL measurements for CT sources
Matthew Randazzo, United States

08:30 SP115.3 - Development of a CT protocol management system for automated review of CT scanner protocols
Josh Grimes, United States

08:45 SP115.4 - Evaluation of automatic exposure control systems in computed tomography
Paulo Costa, Brazil

09:00 SP115.5 - Development of a Software for Image Quality Assessment in Computed Tomography using the Catphan500® Phantom
Paulo Costa, Brazil

09:15 SP115.6 - Performance of attenuation-based dynamic CT beam-shaping filtration for elliptical subject geometries in dependence of fan- and projection-angle
Stella Veloza, Colombia

09:30 SP115.7 - A software tool for automated artifact detection in scans of the CT daily water phantom
Josh Grimes, United States

09:45 SP115.8 - Monte Carlo Simulation of X-ray Spectra in Computed Tomography Scanner using GATE
Mohammad Reza Ay, Iran
SESSION TIME: 08:00 – 09:30
SESSION ROOM: 715B
SESSION TRACK: TRACK 05: DOSIMETRY AND RADIATION PROTECTION
SESSION NAME: SP118 – DIAGNOSTIC RADIOLOGY: DOSIMETRY AND QUALITY CONTROL
SESSION CHAIR(S): JAMILA SALEM AL SUWAIDI, UNITED ARAB EMIRATES
                      ARUN KUMAR L S, OMAN

08:00 SP118.1 - Measuring absorbed-dose to cardiac implantable electronic device using OSL.
           Étienne Létourneau, Canada
08:15 SP118.2 - Organ dose estimation in computed tomography based on Monte Carlo simulation
           Camille Adrien, France
08:30 SP118.3 - Comparative study of Average Glandular Doses of three different digital mammography units in three Ministry of Health Hospitals in Oman: An analysis
           Arun Kumar L S, Oman
08:45 SP118.4 - First Data on Quality Control Test done in Diagnostic X-ray facility at Major Public Hospitals in Kathmandu Valley, Nepal.
           Kanchan Adhikari, Nepal
09:00 SP118.5 - Estimation of dose distributions in mammography into a tissue equivalent phantom
           Josilene Santos, Brazil

09:15 SP118.7 - Radiation Dose Assessment for Retrospectively ECG-Gated Coronary Computed Tomography Angiography (CCTA) Examination
           C H Yeong, Malaysia
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Title</th>
<th>Speaker(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:00</td>
<td>SP120.1</td>
<td>Desaturation event characteristics and mortality risk in severe sleep apnea</td>
<td>Antti Kulkas, Finlandia</td>
</tr>
<tr>
<td>08:15</td>
<td>SP120.2</td>
<td>Static Posturography of Elderly Fallers and Non-Fallers with Eyes Open and Closed</td>
<td>Jennifer Howcroft, Canada</td>
</tr>
<tr>
<td>08:30</td>
<td>SP120.3</td>
<td>Quantitative analysis of ventricular ectopic beats evaluated from short-term recordings of heart rate variability before imminent tachyarrhythmia</td>
<td>Marisol Martinez-Alanis, Mexico</td>
</tr>
<tr>
<td>08:45</td>
<td>SP120.4</td>
<td>An evaluation of Arterial Stiffness Index in Relation to the State of the Cardiovascular System</td>
<td>Jan Havlík, Czech Republic</td>
</tr>
<tr>
<td>09:00</td>
<td>SP120.5</td>
<td>Investigating a Novel Non-invasive Measure to Assess the Upper Airway Narrowing during Sleep</td>
<td>Ying Xuan Zhi, Canada</td>
</tr>
<tr>
<td>09:15</td>
<td>SP120.6</td>
<td>Establishing a New Biomarker to Determine Patients at Increased Risk of Developing Obstructive Sleep Apnea Due To Fluid Overloading</td>
<td>Bojan Gavrilovic, Canada</td>
</tr>
</tbody>
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<tr>
<th>Time</th>
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<th>Title</th>
<th>Speaker(s)</th>
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</thead>
<tbody>
<tr>
<td>08:00</td>
<td>SP121.1</td>
<td>A 16-bit High-Voltage Digital Charge-Control Electrical Stimulator</td>
<td>Ulrich Hofmann, Germany</td>
</tr>
<tr>
<td>08:15</td>
<td>SP121.2</td>
<td>A method for side effect analysis based on electric field simulations for intraoperative test stimulation in deep brain stimulation surgery</td>
<td>Simone Hemm-Ode, Switzerland</td>
</tr>
<tr>
<td>08:30</td>
<td>SP121.3</td>
<td>Comparison of Three Deep Brain Stimulation Lead Designs under Voltage and Current Modes</td>
<td>Fabiola Alonso, Sweden</td>
</tr>
<tr>
<td>08:45</td>
<td>SP121.4</td>
<td>Effect of closed-loop and open-loop deep brain stimulation on chronic seizures control</td>
<td>Muhammad Salam, Canada</td>
</tr>
<tr>
<td>09:00</td>
<td>SP121.5</td>
<td>Clinical validation of a precise tremor assessment system to aid deep brain stimulation parameter optimisation</td>
<td>Thushara Perera, Australia</td>
</tr>
<tr>
<td>09:15</td>
<td>SP121.6</td>
<td>The Role of Microelectrode Recording (MER) in STN DBS Electrode Implantation</td>
<td>Venkateshwarla Raju, India</td>
</tr>
<tr>
<td>09:30</td>
<td>SP121.7</td>
<td>Effectiveness of Micro-Electrode-Recording(MER) in Determining Subthalamic-Nuclei Deep Brain Stimulation (STN-DBS) Lead Position in PD Conditions</td>
<td>Venkateshwarla Raju, India</td>
</tr>
</tbody>
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<tbody>
<tr>
<td>08:00</td>
<td>SP122.1</td>
<td>KEYNOTE: Machine learning for bioinformatics in the face of class imbalance</td>
<td>James Green, Canada</td>
</tr>
<tr>
<td>08:30</td>
<td>SP122.2</td>
<td>Bioinformatics-based identification of osteoarthritis-associated genes in synovial tissues</td>
<td>Yi-Jiang Song, People’s Republic of China</td>
</tr>
<tr>
<td>08:45</td>
<td>SP122.3</td>
<td>Dynamic Epistasis Analysis</td>
<td>Aseel Awdeh, Canada</td>
</tr>
<tr>
<td>09:00</td>
<td>SP122.4</td>
<td>Transcription factor binding in an expanded epigenetic alphabet</td>
<td>Michael Hoffman, Canada</td>
</tr>
<tr>
<td>09:15</td>
<td>SP122.5</td>
<td>Identification of Molecular Phenotypes in Lung Cancer by Integrating Radiomics and Genomics</td>
<td>Patrick Grossmann, United States</td>
</tr>
<tr>
<td>09:30</td>
<td>SP122.6</td>
<td>A machine learning method to build multi-SNP predictive models of clinical radiosensitivity</td>
<td>Jung Hun Oh, United States</td>
</tr>
<tr>
<td>09:45</td>
<td>SP122.7</td>
<td>Updated Free Energy Parameters Increase MicroRNA Prediction Performance</td>
<td>Robert Peace, Canada</td>
</tr>
</tbody>
</table>
08:00 - 08:45
SESSION TIME: 08:00 – 09:45
SESSION ROOM: 701A
SESSION TRACK: TRACK 16: CLINICAL ENGINEERING, CLINICAL PHYSICS, AND PATIENT SAFETY
SESSION NAME: SP123 – PATIENT SAFETY, MEDICAL ERRORS AND ADVERSE EVENTS PREVENTION RELATED TO HEALTH TECHNOLOGIES
SESSION CHAIR(S): MARY COFFEY, IRELAND ANDREW IBEY, CANADA

08:00 SP123.1 - KEYNOTE: Incident reporting and learning systems improving quality and safety in radiation oncology
Mary Coffey, Ireland
08:30 SP123.2 - Applying an Evidence-based Approach to Managing Alarm Safety: A University Health Network Case Study
Anne Li, Canada
08:45 SP123.3 - Using infusion pump logs to recreate a patient safety event: considerations for smart pump improvement
Andrew Ibey, Canada

08:00 – 09:45
SESSION TIME: 08:00 – 09:45
SESSION ROOM: 717A
SESSION TRACK: TRACK 17: EDUCATIONAL AND PROFESSIONAL ACTIVITIES
SESSION NAME: SP124 – MEDICAL PHYSICS IN DEVELOPING COUNTRIES
SESSION CHAIR(S): AGNETTE PERALTA, REPUBLIC OF THE PHILIPPINES W.H. ROUND, NEW ZEALAND

08:00 SP124.1 - Medical Physics Training Resources for Developing Countries
Muthana Al-Ghazi, United States
08:15 SP124.2 - Medical Physics in Indonesia: Current Status and Plans
Supriyanto Ardjo Pawiro, Indonesia
08:30 SP124.3 - Surveying Trends in Radiation Oncology Medical Physics in the Asia Pacific Region
Tomas Kron, Australia

08:00 – 10:00
SESSION TIME: 08:00 – 10:00
SESSION ROOM: 713A
SESSION TRACK: TRACK 17: EDUCATIONAL AND PROFESSIONAL ACTIVITIES
SESSION NAME: SP125 – TECHNOLOGY ENHANCED EDUCATION
SESSION CHAIR(S): JAMES WEAR, UNITED STATES SLAVIK TABAKOV, UNITED KINGDOM

08:00 SP125.1 - KEYNOTE: e-Learning in Medical Physics? pioneering and future trends
Slavik Tabakov, United Kingdom
08:30 SP125.2 - A Desk-Top Optical Scanner for Teaching the Principles of Computed Tomography (CT)
Linada Kaci, Canada
08:45 SP125.3 - Medical Physics e-Encyclopaedia and Multilingual Dictionary? Upgrade and New Developments
Slavik Tabakov, United Kingdom
09:00 SP125.4 - Physics for Medical Students: Technology Enhanced Teaching from the Dipole to the Vectorcardiogram
Ernst Hofer, Austria
09:15 SP125.5 - matRad: a multimodality open source treatment planning toolkit
Eduardo Cisternas, Chile
09:30 SP125.6 - Creation of a model for online education of clinical engineering and management of medical technologies to reach professionals worldwide
Maria Moreno Carbajal, Mexico
09:45 SP125.7 - Develop of a Mixed, Haptic and Virtual System to Simulate Radiographic Images
Guillermo Avendaño, Chile

08:00 – 09:45
SESSION TIME: 08:00 – 09:45
SESSION ROOM: 715A
SESSION TRACK: TRACK 19: BIOPHYSICS AND MODELLING
SESSION NAME: SP126 – COMPUTATIONAL BIOLOGY & HEMODYNAMICS
SESSION CHAIR(S): IYAD FAYSSAL, LEBANON

08:00 SP126.1 - Medical Physics Training Resources for Developing Countries
Muthana Al-Ghazi, United States
08:15 SP126.2 - Medical Physics in Indonesia: Current Status and Plans
Supriyanto Ardjo Pawiro, Indonesia
08:30 SP126.3 - Surveying Trends in Radiation Oncology Medical Physics in the Asia Pacific Region
Tomas Kron, Australia

08:45 SP124.4 - The Status of Medical Physics in Iraq
Muthana Al-Ghazi, United States
09:00 SP124.5 - Evaluation and Adaptation of Medical Physics Practicum for Nicaraguan Students at a Canadian Cancer Centre
Alana Hudson, Canada
09:15 SP124.6 - Coordination of AAPM Educational Courses for Developing Countries with Major International and Regional Organizations of Medical Physicists
Eugene Lief, United States
08:00 SP126.1 - Evaluation of Decomposition Analysis on Multi-Models for Digital Volume Pulse Signal
Sheng-Cheng Huang, Chinese Taipei

08:15 SP126.2 - Discordant alternans in a one-dimensional cable of ischemic heart tissue.
Yunuen Cervantes Espinosa, Mexico

08:30 SP126.3 - A Novel Biomechanical Model of the Left Ventricle for Cardiac Contraction Force Reconstruction Applications
Seyyed Mohammad Hassan Haddad, Canada

08:45 SP126.4 - A simulative model approach of cardiopulmonary interaction
Chuong Ngo, Germany

09:00 SP126.5 - The Development of SIM to Characterize Blood Volumetric Flow Rate and Hemodynamics in Human Coronary Arteries
Iyad Fayssal, Lebanon

09:15 SP126.6 - Determination of Bermang’s Minimal Model parameters for diabetic mice treated with Ibervillea sonora
Rodrigo Sánchez-González, Mexico

09:30 SP126.7 - Investigation of flow and turbulence in carotid artery models of varying compliance using particle image velocimetry
Amanda Dicarlo, Canada

SESSION TIME: 08:00 – 09:30
SESSION ROOM: 713B
SESSION TRACK: PRESIDENT’S CALL
SESSION NAME: SP127 – INFORMATICS IN HEALTH CARE AND PUBLIC HEALTH / BIOSENSOR, NANOTECHNOLOGY, BIOMEMS AND BIOPHOTONICS
SESSION CHAIR(S): RICARDO SILVA, ECUADOR
PETER PENNEFATHER, CANADA

08:00 SP127.1 - A study on the leading cause of immunisation schedule fall up defaulting and early child hood malnutrition sicknesse in developing countries(uganda in particular)rural areas/villages
Waigonda Saad, Uganda

08:15 SP127.2 - From Smart Phones to Smart Health
Ricardo Silva, Ecuador

08:30 SP127.3 - Diagnostic Data: a Manifesto
Peter Pennefather, Canada

08:45 SP127.4 - Comparative analysis of co-expression networks reveals molecular changes during the cancer progression
Pegah Khosravi, Iran

09:00 SP127.5 - Copper Meshed Carbon Black PDMS Electrode for Underwater ECG Monitoring
Justin Bales, United States

09:15 SP127.6 - Smartphone-based Monitoring of Tidal Volume and Respiratory Rate
Bersain Reyes, United States

SESSION TIME: 10:30 – 11:45
SESSION ROOM: 718A
SESSION TRACK: TRACK 01: IMAGING
SESSION NAME: SP128 – MULTIMODALITY IMAGING
SESSION CHAIR(S): ELISA KALLIONIEMI, FINLANDIA

10:30 SP128.1 - Localizing cortical motor representation: A comparative study between navigated transcranial magnetic stimulation, BOLD contrast and arterial spin labeling fMRI
Elisa Kallioniemi, Finlandia

10:45 SP128.2 - Evaluation of probable dementia with Lewy bodies using 123I-IMP brain perfusion SPECT, 123I-MIBG myocardial SPECT and voxel-based MRI morphometry
Naoki Kodama, Japan

11:00 SP128.3 - Targeted all-organic nanovesicles for multimodal PET/CT and optical fluorescence assessment of lymphatic disseminations in gynaecologic cancers: A radio-pharmaceutical kit to prepare parenteral injections for a ‘first-in-woman’ clinical study.
Michael Valic, Canada

11:15 SP128.4 - Generation of 4-Class Attenuation Map for MRI Based Attenuation Correction of PET Data in the Head Area Using a Novel Combination of STE/DIXON-MRI and FCM Clustering
Hamidreza Saligheh Rad, Iran

11:30 SP128.5 - A new low field MRI/gamma detector hybrid system
Andrea Abril, Colombia

SESSION TIME: 10:30 – 12:00
SESSION ROOM: 701B
SESSION TRACK: TRACK 01: IMAGING
SESSION NAME: SP129 – IMAGE QUALITY ASSESSMENT (MAMMOGRAPHY AND OTHER)
SESSION CHAIR(S): JAMES ANHKAH, UNITED KINGDOM
MARÍA-ESTER BRANDAN, MEXICO

10:30 SP129.1 - Kilovoltage-CBCT of a Linear Accelerator as a relative imaging device of a spiral CT scanner - dosimetric results
James Annkah, United Kingdom

10:45 SP129.2 - Overall performance, image quality and dose in CR mammography systems operating in the Mexico public health sector
Maria-Ester Brandan, Mexico

11:00 SP129.3 - A Catphan attachment for three dimensional measurements of the modulation transfer function
Elsayed Ali, Canada
11:15  SP129.4 - Sensitometric analyses of screen-film systems for mammography exams in Brazil  
Luis Magalhaes, Brazil

11:30  SP129.5 - New Line Contrast Figure of Merit for image quality assessment  
Aris Dermitzakis, Greece

11:45  SP129.6 - Assessment of Photostimulable Storage Phosphor Imaging Plates Quality in Computed Radiography  
Bárbara Friedrich, Brazil

SESSION TIME: 10:30 – 12:00  
SESSION ROOM: 718B  
SESSION TRACK: TRACK 04: RADIATION ONCOLOGY  
SESSION NAME: SP130 – TREATMENT PLANNING  
SESSION CHAIR(S): WINNIE LI, CANADA

10:30  SP130.1 - Comprehensive Dosimetric Planning Comparison for Early Stage Non-Small Cell Lung Cancer with SABR: Fixed-Beam IMRT versus VMAT versus Tomotherapy  
Ilma Xhaferllari, Canada

10:45  SP130.2 - Development and Validation of an Open Source Tool for Determining Planning Target Volume Margins in Intracranial Stereotactic Radiotherapy  
Winnie Li, Canada

11:00  SP130.3 - Dosimetric impact of accurately delineating the left anterior descending artery in photon and proton radiotherapy  
Janid Blanco Kiely, United States

11:15  SP130.4 - Objective function surrogates for iterative beam angle selection  
Jan Unkelbach, United States

11:30  SP130.5 - A preliminary study on the effect of modulated photon radiotherapy (XMRT) optimization for prostate cancer treatment planning  
Philip McGeachy, Canada

11:45  SP130.6 - Measuring radiation treatment plan similarity in the cloud  
Jennifer Andrea, Canada

10:30  SP131.1 - Sensitivity of Helical Tomotherapy and Elekta Agility VMAT dose distributions to multileaf collimator motion uncertainties for breast radiation treatment with extensive nodal irradiation  
Eric Vandervoort, Canada

10:45  SP131.2 - Use of Varian Trajectory Log Files for Patient Specific Quality Control of TrueBeam VMAT FFF Treatment Deliveries with Portal Dosimetry and Eclipse  
Michael Fan, Canada

11:00  SP131.3 - Machine Learning Facilitates Failure Mode Analysis and Virtual QA for IMRT  
Gilmer Valdes, United States

11:15  SP131.4 - Dosimetric analysis of respiratory-gated RapidArc with varying gating window times  
Ju Young Song, Republic of Korea

11:30  SP131.5 - Current status of dose-tracking using an integrated commercial system  
Stina Svensson, Sweden

11:45  SP131.6 - Enabling Continuous Quality Improvement in a Rapidly Changing Clinical Environment through a Multi-Year Multi-Centre IMRT QC Program: 3 Year Experience  
Andrea McNiven, Canada

12:00  SP131.7 - A new approach to spatial gradient signal encoding for external beam radiotherapy delivery verification  
Robert Heaton, Canada

10:30-11:30  
SESSION ROOM: 715B  
SESSION TRACK: TRACK 05: DOSIMETRY AND RADIATION PROTECTION  
SESSION NAME: SP132 – SPECIAL SESSION: IMPLEMENTATION OF THE NEW BSS INCLUDING RADIATION SAFETY CULTURE IN MEDICINE  
SESSION CHAIR(S): MADAN REHANI, UNITED STATES

Speaker: SP132.1 - Madan Rehani, United States

Speaker: SP132.2 - Ola Holmberg, Austria

Speaker: SP132.3 - Pablo Jimenez, United States
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<tr>
<td>SESSION TRACK:</td>
<td>TRACK 05: DOSIMETRY AND RADIATION PROTECTION</td>
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<tr>
<td>SESSION NAME:</td>
<td>SP133 – VALIDATION AND VERIFICATION OF THERAPY DOSE DELIVERY: PART 2</td>
</tr>
<tr>
<td>SESSION CHAIR(S):</td>
<td>SARFEHNA ARMAN, CANADA JAMES CHOW, CANADA</td>
</tr>
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</table>

Panelists: SP133.1 - James Chow, Canada  
SP133.2 - Michel Lalonde, Canada  
SP133.3 - Kamlesh Passi, India  
SP133.4 - Nader Moshiri Sedeh, United States

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<tr>
<td>SESSION ROOM:</td>
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<tr>
<td>SESSION TRACK:</td>
<td>TRACK 08: BIOSENSOR, NANOTECHNOLOGY, BIOMEMS AND BIOPHOTONICS</td>
</tr>
<tr>
<td>SESSION NAME:</td>
<td>SP134 – BIOSIGNAL SENSING AND BODY SENSOR NETWORKS</td>
</tr>
<tr>
<td>SESSION CHAIR(S):</td>
<td>KWANG OH, UNITED STATES JONATHAN LOVELL, UNITED STATES</td>
</tr>
</tbody>
</table>

10:30 SP134.1 - Impedance and comfort of dry multipin electrodes for electroencephalography  
*Patrique Fiedler, Germany*

10:45 SP134.2 - Wearable Gait Analysis using Vision-aided Inertial Sensor Fusion  
*Eric Ma, Canada*

11:00 SP134.3 - Two-Vector Capacitive Electrocardiogram Measurement Using Three Fabric Electrodes for Automobile Application  
*Shunsuke Takayama, Japan*

11:15 SP134.5 - Detection of REM Behaviour Disorder Based on Low-Power Compressive Sensing of EMG  
*Sridhar Krishnan, Canada*

11:30 SP134.6 - Externally applied pressure on the skin electrode impedance  
*Bahareh Taji, Canada*
10:30 Opening Remarks
Slavik Tabakov, United Kingdom
Fridtjof Nuesslin, Germany

10:40 SP137.1 - Cost-Effective Provision of Medical Physics and Medical Engineering Services in Healthcare
Peter H S Smith, United Kingdom

10:50 SP137.2 - Implementing Training Modules of the Emerald Program in Brazil
Ricardo Terini, Brazil

11:00 SP137.3 - Pilot Implementation In The Philippines Of Structured Medical Physics Residency Programs Using The Iaea Training Guides For The Clinical Training Of Medical Physicists
Agnette Peralta, Republic of the Philippines

11:10 SP137.4 - Capacity Building of Medical Physics in Bangladesh
Hasin Anupama Azhari, Bangladesh

11:20 SP137.5 - Education & Training of Medical Physics in Africa: Challenges & Opportunities
Ahmed IbnSeddick

11:30 SP137.6 - Retention of trained medical physicists in African states: Do our Governments have a role to play
Rebecca Nakatudde

11:40 SP137.7 - Strengthening Medical Physics Clinical Competencies in a Challenging Environment - Update on the IAEA Supported Nigerian (NIR/6/023) Project
Taofeeq Ige, Nigeria

11:50 SP137.8 - Capacity Building of Medical Physics in Ghana and Africa
Stephen Inkoom, Ghana
16:00 SP139.5 - Development of Polymer Substrates for Waveguide Evanescent Field Fluorescence Microscopy  
*Rony Sharon, Canada*

16:15 SP139.6 - Higher-Order Structural Investigation of Mammalian Septins by Super-Resolution Fluorescence Microscopy
*Adriano Vissa, Canada*

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15:00 SP140.1 - Credentialing of radiotherapy centres in Australasia for a phase III clinical trial on SABR  
*Tomas Kron, Australia*

15:15 SP140.2 - LED-optimized SBRT for Peripheral Early Stage Lung Cancer: A technique to reduce lung dose and potentially allow for re-irradiation  
*Brandon Disher, Canada*

15:30 SP140.3 - Delivery of VMAT treatments with nonstandard SAD using dynamic trajectories  
*Joel Mullins, Canada*

15:45 SP140.4 - Cone-Beam CT assessment of inter-fraction and intra-fraction motions during lung stereotactic body radiotherapy with and without abdominal compression  
*Ruqing Jiang, Canada*

16:00 SP140.5 - Initial experience in establishing frameless intra-cranial stereotactic radiosurgery program with Varian TrueBeam STx, 6DoF couch and VisionRT motion control system  
*Sergei Zavgorodni, Canada*

---

15:00 SP141.1 - Theoretical description of the saturation correction of ionization chambers in pulsed fields with arbitrary repetition rate  
*Leonhard Karsch, Germany*

15:15 SP141.2 - Performance characteristics of Gafchromic EBT3 film in therapeutic electron beams and its practical application as an in-vivo dosimeter in the clinic  
*Amanda Barry, Ireland*

15:30 SP141.3 - Photon and electron spectra inside small field detectors for narrow and broad 6 MV photon beams  
*Hamza Benmakhlfou, Sweden*

15:45 SP141.4 - Real Time Dose Reconstruction in MV Photon Therapy using a 2D solid state detector array.  
*Michael Lerch, Australia*

16:00 SP141.5 - Energy Correction factor for Plane Parallel ion-chamber and its Use in Clinical photon Beam Dosimetry  
*Kamlesh Passi, India*

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15:00 SP142.1 - Proton Minibeam Radiation Therapy (pMBRT): implementation at a clinical center  
*Yolanda Prezado, France*

15:15 SP142.2 - Hadron minibeam radiation therapy: feasibility study at Heidelberg Ion Therapy Center  
*Yolanda Prezado, France*

15:30 SP142.3 - Acoustic Range Verification of Proton Beams: Simulation Assessment of the Challenges of Clinical Application  
*Kevin Jones, United States*

15:45 SP142.4 - Radiochromic Film Based Dose Calibration and Monitoring for Radiobiological Experiments using Low Energy Proton Beams  
*Belal Moftah, Saudi Arabia*

16:00 SP142.5 - Development of 3D measurement device dedicated for range-compensator QA  
*Shigekazu Fukuda, Japan*
### SESSION TIME: 15:00 – 16:00  
### SESSION ROOM: 701A  
### SESSION TRACK: TRACK 07: SURGERY, COMPUTER AIDED SURGERY, MINIMAL INVASIVE INTERVENTIONS, ENDOSCOPY AND IMAGE-GUIDED THERAPY, MODELLING AND SIMULATION  
### SESSION NAME: SP143 – RADIOTHERAPY AND GUIDANCE  
### SESSION CHAIR(S): STEFANIA PALLOTTA, ITALY

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<tbody>
<tr>
<td>15:00</td>
<td>SP143.1 - Sliced Mary: a deformable phantom for the validation of set-up based on surface imaging in radiotherapy treatments</td>
<td>Stefania Pallotta, Italy</td>
</tr>
<tr>
<td>15:15</td>
<td>SP143.2 - Evaluation of ion chamber response in high dose per pulse electron beams of IORT accelerator using EGSnrc Monte Carlo code</td>
<td>Mostafa Robatjazi, Iran</td>
</tr>
<tr>
<td>15:30</td>
<td>SP143.3 - Compared QA of APEX Radiosurgery System using ARCHECK Phantom in Dynamic Conformal Arc System and VMAT System</td>
<td>JaeE Hyuk Seo, Republic of Korea</td>
</tr>
<tr>
<td>15:45</td>
<td>SP143.4 - Head and Neck CT/CBCT Deformable Registration for Image-guided Accurate Radiotherapy System ARTS-IGRT</td>
<td>Xi Pei, People’s Republic of China</td>
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### SESSION TIME: 15:00 – 16:30  
### SESSION ROOM: 716B  
### SESSION TRACK: TRACK 09: BIOSIGNAL PROCESSING  
### SESSION NAME: SP144 – EMG/MMG  
### SESSION CHAIR(S): GREGG JOHNS, CANADA

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<tr>
<td>15:00</td>
<td>SP144.1 - Estimation of dorsiflexion torque from a mechanomyogram using a Kalman filter</td>
<td>Takanori Uchiyama, Japan</td>
</tr>
<tr>
<td>15:15</td>
<td>SP144.2 - Upper-Limb Force Modeling using Rotated Ensembles with Fast Orthogonal Search on High-Density Electromyography</td>
<td>Gregg Johns, Canada</td>
</tr>
<tr>
<td>15:30</td>
<td>SP144.3 - MMG detection of intentional movement in the presence of dyskinetic movements</td>
<td>Marcela Correa Villada, Canada</td>
</tr>
<tr>
<td>15:45</td>
<td>SP144.4 - Dynamic Noise Reduction in Accelerometer-based Mechanomyography during Pediatric Gait</td>
<td>Katherine Plewa, Canada</td>
</tr>
</tbody>
</table>

### SESSION TIME: 15:00 – 17:00  
### SESSION ROOM: 715A  
### SESSION TRACK: TRACK 10: REHABILITATION MEDICINE, SPORTS MEDICINE, REHABILITATION ENGINEERING AND PROSTHETICS  
### SESSION NAME: SP145 – DEVELOPING TOOLS FOR SUCCESSFUL AGING: INDEPENDENT MOBILITY & VISUAL IMPAIRMENT  
### SESSION CHAIR(S): CHARANJIT BAMBRA, CANADA  
OLOF LINDHAHL, SWEDEN

<table>
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<tr>
<th>Time</th>
<th>Title</th>
<th>Speaker/s</th>
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<tbody>
<tr>
<td>15:00</td>
<td>SP145.1 - KEYNOTE: Aging Successfully at Home: Research and Development to Address the Biggest Challenges Older Adults Face</td>
<td>Tilak Dutta, Canada</td>
</tr>
<tr>
<td>15:30</td>
<td>SP145.2 - The effect of age and previous exposure to slippery surface on gait adaptation</td>
<td>Yue Li, Canada</td>
</tr>
<tr>
<td>15:45</td>
<td>SP145.3 - An intelligent rollator for people with mobility impairment</td>
<td>Olof Lindahl, Sweden</td>
</tr>
<tr>
<td>16:00</td>
<td>SP145.4 - Rehabilitation Engineering: A review of current teaching tools ad project based learning</td>
<td>Charanjit Bambra, Canada</td>
</tr>
<tr>
<td>16:15</td>
<td>SP145.5 - Effects of sloped icy surface on older adults? gait in a simulated winter environment</td>
<td>Yue Li, Canada</td>
</tr>
<tr>
<td>16:30</td>
<td>SP145.6 - Judging Weight of an Object by a White Cane</td>
<td>Kiyohiko Nunokawa, Japan</td>
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### SESSION TIME: 15:00 – 16:15  
### SESSION ROOM: 717B  
### SESSION TRACK: TRACK 12: MEDICAL DEVICES  
### SESSION NAME: SP146 – MSK  
### SESSION CHAIR(S): RICARDO ARMENTANO, ARGENTINA  
ANA TERESA GABRIEL, PORTUGAL

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<tr>
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<tr>
<td>15:00</td>
<td>SP146.1 - Development of Personalized Tourniquet Systems Using a New Technique for Measuring Limb Occlusion Pressure</td>
<td>James McEwen, Canada</td>
</tr>
<tr>
<td>15:15</td>
<td>SP146.2 - Vertebral Metrics? development of a third and improved prototype</td>
<td>Ana Teresa Gabriel, Portugal</td>
</tr>
<tr>
<td>16:15</td>
<td>SP146.3 - Does low-intensity pulsed ultrasound stimulation effectively promote bone fracture repair? An overview</td>
<td>Orlando Rey Rúa, Cuba</td>
</tr>
</tbody>
</table>

### SESSION TIME: 15:00 – 16:15  
### SESSION ROOM: 7178  
### SESSION TRACK: TRACK 12: MEDICAL DEVICES  
### SESSION NAME: SP146 – MSK  
### SESSION CHAIR(S): RICARDO ARMENTANO, ARGENTINA  
ANA TERESA GABRIEL, PORTUGAL

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<td>Orlando Rey Rúa, Cuba</td>
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</tbody>
</table>
15:45  SP146.4 - Electrical Stimulation of the Calf Muscle to Reduce Seated Leg Fluid Accumulation and Subsequent Rostral Fluid Shift While Supine
Daniel Vena, Canada

16:00  SP146.5 - Surgical process analysis identifies lack of connectivity between sequential fluoroscopic 2D alignment as a critical impediment in femoral intramedullary nailing
Hamid Ebrahimi, Canada

SESSION TIME:  15:00 – 16:30
SESSION ROOM:  715B
SESSION TRACK:  TRACK 14: INFORMATION TECHNOLOGIES IN HEALTHCARE DELIVERY AND MANAGEMENT
SESSION NAME:  SP147 – INFORMATION TECHNOLOGIES IN HEALTHCARE DELIVERY AND MANAGEMENT: PART 2
SESSION CHAIR(S):  BRUCE CURRAN, UNITED STATES  JOSEPH CAFAZZO, CANADA

15:00  SP147.1 - KEYNOTE: The Electronic Medical Record: Can it be integrated with Treatment Delivery and Management?
Bruce Curran, United States

15:30  SP147.2 - AIM Quality Assurance Program Development for CT X-Ray Systems
Douglas McTaggart, Canada

15:45  SP147.3 - Evaluation of Improved Automatic Speech Recognition Prototype for Estonian Language in Radiology Domain
Andrus Paats, Estonia

16:00  SP147.4 - Usability engineering approach towards secure open networks in the integrated operating room of the future
Klaus Radermacher, Germany

16:15  SP147.5 - Whiteboard ESB: Next Generation Data and Workflow Management for Radiation Oncology
John Wolfgang, United States

SESSION TIME:  17:00 – 18:45
SESSION ROOM:  718A
SESSION TRACK:  TRACK 01: IMAGING
SESSION NAME:  SP149 – ITERATIVE RECONSTRUCTION
SESSION CHAIR(S):  IDRIS ELBAKRI, CANADA  DMITRI MATENINE, CANADA

17:00  SP149.1 - Preliminary study on reduction of cartoon artifact in the iteratively reconstructed images from sparse projection views
Sunhee Wi, Republic of Korea

17:15  SP149.2 - Evaluation of the OSC-TV Reconstruction Algorithm for Optical Cone-Beam Computed Tomography
Dmitri Matenine, Canada

17:30  SP149.3 - Subjective low contrast performance of four CT scanners with iterative reconstruction
Azeez Omotayo, Canada

17:45  SP149.5 - Sparse-view image reconstruction with compressed sensing and its application in low dose CT myocardial perfusion imaging
Esmaeil Enjilela, Canada

18:00  SP149.6 - Feasibility study for 3D cone-beam computed tomography reconstruction with few projection data using MLEM algorithm with total variation minimization
Dong Hoon Lee, Republic of Korea

18:15  SP149.7 - A weighted stochastic gradient descent algorithm for image reconstruction in 3D computed tomography
Davood Karimi, Canada

18:30  SP149.8 - Investigation of sparse-angle view in cone beam computed tomography (CBCT) reconstruction algorithm using a sinogram interpolation method
Dohyeon Kim, Republic of Korea

15:15  SP148.2 - Ways to outreach medical devices in low resource countries (LRC)
K Siddique Rabbani, Bangladesh

15:30  SP148.3 - South African-Swedish effort on pre-hospital diagnostics of stroke and traumatic injuries
Mikael Persson, Sweden

15:45  SP148.4 - A portable multi-frequency impedance measuring device for biodynamic analysis
Takao Nakamura, Japan

16:00  SP148.5 - A Study of the Challenges of Donating Medical Equipment to Developing Countries
Bill Gentles, Canada

16:15  SP148.6 - The Clinicopathologic Characters and Activity Survey of Sudden Death of Infant in a Depressed Economy: South-Eastern Nigeria Experience.
Gideon Ndubuka, Nigeria

SESSION TIME:  17:00 – 18:45
SESSION ROOM:  718A
SESSION TRACK:  TRACK 01: IMAGING
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Dohyeon Kim, Republic of Korea

15:00  SP148.1 - Oncometer
Priyajit Ghosh, India
SESSION TIME: 17:00 – 18:45
SESSION ROOM: 701B
SESSION TRACK: TRACK 01: IMAGING
SESSION NAME: SP150 – X-RAY PHASE CONTRAST & SCATTER IMAGING
SESSION CHAIR(S): PAUL JOHNS, CANADA
RHIANNON MURRIE, AUSTRALIA

17:00 SP150.1 - Reducing signal extraction artefacts for x-ray scatter imaging with multiple pencil beams
Paul Johns, Canada

17:15 SP150.2 - Live animal phase contrast x-ray velocimetry of the lungs: Optimising imaging speed for synchrotron and lab source imaging
Rhiannon Murrie, Australia

17:30 SP150.3 - X-ray Phase-Contrast imaging: from mammography to breast tomodraphy using synchrotron radiation
Renata Longo, Italy

17:45 SP150.4 - 4 Years of X-ray Imaging at 05B1-1 Beamline at BMIT
Tomasz Wysokinski, Canada

18:00 SP150.5 - An energy dispersive bent Laue monochromator for K-edge subtraction imaging
Nazanin Samadi, Canada

18:15 SP150.6 - An incoherent implementation of x-ray phase contrast imaging and tomodraphy that maintains high sensitivity at low delivered doses
Alessandro Olivo, United Kingdom

18:30 SP150.7 - Indirect measurement of average alveolar size using dynamic phase-contrast imaging
Mercedes Martinson, Canada

SESSION TIME: 17:00 – 19:00
SESSION ROOM: 714B
SESSION TRACK: TRACK 03: BIOMECHANICS AND ARTIFICIAL ORGANS
SESSION NAME: SP151 - CARDIO MECHANICS & ORGANS
SESSION CHAIR(S): DAVID MACKU, CZECH REPUBLIC

17:00 SP151.1 - KEYNOTE: Biomechanics and artificial organs
Birgit Glasmacher, Germany

17:30 SP151.2 - The Continuous Flow Total Artificial Heart in Clinical Practice
David Macku, Czech Republic

17:45 SP151.3 - Power Control Range of Operation for the Left Ventricular Assist Device in Bridge-to-Recovery Treatment
Marwan Simaan, United States

18:00 SP151.4 - An quantitative estimation method of peripheral perfusion by using a CCD camera during rotary blood pump support
Yasuyuki Shiraishi, Japan

18:15 SP151.5 - Mathematical Modeling of Left Ventricle Stroke Work Following Transcatheter Aortic Valve Replacement Associated With Paravalvular Leaks
Azadeh Saeedi, Canada

18:30 SP151.6 - Criteria to study Heart Failure derived from ESPVR
Rachid Shoucri, Canada

18:45 SP151.7 - Fluid Dynamics of Transcatheter Aortic Valve Associated with Paravalvular Leak
Azadeh Saeedi, Canada

SESSION TIME: 17:00 – 18:30
SESSION ROOM: 718B
SESSION TRACK: TRACK 04: RADIATION ONCOLOGY
SESSION NAME: SP152 – SPECIAL TREATMENT TECHNIQUES: PART 2
SESSION CHAIR(S): EMILY HEATH, CANADA
CHARLES SHANG, UNITED STATES

17:00 SP152.1 - Optimal timing in concomitant chemotherapy and radiation therapy of colorectal tumors in nude mouse treated with Cisplatin and LipoplatinTM
Thititip Tippayamontri, Canada

17:15 SP152.2 - Grid therapy: impact of radiobiological models on calculation of therapeutic ratio
Hassan Ali Nedaie, Iran

17:30 SP152.3 - Will CyberKnife M6? Multileaf collimator offer advantages over IRIS? collimator in prostate SBRT?
Charles Shang, United States

17:45 SP152.4 - Retrospective analysis of treatment margins for stereotactic ablative lung cancer treatments based on 4D CBCT
Sheeba Thengumpallil, Switzerland

18:00 SP152.5 - Using surgical clips in the tracking of liver tumors applied to CyberKnife SBRT treatments
Leonie Petitclerc, Canada

18:15 SP152.6 - A Novel Couch-Gantry Trajectory Based Stereotactic Treatment Method
Byron Wilson, Canada

17:00 SP154.1 - Biomechanics and artificial organs
Birgit Glasmacher, Germany

17:30 SP154.2 - The Continuous Flow Total Artificial Heart in Clinical Practice
David Macku, Czech Republic

17:45 SP154.3 - Power Control Range of Operation for the Left Ventricular Assist Device in Bridge-to-Recovery Treatment
Marwan Simaan, United States

18:00 SP154.4 - An quantitative estimation method of peripheral perfusion by using a CCD camera during rotary blood pump support
Yasuyuki Shiraishi, Japan

18:15 SP154.5 - Mathematical Modeling of Left Ventricle Stroke Work Following Transcatheter Aortic Valve Replacement Associated With Paravalvular Leaks
Azadeh Saeedi, Canada

18:30 SP154.6 - Criteria to study Heart Failure derived from ESPVR
Rachid Shoucri, Canada

18:45 SP154.7 - Fluid Dynamics of Transcatheter Aortic Valve Associated with Paravalvular Leak
Azadeh Saeedi, Canada
SESSION TIME: 17:00 – 18:45
SESSION ROOM: 701A
SESSION TRACK: TRACK 04: RADIATION ONCOLOGY
SESSION NAME: SP153 – QUALITY ASSURANCE: PART 4
SESSION CHAIR(S): YOUNG LEE, CANADA
DAVID THWAITES, AUSTRALIA

17:00 SP153.1 - Comparison of AAA and CCC Algorithms for H&N RapidArc pre-patient treatment QA
Thuso Ramaloko, South Africa

17:15 SP153.2 - Tuning treatment planning system model parameters for accurate VMAT dose calculation using conformal arc plans
Orest Ostapiak, Canada

17:30 SP153.3 - Prostate brachytherapy with Oncentra Seeds: Intra-operative planning and delivery software validation assisted by an FMEA
Renee Larouche, Canada

17:45 SP153.4 - Investigation of predictive parameters for pre-treatment measurement pass rates in hypofractionated volumetric arc therapy (HF-VMAT) plans of single brain metastasis
Young Lee, Canada

18:00 SP153.5 - Inter-centre comparison of dose delivery accuracy for six different linac-planning system combinations for SBRT lung cancer treatment using FFF beams.
David Thwaites, Australia

18:15 SP153.6 - A pilot study investigating the impact of treatment delivery uncertainties for lung SABR using step and shoot IMRT and VMAT
David Thwaites, Australia

18:30 SP153.7 - Adaptive patient dose assessment using daily 3D cone beam CTs and Monte Carlo simulations
Nevin McVicar, Canada

17:30 SP154.1 - Ferrous - methylthymol blue - gelatin gel dosimeter with improved auto-oxidation stability
Kalim Penev, Canada

17:45 SP154.2 - The dosimetric property of TLD2000 thermoluminescent dosimeter
Nan Zhao, People’s Republic of China

18:00 SP154.5 - Aligning the ALARA principle with FFF treatment modalities
Stephen Sawchuk, Canada

18:15 SP154.6 - Reduction of residual signal in LiF:Mg, Cu, P thermoluminescent material.
Vinod Nelson, Australia

18:30 SP154.7 - Application of dose gels in HDR brachytherapy
Diana Adliene, Lithuania

18:45 SP154.8 - Practical 3D QA for Radiation Therapy Based on High-Resolution Laser CT of Reusable Radiochromic Polymer-Gel Dosimeters in Dedicated Phantoms
Stephen Avery, United States
<table>
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<th>Time</th>
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<tr>
<td>17:00</td>
<td>SP156.1</td>
<td>A Technique for Prostate Registration by Finite Element Modeling</td>
<td>Fangsen Cui, Singapore</td>
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<tr>
<td>17:15</td>
<td>SP156.2</td>
<td>Modeling study of neo-aortic root for arterial switch operation: a structural finite element analysis</td>
<td>Zhaoyong Gu, People's Republic of China</td>
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<tr>
<td>17:30</td>
<td>SP156.3</td>
<td>Preoperative in silico analysis of atherosclerotic calcification vulnerability in carotid artery stenting using Finite Element Analysis by considering Agatston score</td>
<td>Sadegh Riyahi Alam, Italy</td>
</tr>
<tr>
<td>17:45</td>
<td>SP156.4</td>
<td>Biomechanical modeling for foot inversion</td>
<td>Junchao Guo, People's Republic of China</td>
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<tr>
<td>18:00</td>
<td>SP156.5</td>
<td>Deformation Method and 3D Modeling of the female body to simulate Core Biopsy procedure</td>
<td>Lourdes Brasil, Brazil</td>
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<tr>
<td>18:15</td>
<td>SP156.6</td>
<td>Effects of Band Position on Hemodynamics of Pulmonary Artery: A Numerical Study of Patient-specific Virtual Procedure</td>
<td>Jin Long Liu, People's Republic of China</td>
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<tr>
<td>18:30</td>
<td>SP156.7</td>
<td>Experimentally validated Biomechanical Model of in vivo Lung under EBRT considering Diaphragm motion hysteresis</td>
<td>Elham Karami, Canada</td>
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<tr>
<td>17:00</td>
<td>SP157.1</td>
<td>KEYNOTE: On-chip blood Plasma separation using vacuum-assisted micropumping for point-of-care application</td>
<td>Kwang Oh, United States</td>
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<tr>
<td>17:30</td>
<td>SP157.2</td>
<td>Multi-Functional Platform for Blood Group Phenotyping using Surface Plasmon Resonance</td>
<td>Whui Lyn Then, Australia</td>
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<tr>
<td>18:00</td>
<td>SP157.3</td>
<td>Harmonic generation microscopy investigation of human pathological samples for automated cancer determination</td>
<td>Richard Cisek, Canada</td>
</tr>
<tr>
<td>18:00</td>
<td>SP157.4</td>
<td>Protein Patterning: An investigation on the use of different protein deposition techniques and parameters to transfer proteins onto various surfaces.</td>
<td>Kathryn Clancy, Canada</td>
</tr>
</tbody>
</table>
17:00 SP159.1 - KEYNOTE: Dwarfing Big Data for Oncology Applications: Necessity and Possibilities
Issam El Naqa, Canada

17:30 SP159.2 - Improved temperature monitoring and treatment planning for loco-regional hyperthermia treatments of Non-Muscle Invasive Bladder Cancer (NMIBC)
Gerben Schooneveldt, Netherlands

17:45 SP159.3 - A Full 3D CFD Model Coupled with an Outflow Lumped Boundary and Inflow Total Pressure Formulation to Estimate Human Cardiac Perfusion
Iyad Fayssal, Lebanon

18:00 SP159.4 - Simulation Model of Image-Guided Percutaneous Thermal Ablation in the Assessment of Optimal Approach for Complete Tumour Ablation
Chai Hong Yeong, Malaysia

17:00 SP160.1 - From 'Fracking' and 'Macrovoids' to the Onset of Cancer Metastasis: A Mechano-Metabolomics Model of a Plausible Fluid-Solid Network Instability in Tumors
Sai Prakash, United States

17:15 SP160.2 - Surface electromyography in quantifying Parkinson's disease and its treatment with deep brain stimulation
Pasi Karjalainen, Finlandia

17:30 SP160.3 - A Decade of Experience with Intraoperative Microelectrode Recording in Determining the Subthalamic Nuclie (STN) Deep Brain Stimulation? Lead Positions in 260 Parkinson Diseased Conditions in South India? A Retrospective Study
Venkateshwarla Raju, India

17:45 SP160.4 - Vortex of the Magnetic Field on the Growth Rate of Escherichia Coli
Teodoro Cordova - Fraga, Mexico

18:00 SP160.5 - Electro Magnetic Therapy and Laser in the Chronic Pain Of The Woman
Manuel Zuniga, Ecuador
Friday, June 12 2015

SESSION TIME: 08:00 – 09:45
SESSION ROOM: 718A
SESSION TRACK: TRACK 01: IMAGING
SESSION NAME: SP161 – ANGIOGRAPHY / X-RAY IMAGING
SESSION CHAIR(S): JOSÉ CARLOS DE LA VEGA, CANADA
JEFF FRIMETH, CANADA

08:00 SP161.1 - 5D DSA Using Dual Energy Acquisition
Gabe Shaughnessy, United States

08:15 SP161.2 - Investigation of Rhenium-Doped Microsphere-Based Contrast Agents for Diagnostic X-Ray Imaging
José Carlos De La Vega, Canada

08:45 SP161.3 - Theoretical and experimental comparison of image signal and noise for dual-energy subtraction angiography and conventional x-ray angiography
Christiane Burton, Canada

09:00 SP161.4 - Some Physical and Clinical Factors Influencing the Measurement of Precision Error, Least Significant Change, and Bone Mineral Density in Dual-Energy X-Ray Absorptiometry
Jeff Frimeth, Canada

09:15 SP161.5 - Use of Conventional Regional DXA Scans for Estimating Whole Body Composition
Mohammad Reza Salamat, Iran

09:30 SP161.6 - Multiple Energy Synchrotron Biomedical Imaging System? Preliminary Results
Bassey Bassey, Canada

SESSION TIME: 08:00 – 10:00
SESSION ROOM: 716A
SESSION TRACK: TRACK 05: DOSIMETRY AND RADIATION PROTECTION
SESSION NAME: SP163 – PRIMARY DOSIMETRY STANDARDS
SESSION CHAIR(S): NATALKA SUCHOWERSKA, AUSTRALIA
RONALD TOSH, UNITED STATES

08:00 SP163.1 - KEYNOTE: Candidate Technologies for Next-Generation Dosimetry Standards
Ronald Tosh, United States

08:30 SP163.2 - Absorbed dose to water measurements in a clinical carbon ion beam using water calorimetry
Julia-Maria Osinga, Germany

08:45 SP163.3 - Results from the on-going key comparison BIPM.RI(I)-K6 : What have we learned?
Susanne Picard, France

09:00 SP163.4 - Absorbed dose-to-water primary standard and traceability system for radiotherapy in China
Kun Wang, People’s Republic of China

08:00 SP161.2 - To tap or not to tap: A comparison of cranial 3D to 2D ultrasound in extremely preterm neonates with post-hemorrhagic ventricle dilation to predict the necessity of interventional ventricular tap
Jessica Kishimoto, Canada

08:30 SP161.3 - Endoleak and Thrombus Characterization with Dynamic Elastography after Endoleak Embolization following Aneurysm Endovascular Repair
Antony Bertrand-Grenier, Canada

08:45 SP161.4 - Detecting lipid-rich artery plaque using a handheld photoacoustic imaging device
Susumu Hirano, Japan

09:00 SP161.5 - Intersex differences in posterior eye chamber by spectral optical coherent tomography
Zofia Drzazga, Poland

09:15 SP161.6 - Longitudinal Analysis of 3D Pre-Term Neonatal Ventricle Ultrasound Images
Wu Qiu, Canada

09:30 SP161.7 - Breast Invasive Ductal Carcinoma Assessed by Conventional Ultrasound and Contrast-Enhanced Ultrasound in Different T-Stages
Yanchun Zhu, People’s Republic of China

09:45 SP161.8 - Comparison of ultrasound systems in scoliosis measurement
Maggie Hess, Canada

08:00 SP162.1 - Endoluminal Ultrasound Biomicroscopy for in vivo detection of caustic esophagitis in rats
João Machado, Brazil
09:30  SP163.5 - Design of an MRI-compatible water calorimeter for use in an integrated MRI-Linac and Gamma-Knife
        Niloufar Entezari, Canada

09:45  SP163.6 - On the practical use of calorimetry for routine absolute dosimetry in the radiotherapy clinic
        James Renaud, Canada

SESSION TIME: 08:00 – 09:45
SESSION ROOM: 718B
SESSION TRACK: TRACK 06: NEW TECHNOLOGIES IN CANCER RESEARCH AND TREATMENT
SESSION NAME: SP164 – ADAPTIVE RADIATION THERAPY (ART)
SESSION CHAIR(S): EVA BEZAK, AUSTRALIA
                   DANIEL TAMAGI, CANADA

08:00  SP164.1 - Real-time dose reconstruction for adaptive radiation therapy
        Martin Fast, United Kingdom

08:15  SP164.2 - Evaluation of unified intensity-modulated arc therapy (UIMAT) for the treatment of head-and-neck cancer
        Michael Macfarlane, Canada

08:30  SP164.3 - A Hybrid IMRT/VMAT Technique for the Treatment of Nasopharyngeal Cancer
        Nan Zhao, People’s Republic of China

08:45  SP164.4 - Interactive real time adaptation of IMRT treatment plans
        Cornelis Philippus Kamerling, United Kingdom

09:00  SP164.5 - A Hybrid IMRT/VMAT technique for the treatment of non-small cell lung cancer
        Nan Zhao, People’s Republic of China

09:15  SP164.6 - Offline adaptive VMAT - feasibility study using planning CT deformed electron density mapping on daily CBCT to estimate parotid dose volume relationship
        Vellian Subramani, India

09:30  SP164.7 - Plan Optimization for a Lung Patient on a Parallel Linac-MR System
        Daniel Tamagi, Canada

SESSION TIME: 08:00 – 10:00
SESSION ROOM: 714B
SESSION TRACK: TRACK 11: NEUROENGINEERING, NEURAL SYSTEMS
SESSION NAME: SP166 – NEUROPROSTHESES
SESSION CHAIR(S): PAUL YOO, CANADA

08:00  SP166.1 - Enhanced Transcutaneous Electrical Nerve Stimulation (eTENS): A Novel Method of Achieving Posterior Tibial Nerve Stimulation Therapy for Overactive Bladder
        Paul Yoo, Canada

08:15  SP166.2 - Decreasing Upper Extremity Demands During Sitting Pivot Transfers for Individuals with Spinal Cord Injury by Utilizing Functional Electrical Stimulation
        Stephanie Bailey, United States

08:30  SP166.3 - Design of Orthotic Mechanisms to Control Stand-to-Sit Maneuver for Individuals with Paraplegia
        Ronald Triolo, United States

08:45  SP166.4 - Improved Peripheral Nerve Recording with a Small Form-Factor Nerve Cuff Electrode: A Computational Study
        Parisa Sabetian, Canada

09:00  SP166.5 - Effect of stimulation on non-erect postures with a standing neuroprosthesis
        Brooke Odle, United States

09:15  SP166.6 - Automatic Detection of Destabilizing Wheelchair Conditions for Modulating Actions of Neuroprostheses to Maintain Seated Posture
        Ronald Triolo, United States

09:30  SP166.7 - Selecting Upper Extremity Command Signals to Modulate Electrical Stimulation of Trunk Muscles during Manual Wheelchair Propulsion
        Stephanie Bailey, United States

SESSION TIME: 08:00 – 09:15
SESSION ROOM: 718B
SESSION TRACK: TRACK 09: BIOSIGNAL PROCESSING
SESSION NAME: SP165 – EEG
SESSION CHAIR(S): JENS HAUIEWSN, GERMANY
                   TEODIANO BASTOS-FILHO, BRAZIL

08:00  SP165.1 - A Fully Unsupervised Clustering on Adaptively Segmented Long-term EEG Data
        Vaclav Gerla, Czech Republic

08:15  SP165.2 - A Real-Time Clustered MUSIC algorithm for the localization of synchronous MEG/EEG source activity
        Daniel Baumgarten, Germany

08:30  SP165.3 - Spatial harmonics for compressive sensing in electroencephalography
        Jens Hauiesen, Germany

08:45  SP165.4 - An Evaluation of Performance for an Independent SSVEP-BCI Based on Compression Sensing System
        Teodiano Bastos-Filho, Brazil

09:00  SP165.5 - Multi-way based Source Localization of Multichannel EEG signals Exploiting Hilbert-Huang Transform
        Saeed Pouryazdian, Canada
SESSION TIME: 08:00 – 09:45
SESSION ROOM: 717B
SESSION TRACK: TRACK 13: INFORMATICS IN HEALTH CARE AND PUBLIC HEALTH
SESSION NAME: SP169 – SELF ENGAGEMENT, PATIENT EMPOWERMENT AND MHEALTH
SESSION CHAIR(S): GIUSEPPE FICO, SPAIN ELENI KALDOUDI, GREECE

08:00  SP169.1 - KEYNOTE: Empowering patients through information technologies
       Eleni Kaldoudi, Greece

08:30  SP169.2 - Distributed learning: developing a predictive model for dyspnea in lung cancer patients based on data from multiple hospitals
       Johan Van Soest, Netherlands

08:45  SP169.3 - User Centered Design to incorporate predictive models for Type 2 Diabetes screening and management into professional decision support tools: preliminary results.
       Giuseppe Fico, Spain

09:00  SP169.4 - Quantifying Bipolar Disorder for Technology-Assisted Self-Management
       James Amor, United Kingdom

09:15  SP169.5 - Hippocratic Protocol Design to Improve Security and Privacy in Healthcare Applications for NFC Smartphone
       Jose Pirrone Puma, Venezuela

09:30  SP169.6 - Extracting Intention from Web Queries? Application in eHealth Personalization
       George Drosatos, Greece
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<tr>
<td>08:00 – 09:30</td>
<td>715A</td>
<td>TRACK 14: INFORMATION TECHNOLOGIES IN HEALTHCARE DELIVERY AND MANAGEMENT</td>
<td>SP170 – INFORMATION TECHNOLOGIES IN HEALTHCARE DELIVERY AND MANAGEMENT: PART 3</td>
<td>BRUCE CURRAN, UNITED STATES JOSEPH CAFAZZO, CANADA</td>
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08:00  SP170.1 - Wireless equipment localization for medical environments  
   Daniel Laqua, Germany

08:15  SP170.2 - Exploring Approaches to Optimise the Estimation of Preterm Birth Using Machine Learning Techniques  
   Monique Frize, Canada

08:30  SP170.3 - Smartwatch App as the Chest Compression Depth Feedback Device  
   Yujin Jeong, Republic of Korea

08:45  SP170.4 - Diagnosis of the corporal movement in Parkinson’s Disease using Kinect Sensors  
   Jose Pirrone Puma, Venezuela

09:00  SP170.5 - A System to Support Regional Screening Programs to Identify School-age Children at Risk of Neurodevelopmental Disorders  
   Elsa Santos Febles, Cuba

09:15  SP170.6 - Support platform to decision making in research and technological development in public health: a brazilian scenario approach  
   Carlos Rocha, Brazil

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<td>10:30 – 12:00</td>
<td>718A</td>
<td>TRACK 01: IMAGING</td>
<td>SP172 – MAMMOGRAPHY AND TOMOSYNTHESIS</td>
<td>ALESSANDRA TOMAL, BRAZIL KWAN HOONG NG, MALAYSIA</td>
</tr>
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10:30  SP172.1 - KEYNOTE: Evaluation of automatic exposure control in digital mammography  
   Alessandra Tomal, Brazil

11:00  SP172.2 - Comparing the use of force-standardized and pressure-standardized mammographic compression protocols in an Asian context  
   Kwan Hoong Ng, Malaysia

11:15  SP172.3 - Radiation dose of step-and-shoot digital breast tomosynthesis using an anti-scatter grid compared to full field digital mammography in a clinical population  
   Cecile Jeukens, Netherlands

11:45  SP172.4 - Absorbed dose in PMMA and Equivalent Breast Phantom in a Digital Breast Tomosynthesis system: Monte Carlo Assessment  
   Luis Magalhaes, Brazil

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<td>10:30 – 11:45</td>
<td>701B</td>
<td>TRACK 01: IMAGING</td>
<td>SP173 – ULTRASOUND AND OCT: METHODS</td>
<td>BORNA MARAGHECHI, CANADA WILLIAM HRINIVICH, CANADA</td>
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</table>

10:30  SP173.1 - A comparision study on shear wave velocity estimation of thin layered media using shear wave imaging  
   Jun Keun Jang, Japan

08:45  SP171.4 - Myocardial perfusion imaging by low-dose CT  
   Sabee Molloi, United States

09:00  SP171.5 - Renal Dynamic Phantom for Use in SPECT  
   Divanizia Souza, Brazil

09:15  SP171.6 - Physics Plan Checking Practices  
   Gordon Chan, Canada

09:30  SP171.7 - Commissioning of a Flattening Filter Free  
   Satya Ranjan Saha, Bangladesh

09:45  SP171.8 - Effects of 24 hour Wakefulness on Tilt Based Targeting Tasks  
   Jeffrey Bolkhovsky, United States
### SESSION TIME: 10:30 – 11:45
### SESSION ROOM: 701A
### SESSION TRACK: TRACK 04: RADIATION ONCOLOGY
### SESSION NAME: SP174 – MOTION MANAGEMENT: PART 2
### SESSION CHAIR(S): JOANNA CYGLER, CANADA

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<td>10:30</td>
<td>SP174.1 - Assessment of lung dose in patients undergoing deep inspiration breath hold for left sided breast cancer</td>
<td>Peta Lonski, Australia</td>
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<tr>
<td>10:45</td>
<td>SP174.2 - Evaluation of 4D dose accumulation in CyberKnife and IMRT treatments</td>
<td>Vincent Cousineau Daoust, Canada</td>
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<tr>
<td>11:00</td>
<td>SP174.3 - Application of RADPOS System for Dose and Position Quality Assurance of 4D CyberKnife Treatments</td>
<td>Raanan Marants, Canada</td>
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<td>11:15</td>
<td>SP174.4 - Derivation of the probabilistic treatment margin for two targets with correlated motion</td>
<td>Marcel Van Herk, Netherlands</td>
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<td>11:30</td>
<td>SP174.5 - How Truthful Is the 4D Dose Calculation?</td>
<td>Gang Liu, People’s Republic of China</td>
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### SESSION TIME: 10:30 – 11:45
### SESSION ROOM: 718B
### SESSION TRACK: TRACK 04: RADIATION ONCOLOGY
### SESSION NAME: SP175 – TREATMENT PLANNING – BIOLOGY & FRACTIONATION
### SESSION CHAIR(S): JAN UNKELBACH, UNITED STATES

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<tr>
<td>10:30</td>
<td>SP175.1 - Adaptive radiotherapy for bladder cancer using deformable image registration of empty and full bladder</td>
<td>Prabhjot Juneja, Australia</td>
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<td>10:45</td>
<td>SP175.2 - Dosimetric and clinical benefits of conformal radiotherapy combined plus volumetric modulated arc therapy in the treatment of non-small cell lung cancer</td>
<td>Xiance Jin, People’s Republic of China</td>
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<td>11:00</td>
<td>SP175.3 - Non-uniform spatiotemporal fractionation schemes in photon radiotherapy</td>
<td>Jan Unkelbach, United States</td>
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<td>11:15</td>
<td>SP175.4 - Compressed Sensing-Based LDR Brachytherapy Inverse Treatment Planning with Biological Models</td>
<td>Christian Guthier, Germany</td>
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<tr>
<td>11:30</td>
<td>SP175.5 - Investigation of Dosimetric and Biological Differences between Flattened and Unflattened Beams from the TrueBeam System</td>
<td>Bhudatt Paliwal, United States</td>
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10:30 SP177.1 - Simple expression of x-ray doses below 1 MeV grazing incident on shields of concrete and iron backed by lead
Nobuteru Nariyama, Japan

10:45 SP177.2 - Evaluation of conversion coefficients from Air Kerma to Ambient Dose Equivalent for secondary barriers in diagnostic radiological facilities
Paulo Costa, Brazil

11:00 SP177.3 - Shielding photon beams to account for adjacent, underground building of a radiation therapy facility
Dario Sanz, Argentina

11:15 SP177.4 - Vectorization of the time-dependent Boltzmann transport equation for photon beams: applications in radiation shielding
Dario Sanz, Argentina

11:30 SP177.5 - The use of FLUKA Monte Code in the re-design of radiotherapy mazes with the use of lead cladding of a few mm thickness
Ihsan Al-Affan, United Kingdom

SESSION TIME: 10:30 – 12:15
SESSION ROOM: 714B
SESSION TRACK: TRACK 11: NEUROENGINEERING, NEURAL SYSTEMS
SESSION NAME: SP178 – NEUROIMAGING, NEURONAVIGATION AND NEUROLOGICAL DISORDERS
SESSION CHAIR(S): TAUFIK VALINATE, CANADA

10:30 SP178.1 - Characterization of Single Units in Human Neocortical Slices Maintained In Vitro
Sara Mahallati, Canada

10:45 SP178.2 - Astrocytes enhance neuronal long term potentiation in a biophysical model of epilepsy
Vasily Grigorovsky, Canada

11:00 SP178.3 - Influence of the ‘sympathetic slump’ on biomechanics of the sympathetic trunk
Liesbeth Van Hauwermeiren, Belgium

11:15 SP178.4 - Superparamagnetic Nanoparticles for Epilepsy Detection
Ebrahim Ghafar-Zadeh, Canada

11:30 SP178.5 - Automatic detection of epileptic seizures in scalp EEG
Yasser Pérez, Cuba

11:45 SP178.6 - Beta/Theta Neurofeedback Training Effects in Physical Balance of Healthy People
Wenya Nan, People's Republic of China

12:00 SP178.7 - Potential Benefits in Comparing the Neural Control Networks Studies Between the Oculomotor and Cardiac Pacing Systems
Michael Cheng, Canada

10:30 SP179.1 - Acceptance Test of the first Hospital Cyclotron for Production of PET tracers in Iran
Pardis Ghafarian, Iran

10:45 SP179.2 - HiFEM - An Integrated Approach for Human Centered Risk Management for Medical Devices
Klaus Radermacher, Germany

11:00 SP179.3 - Ultrasonic Microscanning for Digital Dental Impressioning
Klaus Radermacher, Germany

11:15 SP179.4 - A study on prefrontal blood flow in patients with moderate dementia and severe dementia using near-infrared
Shingo Takahashi, Japan

SESSION TIME: 10:30 – 11:30
SESSION ROOM: 715B
SESSION TRACK: TRACK 12: MEDICAL DEVICES
SESSION NAME: SP179 – MEDICAL DEVICES: MISCELLANEOUS
SESSION CHAIR(S): KLAUS RADERMACHER, GERMANY

10:30 SP180.1 - Increasing efficiency of data transfer in WBANs
Luka Celic, Croatia

10:45 SP180.2 - Decision support system for no common emergency in a big city with intelligent routing algorithm and attention quality parameters evaluation.
Lupe Toscano, Peru

11:00 SP180.3 - Development of a Multi-Center Clinical Trial Data Archiving and Analysis Platform
Brandon Driscoll, Canada

11:15 SP180.4 - Global Health Catalyst: A systematic Space-time compression platform for catalyzing global health collaborations in Radiation Oncology
Wilfred Ngwa, United States
The IUPESM 2015 Posters will be displayed in the Exhibit Hall during open hours.

Presenting Author Stand By Time: Presenters are requested to stand by their posters during the networking breaks scheduled 10:00 - 10:30 and 16:30 - 17:00 Monday, June 8 to Thursday, June 11.

**PS01 – TRACK 01: IMAGING**

**PS01.001** – A discontinuity artefact at the isocenter of on-board CBCT images
Elsayed Ali, Canada

**PS01.002** – Correction of Metal Artefacts Induced from Pacemaker and ICD Leads in CT-Based Attenuation Correction of Cardiac SPECT data
Mohammad Reza Ay, Iran

**PS01.003** – Anthropomorphic Phantom of the Pancreas for Scintillation Camera Tests
Lourdes Brasil, Brazil

**PS01.004** – Comparing two image processing techniques, Wavelet and Segmentation by threshold, for detecting microcalcifications in an image mammographic.
Lourdes Brasil, Brazil

**PS01.005** – Measuring red blood cell velocity in capillary using video and image processing
Surapong Chatpun, Thailand

**PS01.006** – Development of a Quantitative PET QA Procedure for Multi-Center Clinical Trials
Brandon Driscoll, Canada

**PS01.007** – Unwrapping highly wrapped phase using Nonlinear Multi-Echo phase unwrapping
Chemseddine Fatnassi, Switzerland

**PS01.008** – Investigation of optimal display size for viewing MRI images using a digital contrast-detail phantom
Hideki Fujita, Japan

**PS01.009** – Investigation of presampled MTF using a slit device with slightly wider aperture
Rumi Gotanda, Japan

**PS01.010** – 3D Tumor delineation in Positron Emission Tomography reconstructed images restored by the use of Lucy Richardson blind deconvolution method
Albert Guvenis, Turkey

**PS01.011** – Different options for stimulation intensity in mapping cortical motor area in navigated transcranial magnetic stimulation
Petro Julkunen, Finland

**PS01.012** – Software Breast Phantom for Phase Contrast Imaging Applications
Nicolas Pallikarakis, Greece

**PS01.013** – Actions for Implementation Program of Image Quality of Mammography
Ana Cláudia Patrocinio, Brazil

**PS01.014** – Evaluating Techniques of Transformation Intensity for Contrast Enhancement in Mammographic Images
Ana Cláudia Patrocinio, Brazil

**PS01.015** – Influence of Contrast Enhancement to Breast Density Classification by Using Sigmoid Function
Ana Cláudia Patrocinio, Brazil

**PS01.016** – Evaluation of the difficulties of the learning process of mammographic readings
Ana Cláudia Patrocinio, Brazil

**PS01.017** – Non-deterministic optimization using Differential Evolution algorithm to launch seeds for liver segmentation in MDCT
Ana Cláudia Patrocinio, Brazil

**PS01.018** – Influence of ROI pattern on segmentation in lung lesions
Ana Cláudia Patrocinio, Brazil

**PS01.019** – Comparison between Elliptical and Squared ROI to Launch an Automatic Seed to Region Growing Algorithm on Hepatic Segmentation using CT images
Ana Cláudia Patrocinio, Brazil

**PS01.020** – Gd-based Nanoparticles Mediated Magnetic Field Enhancement Inside Homogenous Tissue: Simulation using Finite Element Method
Nader Riyahi-Alama, Iran

**PS01.021** – Novel Cylindrical Source Tank for Inserts of Emission Computed Tomography Phantoms
Inayatullah Sayed, Malaysia

**PS01.022** – Linear tomosynthesis with flat-panel detector for image guided radiation therapy
Tae-Suk Suh, Republic of Korea

**PS01.023** – Evaluation of image quality and dose for digital breast tomosynthesis (DBT) using a semi-analytical model
Alessandra Tomal, Brazil

**PS01.024** – Optimization of acquisition parameters of the test of an overall SPECT/CT system performance.
Piotr Tulik, Poland

**PS01.025** – Dosimetric Analysis of Patient to a Z-Gradient Coil in Head Magnetic Resonance Imaging
Shoogo Ueno, Japan

**PS01.026** – A Novel Optical System for Contrast Enhancement in Histological Plates to Be Processed Digitally
Rubiel Vargas-Canas, Colombia

**PS01.027** – Pixel-based dynamic contrast-enhanced CT study with low temporal resolution
Ivan Yeung, Canada
PS02 – TRACK 02: BIOMATERIALS AND REGENERATIVE MEDICINE

PS02.001 – Chitosan: A Chitinous Biopolymer For The Treatment Of Crude Oil Polluted Water
Eileen Agoha, Nigeria

PS02.002 – Temperature of ice formation affects integrity of alginate 3D constructs after cryopreservation
Birgit Glasmacher, Germany

PS02.003 – Influence of proteins on magnesium in vitro degradation
Birgit Glasmacher, Germany

PS02.004 – Electrospinning of vascular prostheses with anti-kinking properties
Birgit Glasmacher, Germany

PS02.005 – Electrospinning of polycaprolactone/chitosan polymeric fibrous membranes as scaffolds for cardiovascular tissue engineering applications
Birgit Glasmacher, Germany

PS02.006 – Coaxial electrospinning of piezoelectric PVDF/PCL scaffolds for nerve regeneration
Birgit Glasmacher, Germany

PS02.007 – Bio rapid prototyping project: Evaluation of spheroid formation for cells construct
Takeshi Shimoto, Japan

PS02.008 – Scaffold Prototype for Heart Valve Tissue Engineering: Design and Material Analyses
Marcia Simbara, Brazil

PS02.009 – Unidirectionally-frozen silk/gelatin scaffolds for cardiac tissue engineering
Siew-Lok Toh, Singapore

PS02.010 – Engineering Mesenchymal Stromal Cells (MSCs) to be More Immunoevasive by Altering Cell Culture Conditions
Sowmya Viswanathan, Canada

PS02.011 – Novel zwitterionic polypeptides for improving resistance to non-specific protein adsorption
Xiaojuan Wang, People’s Republic of China

PS02.012 – Study on preparation and mechanical properties of polyurethane foam with negative Poisson’s ratio
Lizhen Wang, People’s Republic of China

PS02.013 – Proliferation of cardiomyocytes in neonatal, further implication in heart regeneration
Lincai Ye, People’s Republic of China

PS02.014 – Synergetic effects of released ions from CaO-MgO-SiO2-based multiphase bioceramics on osteogenic proliferation and differentiation
Meng Zhang, People’s Republic of China

PS02.015 – Cooling Rate Effects on the Microstructure Evolutions of Biodegradable Mg2Ca Potential Medical Implant Alloy
Li Li Zhou, People’s Republic of China

PS02.016 – Estimation of Compressive and Shear Forces on Lumbar Spine during Lifting by Wii Balance Board
Hieyong Jeong, Japan

PS02.017 – A biomechanical evaluation of a novel pedicle screw-based interspinous device used to stabilize the lumbar spine
Yu-Shu Lai, Chinese Taipei

PS02.018 – Hematological, Biochemical, and End-organ effects of the CH-VAD in Ovine Model
Changyan Lin, People’s Republic of China

PS02.019 – Novel Low-Profile External Fixator with Simple Locking Mechanism Compared with Commercial Available External Device Could Provide Better Stability in Multicycle Dynamic Loadings
Kang-Ping Lin, Chinese Taipei

PS02.020 – A simple external fixation technique for treating bicondylar tibial plateau fracture: a finite element study
Kang-Ping Lin, Chinese Taipei

PS02.021 – Numerical analysis of the elaborate sound amplification mechanism of the mammalian inner ear
Michio Murakoshi, Japan

PS03 – TRACK 03: BIOMECHANICS AND ARTIFICIAL ORGANS

PS03.001 – Musculoskeletal and Finite Element Simulation of Archery
Yahia Al-Smadi, United States

PS03.002 – Dysfunction Screening in Experimental Arteriovenous Grafts for Hemodialysis Using Inflow and Outflow Hemodynamic Game Analysis
Wei-Ling Chen, Chinese Taipei

PS03.003 – The Effects of Limb Dominance, Sex, and Gait Speed on Multisegment Foot Kinematics During Gait
Victoria Chester, Canada

PS03.004 – Investigation of transfibular locking plate to treat open extra-articular distal tibia fractures
Helena Greene, Canada

PS03.005 – Kinematic analysis after total hip arthroplasty during weight-bearing activities
Satoru Ikebe, Japan

PS03.006 – Hematological, Biochemical, and End-organ effects of the CH-VAD in Ovine Model
Changyan Lin, People’s Republic of China

PS03.007 – Estimation of Compressive and Shear Forces on Lumbar Spine during Lifting by Wii Balance Board
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PS03.011 – Numerical analysis of the elaborate sound amplification mechanism of the mammalian inner ear
Michio Murakoshi, Japan

PS04 – TRACK 04 RADIATION ONCOLOGY

PS04.001 – Image-Guided Intra-arterial Delivery of Yttrium-90 Radioactive Microspheres for the Treatment of Liver Tumors
Muthana Al-Ghazi, United States

PS04.002 – Commissioning of an ASi EPID for patient specific IMRT QA.
David Alonso Fernández, Cuba

PS04.003 – Status of Radiotherapy Treatment in Lebanon
Antar Aly, Qatar

PS04.004 – Verification of VMAT Arc Radiation Therapy Technique for Full Scalp Treatment
Cynthia Araujo, Canada

PS04.005 – Estimating Setup Margins using IGRT Techniques. Preliminary results in Havana
Raul Argota, Cuba
PS04.006 – Uncertainty evaluation of radiation treatment with DIBH for left-sided breast cancer using MV cine imaging
Jae Beom Bae, Republic of Korea

PS04.007 – Evaluation of the Applicability of Pinpoint ion chamber for Dosimetric Quality Assurance of SRS
Jong Geun Baek, Republic of Korea

PS04.008 – Development of a VARIAN 600 C/D Linear Accelerator model using MCNPX 2.6 Monte Carlo code.
Jorge Batista Cancino, Brazil

PS04.009 – A Comparison of Dosimetric Characteristic Between Integrated and Cine Acquisition Modes of a-Si EPID
Omennh Bawazeer, Australia

PS04.010 – Predicting clinical outcomes in locally-advanced non-small cell lung cancer using machine learning focusing on tumor and node imaging features
Nathan Becker, Canada

PS04.011 – Risk estimate of second primary cancers after breast radiotherapy
Eva Bezak, Australia

PS04.012 – A beam angle optimization technique for proton pencil beam scanning treatment planning of lower pelvis targets
Janid Blanco Kiely, United States

PS04.013 – Neutron-Photon mixed field dosimetry by TLD700 glow curve analysis and its implementation in dose monitoring for Boron Neutron Capture Therapy (BNCT) treatments
Esteban Boggio, Argentina

PS04.014 – Boron Neutron Capture Therapy (BNCT) neutron beam at RA-6 reactor: Quality Assurance and Quality Control
Esteban Boggio, Argentina

PS04.015 – Improved Pareto navigation using a plan database with segmented plans
Rasmus Bokrantz, Sweden

PS04.016 – Automated measurement of dwell and tandem position in ring HDR applicators
Bruno Carozza, Canada

PS04.017 – eMU Whisperer: An application for assessing patient surface topology and its impact on monitor units in electron beam therapy
Paule Charland, Canada

PS04.018 – Beam modeling of the flattening filter-free beams for VMAT SBRT using the collapsed cone convolution superposition algorithm
Samju Cho, Republic of Korea

PS04.019 – Dependence of Collimator Angle on Prostate VMAT: A Treatment Planning Study
James Chow, Canada

PS04.020 – Dosimetry of Pacemaker in VMAT for Lung SBRT
James Chow, Canada

PS04.021 – Determination of ion chamber correction factors for small composite fields used by the CyberKnife radiosurgery system
Eric Christiansen, Canada

PS04.022 – One-year review of a real-time, ultrasound-based, single-fraction prostate HDR program ? the Halifax experience
Krista Chytyk-Praznik, Canada

PS04.023 – Retrospective evaluation of visually monitored deep inspiration breath hold for breast cancer patients using edge detection
Leigh Conroy, Canada

PS04.024 – DECT Tissue Characterisation and Artefact Suppression Method for Improved Dose Calculations in Brachytherapy Treatments.
Nicolas Cote, Canada

PS04.025 – Radiotherapy Planning using CEER and CADPLAN in a Prostate Cancer Patient
Juan Alberto Cruz, Brazil

PS04.026 – Impact of increasing irradiation time on the treatment of prostate cancers
Alexandru Dasu, Sweden

PS04.027 – Hemi-body Electron irradiation: Development and Verification of this new technique
Panagiotis Delinikolas, Greece

PS04.028 – Deformable image registration and automatic contouring using Cone-Beam CT imaging: A study of volume statistics and similarity measures
Olivier Fillion, Canada

PS04.029 – Acceptance Modulated Radiation Intensity and Enhanced Dynamic Wedge using 2D Ion Chamber Array
Oscar Garcia Contreras, Colombia

PS04.030 – Dose Calculation in Gynecological Brachytherapy using Monte Carlo simulation for intracavitary treatment of Cervical Cancer
Oscar Garcia Contreras, Colombia

PS04.031 – An inverse treatment planning module for Gamma Knife® Perfexion? using 3D Slicer
Kimia Ghobadi, Canada

PS04.032 – Bladder and rectum DVH prediction: a statistical approach for prostate treatment
Frédéric Girard, Canada

PS04.033 – Retrospective evaluation of applicator localization for HDR cervix brachytherapy ? A comparison of MR versus CT
Lisa Glass, Canada

PS04.034 – A general source model for clinical linac heads in photon mode
Wilfredo González, Spain

PS04.035 – Measurement of the beam quality TPR 20,10 of small radiotherapy fields: Comparison of experimental measurements and Monte Carlo simulations
Eduardo González-Villa, Mexico

PS04.036 – The Effect of Assessment Criteria on Inter-rater Variability in the Evaluation of Skin Reactions following Breast Cancer Radiation Therapy
Riya Goyal, United States

PS04.037 – Two-dimensional probability density function presenting the pre-treatment variability of the rectal wall integrating the variability of the motion of the rectum and the rectal wall thickness
Grigor Grigorov, Canada

PS04.038 – Unbiased Assessment of Detail Detectability in Image Guided Radiation Therapy
Victor Gurvich, United States
PS04.039 – Assessing radiation protection of members living close to patients with implanted 125I seeds in prostate
Takashi Hanada, Japan

PS04.040 – Improvement of MV planar image by elimination of Compton scattered photons and re-projection as primary photons
Masatsugu Hariu, Japan

PS04.041 – Determination of exit fluence by MCNP4 code for IMRT treatment fields and its validation with a conventional EPID system
Benjamin Hernandez Reyes, Mexico

PS04.042 – Accuracy in simulating tumor translation and rotation: Commissioning a motion platform, Hexamotion for tumor motion management QA
Chen-Yu Huang, Australia

PS04.043 – Dosimetric impact of the Acuros XB Algorithm for 25 lung SABR patients treated using the TrueBeam FFF 6MV
Derek Hyde, Canada

PS04.044 – Dynamic resource allocation: Investigating ways to distribute resources in a patient cohort based on plan quality
Elin Hynning, Sweden

PS04.045 – Physical plan evaluation of Head and Neck Cancer at Square Hospital, Bangladesh.
Md. Anwarul Islam, Bangladesh

PS04.046 – IAEA multicentre study of the methodology for advanced dosimetry audit: single IMRT field dose delivery
Joanna Izwieka, Austria

PS04.047 – Electron Density Measurements of Metallic Implants with Cobalt-60 Computed Tomography
Christopher Jechel, Canada

PS04.048 – A Systematic Analysis Of The Error Sources Within The CyberKnife M6 Daily AQA Test
Kevin Jordan, United States

PS04.049 – The Use of Boron Neutron Capture Therapy in the Treatment of Cancer Tumours in the Czech Republic
Ivana Jurickova, Czech Republic

PS04.050 – Partial Arc Breast Boost
Tania Karan, Canada

PS04.051 – Determination of the optimal phase for respiratory gated radiotherapy from statistical analysis using a visible guidance system
Sung Kyu Kim, Republic of Korea

PS04.052 – Dosimetric Verifications of the Output Factors in the Small Field less than 3 cm2 using the Gafchromic EBT2 films and the Various Detectors
Sung Kyu Kim, Republic of Korea

PS04.053 – Methodology to Evaluate Combined EBRT and HDR Brachytherapy for Cervical Cancer using Equivalent Uniform Dose (EUD) and Tumor Control Probability (TCP)
Yusung Kim, United States

PS04.054 – International Multi-Institutional Bench Mark Study on Dosimetric and Volumetric Modulation using Helical TomoTherapy Treatment Planning for Malignant Pleural Mesothelioma Tumors
Tommy Knöös, United States

PS04.055 – Factors predicting of local relapse in irradiated patients with breast cancer: A Syrian Cohort study
Moussa Krayem, Syria

PS04.056 – Automated Routine Quality Assurance of VMAT
Michael Lamey, Canada

PS04.057 – Evaluation of the clinical usefulness of modulated Arc treatment
Young Kyu Lee, Republic of Korea

PS04.058 – A comparison of linac-based IMRT with helical tomotherapy for craniospinal irradiation
Young Lee, Canada

PS04.059 – A Hardware-Accelerated Software Platform for Adaptive Radiation Therapy
Junghoon Lee, United States

PS04.060 – Predicting the Impact of Surgery on Quality of Life and Risk Management in Patients Afflicted with Glioblastoma Multiforme
Luca Li, Canada

PS04.061 – A memetic algorithm for body gamma knife stereotactic radiotherapy treatment planning
Bin Liang, People’s Republic of China

PS04.062 – Gamma evaluation of dose distributions from newly developed dosimetry system for helical tomotherapy
Sangwook Lim, Republic of Korea

PS04.063 – Suitability of a Light Transparent and Electrically Conductive Glass Plate for Construction of a Beam Monitor for Radiation Therapy
Xun Lin, Canada

PS04.064 – Objective assessment of skin erythema caused by radiotherapy
Hiroaki Matsubara, Japan

PS04.065 – Nasopharyngeal carcinoma tumor response to induction chemotherapy followed by concurrent chemoradiotherapy: A volumetric magnetic resonance imaging study
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PLENARY SESSIONS  PAGE  775
This paper describes an experimental search for the best wavelets, to reduce Poisson noise in CT.

Five slices containing the posterior fossa from an anthropomorphic phantom and from patients were selected. As their original projections contain noise from the acquisition process, some simulated noise-free lesions were added on the images. After that, the whole images were artificially contaminated with Poisson noise over the sinogram-space. The configurations using wavelets drawn from four wavelet families, using various decomposition levels, and different thresholds, were tested in order to determine de-noising performance. The 10 preselected best filters were Sym4, Bior3.5, Bior3.7, Coif3, Coif5, db3, db45, db8, Sym 20.

The quality of the resulting images was evaluated using Contrast to Noise Ratio (CNR), Human Visual System absolute norm (H1), Mean Structural Similarity Index (MSSIM) and the jackknife free-response methodology. The results were compared with other traditional filters.

The de-noising with wavelet filters improved the image quality of posterior fossa region in terms of an increased CNR (see Fig. 1), without noticeable structural distortions (see Fig. 2).

The wavelet filter Coif 3 (MSSIM = 0.8152) had the best performance. It was also better than Median (MSSIM = 0.7914) or Wiener filters (MSSIM = 0.7796) and similar to Butterworth (MSSIM = 0.8228) to remove similar amount of noise with lower spatial resolution lost.

In Conclusion: Wavelet filtering is an alternative to be considered for Poisson noise reduction in image processing of posterior fossa head CT images.
Euclidean distance was used in the K-NN model. In the leaf node of each decision tree, testing samples are predicted with a K-NN model using the relative spatial location and the structural prior of the liver.

Results

The performance of our method for liver localization was tested on 19 contrast enhanced CT datasets from Visceral challenge (http://www.visceral.eu). We adopted the leave-one-out cross validation using Dice coefficient and Hausdorff distance metric. Compared with AdaBoost and traditional random forest method, our methods had a Dice coefficient of 0.878±0.043 and a Hausdorff distance of 22.13±10.12mm, while AdaBoost with a Dice coefficient of 0.795±0.075 and a Hausdorff distance of 30.94±9.41mm; and traditional random forest with a Dice coefficient of 0.829±0.134 and a Hausdorff distance of 30.42±13.42mm. Paired t-test was used to compare among the three methods, and the difference was statistically significant (p<0.001) except the Dice coefficient of our method and the traditional random forest.

Conclusion

We have proposed a fully automated approach for robust liver localization. As in medical images, anatomy structures are spatially dependent, we applied a spatial KNN model to predict the testing sample from k nearest samples from the same leaf node. Compared with AdaBoost and traditional classification random forest, our method has higher performance.

SP001.3 - Brain Tumor Target Volume Segmentation: Local Region Based Approach

Author(s): Mehdī Astarakī1, Hossein Aslian2
1Biomedical Engineering, IAU Science and Research branch, Tehran/IRAN, 2Medical Physics, International Centre for Theoretical Physics (ICTP) and university of Trieste, Trieste/ITALY

In this paper, we comprehensively evaluated clinical application of local robust-region based algorithms to delineate the brain target volumes in radiation therapy treatment planning. Localized region based algorithms can optimize processing time of manual target tumor delineation and have perfect correlation with manual delineation defined by oncologist due to high deformability. Accordingly, they can receive much attention in radiation therapy treatment planning. Firstly, clinical target volumes (CTVs) of 135 slices in 18 patients were manually defined by two oncologists and the average of these contours considered as references in order to compare with semi-automatic results from different four algorithms. Then, four localized region based algorithms named Localizing Region Based Active Contour (LRBAC), Local Chan-Vese Model (LCV), Local Region Chan-Vese Model (LRCV) and Local Gaussian Distribution Fitting (LGDF) were applied to outline CTVs. Finally, comparisons between semi-automatic results and baselines were done according to three different metric criteria: Dice coefficient, Hausdorff distance, and mean absolute distance. Manual delineation processing times of target tumors were also performed. Our result showed that LCV has advantage over other algorithms in terms of the processing time and afterward LRCV is the second fastest method. LRBAC was the second slowest technique; however, we found that processing speed in LRBAC can be almost doubled by replacing the time-consuming re-initialization process with energy penalizing term. Accordingly, due to high accuracy performance of LRBAC algorithm, it can be concluded that the modified version of LRBAC has the best performance in brain target volumes in radiation therapy treatment planning among other localized algorithms in terms of speed and accuracy.
Costa loss of background information of the image. The proposed method, thresholds, producing flat cutoffs. So, just a small part of the total signal “clipping”, with its amplitude saturated to lower and upper classical model used in almost all ultrasound systems, there is a

### Results, Discussion and Conclusions:

Conclusions: The experimental results show that the proposed method performs better than others in the effectiveness of white imaging adjusted to the human visual system. All image and data processing were cation (proposed by Liu and Huang), which determines the distance between tones that make them distinct. The proposed method was tested with phantom images obtained with a commercial B-mode scanner that allows the capture of raw data for image and signal post processing. The results were compared to those of traditional compression methods. We have quantified image information loss for each log compression method using the error relative to the

<table>
<thead>
<tr>
<th>Method</th>
<th>Original</th>
<th>GW</th>
<th>RAWB</th>
<th>VCAWB</th>
<th>PRM</th>
<th>Proposed method</th>
</tr>
</thead>
<tbody>
<tr>
<td>ED-left</td>
<td>31.403</td>
<td>24.757</td>
<td>28.049</td>
<td>27.005</td>
<td>27.352</td>
<td>12.080</td>
</tr>
<tr>
<td>BD</td>
<td>0.203</td>
<td>0.202</td>
<td>0.205</td>
<td>0.180</td>
<td>0.194</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Table 1 The values of ED and BD for the 3D image of stereoscopic endoscopy

However, preserves signal integrity. The proposed log compression is more suitable to human vision, by considering contrast perception and tone differentiation and, since it preserves the echo information, it is better to represent the structures contained in the ultrasonic signal. The proposed method has lead to relative error of less than 0.01% (best case) or 4.5% for the worst case. The proposed method shows potential to reduce compression parameter adjustments for imaging of the anatomical structures of interest.

### SP001.6 - Comparison of Independent Component Analysis (ICA) Algorithm for Heart Rate Measurement Based on Facial Imaging

**Author(s):** Lina Septiana1, Freddy Haryanto2, Kang-Ping Lin3  
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This paper deals with the heart rate measurement by performing automatic face tracking and blind source separation of three color channel into independent components. A class of the so-called Independent Component Analysis (ICA) represents a powerful tool for such a detection. Various ICA algorithms have been introduces in the literature; therefore there is a need to compare these methods. In this contribution, two of the most common ICA methods are studied and compared to each other as regarding their ability to recover the independent source signal from normalized RGB of the facial image. These are the Joint Approximate Diagonalization of Eigen matrices (JADE), and the Second Order Blind Identification (SOBI). These two algorithms have been applied to the same data set of RGB traces then compare with commercially calibrated BPV sensor. Both two methods have given approximately consistent results. However SOBI method has shown better accuracy of heart rate measurement over JADE.

**Methodology:** This new log compression method is not only unique for presenting the whole ultrasonic signal compressed to a certain range and not just part of its dynamic range, but for considering more features, such as contrast and its relation to dynamic range and to brightness perceived by the eyes, or visually distinguishing neighboring tones. Our proposed model for logarithmic compression is divided into three stages: compression, mapping and tonal adjustment. The compression presents, on a logarithmic scale, the signal amplitude compressed to the chosen range; the mapping step relates the intensity of the post-compression with a grayscale level using a sigmoid curve that tends to change the contrast in the central intensity levels giving priority to texture perception and improving contrast. The last step takes into account the tonal differentiation (proposed by Liu and Huang), which determines the distance between tones that make them distinct. The proposed method was tested with phantom images obtained with a commercial B-mode scanner that allows the capture of raw data for image and signal post processing. The results were compared to those of traditional compression methods. We have quantified image information loss for each log compression method using the error relative to the original signal information. All image and data processing were carried out using Matlab.

**Results, Discussion and Conclusions:** We noted that for the classical model used in almost all ultrasound systems, there is a signal “clipping”, with its amplitude saturated to lower and upper thresholds, producing flat cutoffs. So, just a small part of the total dynamic range is used in the traditional method, leading to possible loss of background information of the image. The proposed method, whereas, performs better than others in the effectiveness of white imaging adjusted to the human visual system.

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SP002 - Stem Cells in Tissue Engineering and Regeneration

SP002.1 - Biomaterials and Regenerative Medicine: Micro-environmental Modulation for Controlled Cell Differentiation and Tissue Development
Author(s): Gilda Barabino1, Stephen Goldman2, Yueh-Hsun Yang3
1 The Grove School Of Engineering, Dean, The City College of New York, New York/NY/UNITED STATES OF AMERICA, 2 Army Institute of Surgical Research, San Antonio/TX/UNITED STATES OF AMERICA, 3 The City College of New York, New York/NY/UNITED STATES OF AMERICA

The engineering and regeneration of tissues and organs holds great promise for the treatment and prevention of disease and is enabled by natural and synthetic biomaterials that serve as anchors for bioactive molecules and cells. Successful creation of engineered tissues requires a thorough understanding of microenvironments that regulate cellular behavior and tissue formation. Microenvironments define the immediate surroundings of a cell and encompass essential mediators such as soluble factors and extracellular matrix molecules bound to the cell and to adjacent cells. Tissue engineering approaches that aim to manipulate culture parameters and emulate natural microenvironments are sought by combining cells, bioactive agents and biocompatible or biodegradable materials in scalable bioreactors. Among these components, scaffolds or hydrogels made of synthetic or naturally derived polymers are fabricated to meet the requirements for cell survival, matrix biosynthesis, mechanical integrity and integration capacity with host tissues and thus provide appropriate three dimensional substrates for cell growth and tissue development. Bioreactor systems do their part by delivering biophysical and mechanical cues to cultured cells in a tunable, well-defined environment, which greatly improve mass transfer efficiency and tissue quality. Lately, adult stem cells derived from different origins such as bone marrow and adipose tissues have become attractive for repair and regeneration of damaged tissues or organs due to their multi-potency and expandable lifespan, yet achieving controlled stem cell differentiation into a desired cell lineage remains challenging. As an important step toward the fabrication of clinically relevant functional tissue replacements, our laboratory has focused on developing combinatorial methods that endeavor to understand the synergy between cells and micro-environmental factors in order to optimize culture conditions for stem cell differentiation and tissue regeneration. This talk will summarize recent examples of tissue engineering strategies for development of cartilage tissue constructs using stem cells, hydrodynamic bioreactors and microfluidic hydrogels.

SP002.2 - Defining the regulatory metrics for regenerative medicine using novel biomaterial tagging strategies
Author(s): Alicia J. El Hai1, Katie Bardsley, Ying Yang2
1 Institute Of Science And Technology In Medicine, Keele University, Stoke-on-trent/UNITED KINGDOM

Biomaterials can provide a useful platform for controlling the regeneration of tissues with or without the use of different types of stem cells. In order to meet the regulatory needs for clinical use, the standards must be established which enable the complex products to be manufactured in a reproducible way. A non-destructive protocol which can define a biomaterial’s degradation and its associated ability to support proliferation and or promote extracellular matrix deposition or differentiation could be an essential tool for process manufacturing in regenerative medicine. To achieve this aim, we have designed fluorescent tagged degradable materials which can be monitored on line non-invasively in vitro for assessment of tissue engineered products and also in vivo for measuring tissue regeneration in vivo. Three fluorescently tagged biomaterials, chitosan, fibrin and poly(ethylene glycol) diacrylate-fibrinogen conjugates, were fabricated and the effect of their degradation on cell proliferation and osteogenic protein production was investigated. Alterations observed in fluorescence retention within the biomaterials and the release of fluorescent soluble by-products accurately quantified degradation and was cross-validated by weight loss measurements. Assessment of biomaterial behaviour with and without cells has been measured in vitro in bioreactors, ex vivo and in vivo in rat models. Degradation was shown to have a significant effect on cellular activities, with faster degradation eliciting a decreased cell proliferation and concurrently an increased osteopontin production. A turnover index (TI), which directly describes the effect of biomaterial degradation on cell behaviour, has been defined, with high TIs for matrix production observed on fast degrading biomaterials. This novel TI has the potential to become an essential tool for tissue engineers as it has the ability to highlight biomaterials which are suitable for various applications, such as cell proliferation or differentiation. This ability to predict cellular reactions and pre-select certain biomaterials before clinical studies would be invaluable tool not only for tissue engineering but for regenerative medicine as a whole and may lead to the development of clinically successful therapies.

SP002.3 - The role of electric fields in promoting precursor cell migration to enhance wound repair
Author(s): Stephanie Iwasa1, Robart Babona-Pilipos2, Milos R. Popovic1, Cindi M. Morshede3
1 Institute Of Biomaterials And Biomedical Engineering, University of Toronto, Toronto/ON/CANADA, 2 Toronto Rehabilitation Institute, University Health Network, Toronto/ON/CANADA, 3 Department Of Surgery, University of Toronto, Toronto/ON/CANADA

Studies have shown that endogenous electric fields (EFs) are important for directed cell migration and further, externally applied EFs have demonstrated success in promoting wound closure. However, the cellular mechanisms of this therapy remain unclear and limit its potential use. We have previously demonstrated that neural stem and progenitor cells (together termed neural precursor cells, NPCs), undergo rapid and directed cathodal migration in the presence of an EF in vitro. Notably, differentiated NPCs do not undergo rapid and directed migration in the presence of an EF. To build on this finding, fluorescent NPCs are plated on ex vivo spinal cord or brain slices to examine NPC migration in a more biologically relevant environment. Initial results show NPCs migrate in the presence of an EF on spinal cord slices, albeit at a slower speed. We hypothesized that the induced cell migration in the presence of EFs is a generalized feature of precursor cells regardless of their tissue of origin. We tested our hypothesis using skin-derived precursor cells (SKPs), found in the dermal papillae of the skin. SKPs are multipotent and give rise to mesodermal and neural progeny. We examined SKPs colonies isolated in vitro and performed the same migration assay as per the NPCs. Interestingly, unlike in NPC migration where >98% of the cells migrated in the EF, the vast majority of SKP cells did not migrate. Of the few cells that displayed directed migration, ~1% migrated to the cathode while another small subpopulation migrated rapidly towards the anode. We have demonstrated through PCR and live-imaging that NPCs express voltage gated calcium channels (VGCCs) that are critical for migration. Indeed, blocking VGCCs leads to a significant reduction in the speed of migration. We predicted the lack of SKP migration might also be the result of the lack of VGCC expression. However, we found that SKPs expressed similar VGCCs to NPCs, suggesting that this was not the reason for the lack of migration. We next proposed that SKPs were differentiating into mature phenotypes in our culture conditions and hence lost their migratory potential.
ability as was seen with differentiated NPC cultures. Our preliminary staining reveals that a small population of plated cells express the neural precursor cell marker Nestin and we hypothesize that it is this neural precursor subpopulation of SKPs that is demonstrating cathodal migration. We are further characterizing the phenotypes of cells migrating towards the anode. Together these findings suggest that cells maintaining a neural precursor phenotype are responsive to EF’s, regardless of their tissue of origin.

SP002.4 - The role of niche architecture on muscle stem cell division orientation
Author(s): Richard Y. Cheng1, Penney Gilbert2
1Ibme, University of Toronto, Toronto/ON/CANADA, 2Ibme, University of Toronto, Toronto/CANADA

Skeletal muscle is comprised of muscle fibres (myofibres) that are embedded within connective tissue. Reconstruction of the adult muscle tissue relies on a pool of resident committed muscle stem cells (MuSCs) situated between the basal lamina and sarcolemma known as “satellite cells” which express the paired-box transcription factor Pax7 necessary for their specification during embryonic development and long-term maintenance during adult life. To maintain tissue homeostasis, MuSCs undergo asymmetric division to produce a committed daughter cell that repairs damage to local fibers and an uncommitted daughter that repopulates the niche. Upon an injury where extensive regeneration is required, MuSCs undergo symmetric divisions in which two uncommitted daughter cells are produced to expand the myogenic progenitor pool. Recent studies indicate that MuSC ‘stemness’ is contingent on maintaining contact with the basal lamina during division such that asymmetric divisions occur in an apical-basal orientation with respect to the fiber, while symmetric divisions proceed in plane with the fiber (planar). Understanding the molecular mechanisms by which MuSCs undergo cell fate decisions, especially self-renewal, during muscle regeneration is a fundamental goal of modern muscle research.

Using a cyclic compression machine to evaluate the Young’s modulus, we found that the bulk stiffness of regenerating muscle is significantly higher compared to healthy control mice. We propose that these changes manifest due to the increased deposition of extracellular matrix (ECM) components in the MuSC niche immediately after injury. We confirmed this using immunohistochemistry and western blotting and observed that the injured MuSC niche contains increased amounts of aligned ECM components such as collagen, fibronectin, and laminin. In addition, atomic force microscopy on isolated individual fibers revealed significant differences between the stiffness of healthy fibers versus injured fibers, indicating that the increased ECM during regeneration is associated with a stiffer niche, which is an aspect capable of modulating MuSC self-renewal in culture as previously showed. To understand if fibrosis alters the niche architecture by physically restricting apical-basal oriented division, we mimicked the healthy and regenerating niche by culturing isolated muscle fibers within soft (12kPa) and stiff (24kPa) agarose gels. Confocal timelapse microscopy allowed us to track cell division orientations over 48 hours of 3D culturing, and here we report that MuSC in a soft environment had a tendency to divide both in the apical-basal (75%) and planar direction (25%), whereas the stiff environment was permissive for mostly planar divisions (84%). Together, this data suggests that changes in the niche architecture due to increased ECM deposition during regeneration play a significant role in supporting MuSC division orientation.

SP002.5 - Mapping the Stem Cell’s Mechanome using Paired Live Cell Multiplexed Imaging and Modeling
Author(s): Melissa L. Knothe Tate
Graduate School Of Biomedical Engineering, University of New South Wales, UNSW Sydney/AUSTRALIA

INTRODUCTION

A series of studies using model mesenchymal stem cells [1-5], primary embryonic stem cells [6], and primary adult stem cells [7,8], has established the profound role of mechanoadaptation on lineage commitment and tissue genesis. Here we aimed to develop novel methods to allow for live cell multiplexed fluorescent imaging for the spatiotemporal distribution of the cell nucleus, membrane and cytoskeleton concomitant to delivery of controlled mechanical stresses and measurement of sub-cellular strains.

METHODS

Cells were cultured per previous protocols [1,9] to achieve targeted densities and developmental contexts. Cells were tagged at time zero with Con-A conjugated, microbeads [4]. Actin and tubulin were tagged during transcription using BacMem 2.0 assays (Invitrogen) [3]. Live cell membranes and nuclei were stained using Cyto9, Hoechst, and fluorescence-tagged Wheat Germ Agglutinin [3,10]. Thus, the displacement and spatiotemporal distributions of each cellular constituent could be tracked as a function of controlled mechanical environment (Fig 1). Using a paired multiphysics computational model (Comsol) [5], we then mapped deviatoric and dilatational stresses as a function of stem cell mechanoadaptation.

RESULTS

Live stem cell imaging of the nucleus (red), actin (green), tubulin (blue) and compiled cell structure, followed by multicell image, depicting the same cellular constituents spatially. Scale bar: 20 microns.

DISCUSSION

The novel paired imaging and modeling method allows for live cell multiplexed fluorescent imaging of cell/nucleus shape and volume concomitant to monitoring of spatiotemporal actin and tubulin distribution, as well as in situ strain assessment. Akin to mechanical testing of a cell as it evolves and optimizes its structure for prevailing dynamic function, the novel method will enable elucidation of the underlying mechanisms of stem cell mechanoadaptation, potentially paving the way for targeted delivery of physical cues to achieve targeted tissue genesis and healing.

REFERENCES

**SP003 - Brachy Therapy: Part 1**

**TRACK 04: RADIATION ONCOLOGY**

**SP003.1 - The impact of in-homogeneity corrected dose calculations for various clinical HDR brachytherapy sites.**

**Authors:** S V. Jamema, Siji Paul, Reena Devi, Kishore Joshi, Mayur Sawant, Pooja Moundekar, Deepak Deshpande

Medical Physics, Tata Memorial Hospital, Mumbai/INDIA

**Purpose:** To determine and the impact of in-homogeneity corrected dose calculations for various clinical brachytherapy sites, and to quantify the variation between the two algorithms: TG 43 & Acuros.

**Methods:** Various clinical sites have been investigated: surface mould of the nose, base of tongue-tonsil implant, soft tissue sarcoma of the chest wall, breast multi catheter APBI, lip, eyelid implant, and gynaecological applications which consisted of two applicators, namely Vienna and ring made up of polymer and stainless steel material respectively. After the implantation, CT scans were obtained, followed by reconstruction of the implant, dose calculation and treatment delivery. The clinical dose calculations were carried out using TG 43 algorithm, which were then re-calculated using Acuros model based dose calculation (Eclipse v 10, VMS). The dose to the target, OARs were evaluated using the DVH parameters, volumes of various isodose levels (V300%, V200%, V100%, V50%) and isodose distribution.

**Results:** TG 43 overestimated the dose as compared to Acuros for all the implant types. Implants such as eyelid and lip had larger variation >10%, while implants of breast, soft-tissue sarcoma of the chest wall and base of tongue resulted in variation of the order of 5-10%. The gynaecological implants resulted with lowest variation of <5% (Table 1). In surface mould of the nose, the mean dose to the ipsilateral eye resulted in a variation of 11%, while in tongue implant, the dose to the underlying bone resulted in a variation of 9%. In soft tissue sarcoma and breast implant, TG 43 over estimated the dose to the skin by 20 and 35 cGy while the dose to the lung was underestimated by 10cGy per fraction (prescription dose: 4Gy/fraction) (Figure 1). The dose profile at the superficial region was overestimated by 50cGy and 200cGy for lip and eyelid implant.

**Conclusion:** The impact of in-homogeneity corrected dose calculations for various clinical brachytherapy sites, between the two algorithms, TG 43 & Acuros has been quantified.

**Table 1:**

<table>
<thead>
<tr>
<th>Implant</th>
<th>% variation of volumes of isodose levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface mould of the nose</td>
<td>9±7</td>
</tr>
<tr>
<td>Base of Tongue and tonsil</td>
<td>8±8</td>
</tr>
<tr>
<td>Soft tissue sarcoma of the chest wall</td>
<td>7±2</td>
</tr>
<tr>
<td>Breast APBI Multi catheter</td>
<td>8±2</td>
</tr>
<tr>
<td>Lip Implant</td>
<td>11±14</td>
</tr>
<tr>
<td>Eye Lid Implant</td>
<td>22±37</td>
</tr>
<tr>
<td>Gynaecology- Vienna applicator</td>
<td>1±0.2</td>
</tr>
<tr>
<td>Gynaecology-ring applicator</td>
<td>4±0.7</td>
</tr>
</tbody>
</table>


**ACKNOWLEDGEMENTS**

This project has been supported in part through the Paul Trainor and the U.S. National Science Foundations.
SP003.2 - A novel QA device for brachytherapy applicator QA
Author(s): Yi Le, Sook Kien Ng, Esteban Velarde, Elwood Armour, John Wong
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Purpose/Objective(s): The commissioning and routine quality assurance (QA) of the source positions for HDR applicators usually requires double exposures of films which is time consuming. The objective of this study is to develop an effective and efficient filmless method for evaluating dwell positions of HDR applicators using a novel QA device.

Materials/Methods: Material. A device that unifies comprehensive real-time mechanical and dosimetric QA measurements has been developed in our institute for routine external beam QA originally and extended to brachytherapy application. This device comprises an imaging surface for receiving multiple energy sources, a camera for measuring and recording data related and a mirror system for directing the energy sources to a stationary camera. The imaging surface has a resolution of 0.25 mm. Source dwell positions QA for HDR ring and tandem (R&T) applicator sets was performed using this device as a case study.

Methods: R&T applicator sets were secured to the imaging surface of the QA device (Figure 1a). Two sets of images of the applicators were acquired by the QA device. First set of images were acquired using fluoroscopy x-ray with dummy marker in the applicators (Figure 1b). This serves as the reference image and provides the markers’ positions for comparison with active source positions. The second set images were acquired using HDR Ir-192 sources (Figure 1c). The images were acquired in integration mode with 20 second integration time. Measurements were repeated five times for each set of applicator and the mean value of the dwell position were determined (Figure 1b). No image registration is necessary since the images were taken by the same device at same location. Data analysis was automated using MATLAB to improve efficiency and eliminate user dependence.

Results: Tandem applicator measurements indicated all dwell positions were within 1.0±0.4mm from the dwell positions to the corresponding dummy markers. The most distal dwell position for the ring applicator was found to be within 1.2±0.7mm from the tip of the dummy mark. Results for symmetric source position analysis are in good agreement with the recommended angle (90°). Using this QA device, the applicator sets only need to be setup once on the imaging surface for repeat measurements.

Conclusions: A method utilizing a novel QA device for HDR applicators QA was demonstrated. The digital high resolution images allow the source dwell positions to be determined quantitatively. Automatic data analysis method significantly reduces time required for repeat measurements.

SP003.3 - Electromagnetic tracking for catheter reconstruction in ultrasound-guided high-dose-rate brachytherapy of the prostate
Author(s): Shyam Bharat1, Cynthia Kung1, Ehsan Dehghan1, Alexandru M. Nicolae2, Ananth Ravi2, Niranjan Venugopal3, Antonio Bonillas1, Doug Stanton1, Jochen Kreucker1
1Philips Research North America, New York/UNITED STATES OF AMERICA, 2Medical Physics, Odette Cancer Centre, Toronto/CANADA, 3Saskatoon Cancer Centre, Saskatoon/CANADA

Purpose: The accurate delivery of high-dose-rate (HDR) brachytherapy is dependent on the correct identification of the position and shape of the treatment catheters. In many brachytherapy clinics, transrectal ultrasound (TRUS) imaging is used to identify these catheters. However, manual catheter identification on TRUS can be time consuming, subjective, and operator dependent due to a number of imaging artifacts. We report the use of electromagnetic (EM) tracking technology to determine the position and orientation of catheters inserted in a tissue-equivalent prostate phantom.

METHODS AND MATERIALS: An Aurora EM system (NDI, Waterloo, ON, Canada) was used in this experiment. The accuracy of the EM system was quantified using a three-axis robotic system. In addition, EM tracks acquired from catheters were compared with catheter positions determined from TRUS and CT images, to compare EM system performance to standard clinical imaging modalities. The tracking experiments were performed in a controlled laboratory environment (no EM-signal distorters present), and in a typical brachytherapy operating room (EM-signal distorters present). Additionally, the positional distortion in multiple sensors resulting from the distorting effects of the brachytherapy operating room was characterized.

Results: The robotic validation of the EM system yielded a mean
accuracy of < 0.5 mm for a clinically acceptable field of view in a non-EM-distorting (laboratory) environment. The largest distortion in sensor signal (30 s acquisition at 40 Hz), was associated with the brachytherapy equipment cart placed in the proximity of the EM field generator in the brachytherapy operating room. The achievable system accuracy depended largely on the calibration of the TRUS probe, geometry of the tracked devices relative to the EM field generator, and locations of surrounding clinical equipment. To address the issue of variable accuracy, a robust calibration algorithm was developed and integrated into the workflow. The EM-tracked catheter representations were found to have an accuracy of < 1 mm when compared with TRUS- and CT identified positions, both in the laboratory environment and in the brachytherapy operating room, with the addition of the robust calibration. The proposed mapping technique was also found to improve the workflow efficiency of catheter identification.

Conclusions: The high baseline accuracy of the EM system, the consistent agreement between EM-tracked, TRUS- and CT-identified catheters, and the improved workflow efficiency illustrate the potential value of using EM tracking for catheter mapping in high-dose-rate brachytherapy.

SP003.4 - Dosimetric and radiobiological comparison of volumetric modulated arc therapy, high-dose-rate brachytherapy and low-dose-rate permanent seeds implant for localized prostate cancer

Author(s): Ruijie Yang, Junjie Wang
Radiation Oncology, Peking University Third Hospital, Beijing/CHINA

Purpose: To assess the dosimetric and radiobiological differences among volumetric modulated arc therapy (VMAT), high-dose-rate (HDR) brachytherapy, and low-dose-rate (LDR) permanent seeds implant treatment for localized prostate cancer.

Methods and Materials: Ten patients with localized prostate cancer were selected for this study. Volumetric modulated arc therapy, high-dose-rate brachytherapy and low-dose-rate permanent seeds implant plans were created for each patient. For volumetric modulated arc therapy, planning target volume (PTV) was created by adding a margin of 5 mm to the clinical target volume. Rectum, bladder, urethra and femoral heads were considered as organs at risk. 78 Gy in 39 fractions were prescribed for PTV. The dose prescription was D90 of 34 Gy in 8.5 Gy per fraction for HDR (Ir), and 145 Gy to clinical target volume (CTV) for LDR (I) plans, respectively. The dose and dose volume parameters were evaluated for target, organs at risk and normal tissue. Physical dose were converted to dose based on 2-Gy fractions (equivalent dose in 2 Gy per fraction, EQD2) for comparison of three techniques.

Results: HDR and LDR significantly reduced the dose to rectum and bladder compared with VMAT. The Dmean (EQD2) of rectum decreased 22.36 Gy in HDR and 17.01 Gy in LDR from 30.24 Gy in VMAT, respectively. The Dmean (EQD2) of bladder decreased 6.91 Gy in HDR and 2.53 Gy in LDR from 13.46 Gy in VMAT.

For the femoral heads and normal tissue, the mean doses were also significantly reduced in both HDR and LDR compared with VMAT. For the urethra, the mean dose (EQD2) was 80.26 Gy, 91.23 Gy and 104.91 Gy in VMAT, HDR and LDR, respectively.

Conclusion: For localized prostate cancer, both HDR and LDR brachytherapy were clearly superior in terms of the sparing of rectum, bladder, femoral heads and normal tissue compared with VMAT, with a little higher mean dose to the urethra in LDR. HDR provided the advantage in sparing of urethra compared with LDR.

Conclusions: The high baseline accuracy of the EM system, the consistent agreement between EM-tracked, TRUS- and CT-identified catheters, and the improved workflow efficiency illustrate the potential value of using EM tracking for catheter mapping in high-dose-rate brachytherapy.
SP003.5 - A novel system for real-time planning and guidance of breast HDR brachytherapy

**Author(s):** Eric Poulin¹, Lori Gardi², Kevin Barker², Jacques Montreuil², Jean Pouliot¹, Aaron Fenster³, Luc Beaulieu¹
¹Radio-oncologie, CHU de Quebec, Quebec/QC/CANADA, ²Imaging Research Laboratories, Robarts Research Institute, London/ON/CANADA, ³Radiation Oncology, University of California San Francisco, San Francisco/CA/UNITED STATES OF AMERICA

**Purpose:** In breast interstitial high dose rate (HDR) brachytherapy, the number and positions of the catheters are usually chosen manually using a preimplant CT scan or fixed using 2D ultrasound. Furthermore, there is currently no automated real-time ultrasound guidance system available. In this work, we present a novel system for real-time planning and guidance of breast HDR brachytherapy treatment, using 3DUS.

**Methods:** A computer controlled robotic 3DUS scanner has been designed to fit on a modified Kuske assembly (Elekta Brachytherapy, Veenendaal, The Netherlands). The scanner can be mounted at several positions on the assembly, which allows the user to personalize the position of acquisition, as shown in Fig. 1a. Figure 1b shows the larger field-of-view provided by the hybrid motion of the new 3DUS system. Software modules were developed for the acquisition and reconstruction of ultrasound images. A semi-automatic segmentation algorithm and a needle reconstruction algorithm were integrated into the software to segment the planning target volume and reconstruct the catheters. A tracking module and a catheter optimization algorithm were developed in order to perform real-time planning and guidance of the needle. Linearity, volume and catheter trajectory measurements were performed, using agarose-based phantoms in MRI, CT or 3DUS scanners to validate the new 3DUS system. A new approach, using the template, was used for real-time planning. The method snaps the optimized catheter positions to the available position within the template. The procedure was tested with 14 and 16 catheters, six times each, in an agarose-based phantom with an hypo-echoic mass.

**Results:** The 3DUS acquisition time requires approximately 20s and the catheter optimization algorithm can obtain 10 complete treatments plans, with the corresponding dosimetric indices, in 90s. There were respectively 3.4 % and 1.4 % difference between MRI/3DUS as well as CT/3DUS volume. Both MRI and CT volume were not statistically significantly different from 3DUS volume (Student t-test; p>0.05). The 3DUS system was found to measure efficiently the linear dimensions. The mean angular separation distance between catheter trajectories segmented from 3DUS and CT images was 0.42 ± 0.24 °, while the mean trajectory separation was 0.37 ± 0.17 mm. After the insertion procedure, the real-time approach was shown to enable reduction of the number of catheters without breaking ABS dosimetric recommendations.

**Conclusions:** A novel system was designed and validated for real-time planning and guidance of breast HDR brachytherapy treatment. A modified system could also be used for permanent breast brachytherapy.

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**SP003.6 - Investigation of electromagnetic catheter tracking approach for spatial reconstruction of implant geometry in high dose rate brachytherapy of prostate cancer**

**Author(s):** Stephen Macgregor¹, Chandra P. Joshi¹, Andras Lasso², Carey Shenfield¹, Gabor Fichtinger², L. John Schreiner¹
¹Departments Of Physics And Oncology, Queen’s University, Kingston/ON/CANADA, ²School of Computing, Queen’s University, Kingston/ON/CANADA

**Introduction:** An accurate and rapid spatial reconstruction of implanted catheters in planning image space is vital in the high dose rate (HDR) brachytherapy. This work investigates the accuracy of electromagnetic (EM) catheter tracking for CT-based treatment planning of HDR brachytherapy of prostate cancer.

**Methods:** A 16-catheter implant was performed under ultrasound guidance on a tissue-equivalent prostate phantom (Model-053G, CIRS, Norfolk, VA) embedded into a pelvic phantom (Figure 1). Seven PinPoint-128 markers (Beekley, Bristol, CT) on the phantom were used to achieve ground-truth registration between the CT image (2mm slices) and EM tracking space. EM tracking was performed with driveBAY magnetic field generator, and Model-600 (reference) and Model-55 (tracking) EM sensors (Ascension Technology, Shelburne, VT). The EM sensor was inserted sequentially into the catheters to obtain location measurements. Data collection was completed using Plus (www.plustoolkit.org) and SlicerIGT (www.SlicerIGT.org) software, and analyzed in MATLAB. EM tracking was performed at field generator-to-surface distances of 5.5cm and 8.0cm for ultrasound probe inside and withdrawn from the rectum. Catheter tracks were reconstructed from locations measured in EM tracking, and catheter reconstruction error was computed as the shortest distance between the EM tracked points and the catheter centrelines reconstructed with spline curve fitting from the CT image space.

**Results and Conclusions:** Both ground-truth registration and catheter reconstruction were more accurate closer to the field generator, and when the ultrasound probe was withdrawn from the rectum (Table 1). With the probe withdrawn, the sum of RMS errors was less than the catheter diameter and is clinically acceptable. Large range values indicate presence of tracking outliers due to EM tracking inaccuracies in dynamic noise environment (Table 1). These outliers will be eliminated by using extended Kalman filters combining geometric and kinematic constraints; currently a work in progress.

**Acknowledgements:** RideForDad, Prostate Cancer Research Grant (Kingston-Quinte), and Cancer Care Ontario
We report our initial clinical testing of this technique on patients with esophageal cancer treated with high dose rate brachytherapy. Feasibility and workflow based on physician and therapist feedback will be presented. A preliminary assessment of the accuracy of the applicator placement when compared to the current standard of care will also be presented.

### Table 1: Reconstruction errors in catheter tracks measured in EM tracking space versus the catheter centrelines in CT image space

<table>
<thead>
<tr>
<th>Distance between EM field generator and the phantom surface</th>
<th>Presence of the ultrasound probe in rectum?</th>
<th>Ground Truth Error (RMS registration error between EM and CT spaces)</th>
<th>Catheter Reconstruction Error (RMS distance of catheter tracks reconstructed from EM and CT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 mm</td>
<td>YES</td>
<td>1.0 mm</td>
<td>0.0 – 9.0 mm</td>
</tr>
<tr>
<td></td>
<td>NO</td>
<td>0.8 mm</td>
<td>0.1 – 3.9 mm</td>
</tr>
<tr>
<td>55 mm</td>
<td>YES</td>
<td>1.0 mm</td>
<td>0.2 – 5.8 mm</td>
</tr>
<tr>
<td></td>
<td>NO</td>
<td>1.1 mm</td>
<td>0.0 – 3.2 mm</td>
</tr>
</tbody>
</table>

### SP003.7 - Endoscopic Tracking for improved Applicator Insertion in Esophagus and Lung HDR Brachytherapy

**Authors:** Robert A. Weersink, Jimmy Qiu, Rebecca Wong, Gail Darling, Jonathon Irish, David A. Jaffray

1Radiation Oncology, University Health Network, Toronto/ON/ CANADA, 2Techna Institute, University Health Network, Toronto/ CANADA, 3Surgical Oncology, University Health Network, Toronto/ CANADA

Intracavitary applicators are used in high dose rate brachytherapy for lung, esophagus and gynecological applications. For lung and esophagus applications, the linear applicators are typically inserted using a combination of endoscopy and fluoroscopy. In the current procedure, endoscopy is used to define the proximal and distal ends of the planned target length. With the endoscope located at these sites, the endoscope and a surface marker are aligned using fluoroscopic imaging. Applicator insertion follows removal of the endoscope, with fluoroscopy guiding placement of the applicator relative to the surface marker. Since visualization is only two-dimensional, applicator placement is prone to error. Furthermore, it exposes staff to unnecessary radiation exposure.

We are developing a new method of applicator insertion that employs tracking and navigation of the endoscope and brachytherapy applicator. The objective is to accurately place the applicator based on direct localization of the endoscopic findings. An electromagnetic tracking device (Aurora, NDI, Waterloo, ON) is fixed inside a standard 8mm diameter flexible endoscope (Olympus). The tracking device measures both position and orientation of the end of the flexible endoscope.

Software developed in-house simultaneously displays and records the coordinates and video stream of the endoscope. If a prior volumetric image has been acquired, the endoscopic recording can be further registered to this image. When the endoscope is at a position of interest, such as the proximal or distal end of the target, the location can be recorded and displayed simultaneously with the position of the endoscope. Multiple points can be recorded. A second tracking device is inserted into the applicator to allow tracking of the coordinates of the applicator. As the applicator is inserted into the esophagus or lung, the previously recorded video is replayed by displaying the closest frame associated with the tracking coordinates of the applicator. The distance of the applicator to the previously recorded points of interest is also displayed as an aid in positioning the applicator. Hence two checks provide confirmation of correct applicator placement: distance to the points of interest and the video frame associated with the location.
**SP004 - Quality Assurance: Part 1**

**TRACK 04: RADIATION ONCOLOGY**

**SP004.1 - In Vivo EPID Dosimetry Detects Interfraction Errors in 3D-CRT of Rectal Cancer**

**Author(s): Stefano Peca1, Derek Brown2, Wendy L. Smith1**

1Department Of Medical Physics, Tom Baker Cancer Centre, Calgary/AB/CANADA, 2Dept Of Radiation Medicine And Applied Sciences, Moores Cancer Center, UC San Diego, La Jolla/CA/UNITED STATES OF AMERICA

**BACKGROUND**

*In vivo* dosimetry can record the delivered dose during radiotherapy, which may be used to trigger adaptive radiotherapy or other user intervention. We demonstrate the use of our in-house *in vivo* electronic portal imaging dosimetry in quantifying interfraction dose variability in rectal cancer.

**METHODS**

We recorded MV images from nine treatment beams for six patients prone on the belly board, during 4-7 fractions, for a total of 50 measurements. Images were processed with our dosimetry system to produce dose maps. The dose map from the reference fraction was compared to all subsequent ones to determine interfraction delivery variation, yielding 41 dose difference maps.

**RESULTS**

We identified a number of dose discrepancies. In several patients, persistent gas bubbles may result in cumulative dose deviations large enough to warrant adaptive radiotherapy. In one patient, discrepancies in dose resulted from variability of patient positioning with respect to the belly board (see Figure). In two other patients, dose differences were likely due to variations in compression of the abdomen in the board-couch interface. These issues accumulated significant dose differences throughout treatment and were not readily identified by standard imaging procedures.

**CONCLUSION**

We are developing an open-source *in vivo* portal dosimetry method to automatically track delivered dose at every fraction. Results can be used to flag unexpected discrepancies, guide adaptive radiotherapy, modify setup technique, or warrant image guidance. Further data is needed to test applicability with other treatment sites and setups.

**CAPTION TO FIGURE**

Patient F, PA field (GA=0°). (a) Raw EPID images. (b) Lateral view from the TPS showing the imaging plane (red) and the body adapting to the belly board opening. (c) Dose difference maps between the first imaged fraction (Im.Fx.) and five later treatment days. The large horizontal mismatch is located at the edge of the belly board opening (red arrows), indicating inconsistent setup of the patient with respect to the board in the SUP-INF direction. This was verified by visual inspection of the raw images (blue arrows). As well, all dose difference maps are affected by the gas bubble present during the Ref fraction (white arrow).

**SP004.2 - Establishing action thresholds for patient anatomy changes and machine errors during complex treatment using EPID and gamma analysis**

**Author(s): Ophélie Piron1, Nicolas Varfalvy1, Louis Archambault2**

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**INTRODUCTION**

Our long-term objective is to use *in vivo* data from daily EPID images to identify patients at risk of deviating from their planned treatment. To achieve this, a gamma analysis is performed relative to a reference fraction. The specific objectives of this work are (1) evaluate the sensitivity for different types of error and (2) evaluate the impact of the treatment modality (step-and-shoot IMRT versus VMAT) on the results.

**METHODS AND MATERIALS**

A homemade head-and-neck phantom was used for all irradiations. A CT scan of the phantom was acquired and clinical treatment plans were applied to it. Errors were introduced and EPID images were acquired. Analysis is performed using the gamma index (3%/3 mm)
relative to a no-error delivery. The fraction of points above certain thresholds and the average gamma value is recorded in every case. Daily reproducibility was also assessed by repeating measurements 5 times.

RESULTS

The errors introduced included: patient positioning, weight losses using a uniform sheet of bolus and leaf errors. Figure 1 and 2 show the fraction of points beyond certain gamma values for patient related errors for both VMAT and IMRT cases. From these figures, it is clear that for similar errors EPID images of arc-based treatments are less perturbed than for step-and-shoot IMRT. Similar results were obtained for errors of different magnitudes. When no error is inserted, 99.4% of pixels have a gamma index below 1 on average using a 1%/1 mm criterion.

CONCLUSION

A wide range of errors was introduced to test the sensitivity of EPID to detect treatment errors. For identical errors, those introduced in IMRT treatments were easier to detect than those introduced in VMAT. This will serve to established personalized action threshold to identify patients at risk of deviating from their planned treatment.
SP004.4 - Radiation field size, junction and MLC QA using amorphous silicon electronic portal imaging device, an efficient approach to improve routine accuracy

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Département De Radio-oncologie, CHUM - Hôpital Notre-Dame, Montréal/CANADA

**Introduction:** Films have been used for linac QA as a reference 2D detector, but amorphous silicon electronic portal imaging device (EPID) are getting increasingly used for this task even if they offer much lower resolution. EPID is a standard component of modern linacs and it can be used to accelerate QA process. We developed in-house QA tools using EPID to replace films with the objectives of being more efficient, more reproducible, precise, Varian/Elekta compatible and integrated with the QC program database QAtrack+.

**Method:** We designed a phantom to identify beam crosshair on the images with four 5mm diameter truss head screws 4cm apart from the center. The crosshair is marked over 34cm to achieve precise phantom alignment. 10x10cm² and 30x30cm² field limits are also marked with dashed lines to ease jaw projections visualization. Line thickness corresponds to our test tolerances for quick inspection. Our mechanical technician manufactured three high precision copies with a 2D router.

We developed Matlab® EPID image analysis tools to perform fully automatic processing and recording in QAtrack+. We implemented functions that allow accuracy beyond the detector resolution for screw and edge detection. Screws are identified using an image correlation with a screw model followed by a circular Hough transform. An oversampling technique is used to enhance edges detections precision. Distances between screws detected are used to evaluate the magnification factor of the phantom on the detector.

Radiation size QA phantom allows light field check (30x30cm²), light/radiation field coincidence (10x10cm²) and radiation field verification (other field sizes).

Junction QA does not require the phantom. Images are integrated over 20MU to remove any effects of beam stabilization on this oversensitive test (Typical edge gradient of 3% / 0.1mm). Four quarter fields are delivered on the portal imager, by moving the jaws, and then summed to get one junction image. Profiles across the four junctions are analyzed to determine the percentage of local dose variation.

MLC positioning QA consists of portal images acquired for different field sizes collimated with the leaves. To get all MLCs over a 40 cm field at isocenter, two half-blocked images are acquired with opposite EPID lateral translation.

**Results:** For all phantoms, distances of 80.08±0.07mm between screws have been measured with a digital caliper. Magnification factor accuracy of 0.2% has been attested by comparing EPID and film profiles acquired simultaneously. Radiation size QA with EPID was compared with film QA and an average absolute difference of 0.3mm have been observed on jaws opening. Using EPID, we are able to reproduce measurements within a standard deviation of only 0.2mm, 3 times lower than film. Similar reproducibility gain is observed for monthly clinical measurement. An average absolute difference of 0.3mm has also been observed between MLC positioning QA with EPID and film QA.

**Conclusion:** We demonstrated that our in-house QA using EPID achieves our objectives: efficiency, reproducibility, precision, compatibility and integration. We replaced films for regular QA and we are working to develop new tests using EPID technology to enhance our QA program.

SP004.6 - Real-time detection of deviations in radiotherapy beam delivery using a head-mounted detector

**Author(s):** Richard Canters1, Martijn Kusters2, Juergen Oellig2, Juan-Pablo Carrasco2, Henk Huizenga2
1Radiotherapy, Radboud UMC, Nijmegen/NETHERLANDS, 2IRT Systems GmbH, Koblenz/GERMANY

**Purpose:** Correct delivery of the planned treatment is of vital importance in radiation therapy. To be able to monitor beam delivery online, the Integral Quality Monitor (IQM, IRT Systems GmbH) was developed. Mounted on the linac head it enables real-time, per-segment evaluation of the delivered beam. In this study we tested the sensitivity for potential errors in a variety of beams on an Elekta linac with MLCi2 head as a beta test in the last development stage.

**Methods:** We incorporated various forced deviations/errors in four treatment plans (stereotactic lung, lung (VMAT), larynx (VMAT), and head & neck (IMRT)):

An unintentionally performed re-optimization of the beams after plan approval by the radiation oncologist

Incorrect number of monitor units (MU) in two segments of 10, 5, or 2 MU. The beam MU remained the same.

Incorrect leave positioning (retraction of leaves by 1, 0.5, or 0.2 cm) in a single segment.

The clinical beams, without incorporated errors, are used as a reference.

For VMAT beams, we have chosen to smooth the IQM signal over the segments with a Gaussian filter to account for the exact segment timing. Evaluation takes place on the maximum difference in a segment and in the cumulative signal, with respect to the clinical beam. Additionally, the clinical beams were measured repeatedly to take into account machine variations.

As a comparison, all beams are additionally measured with the Delta4-system (Scandidos), the standard QA tool in our department. Analogously to the IQM measurements, the clinical beams are used as references. Median dose difference (DD50) and 95% dose difference (DD95) are assessed as measures of agreement between the beams.

A receiver-operating characteristic (ROC) curve is created by varying the cut-off criterion for error detection to assess the sensitivity and specificity of error detection.

**Results:** In figure 1, the results of the IQM and Delta4-system measurements are plotted. The left graph shows the IQM results, where modified beams can be clearly distinguished from reference beams. In the Delta4-measurements (middle graph) this effect is less pronounced. This is confirmed by the ROC-curve (right graph), which shows an improved sensitivity and specificity for error detection by the IQM system compared to the Delta4 system.

**Conclusions:** Our tests of the IQM system on the MLCi2 linac show an excellent sensitivity and specificity in error detection during beam delivery, even for very small deviations in a single segment.
**SP005 - Patient Specific QA**

**SP005.1 - Verifying dynamic planning in gamma knife radiosurgery using gel dosimetry**

**Authors:** Gopishankar Natanasabapathi1, Subbiah Vivekanandhan2, Ss Kale1, G K. Rath3, R K. Bisht1, P Agarwal3, P Sathiaraj4, B S. Sharma1

1Gamma Knife Unit, All India Institute of Medical Sciences, New Delhi/INDIA, 2Neurosciences Centre, All India Institute of Medical Sciences, New Delhi/INDIA, 3Radiation Oncology, All India Institute of Medical Sciences, NEW DELHI/INDIA, 4VIT, VELLORE/INDIA

**Purpose:** To assess dynamic planning based on convolution based algorithm (CABP) in Gamma Knife using gel dosimetry. Materials and Methods: PAGAT gel was prepared and filled into cylindrical container of size 8 cm in diameter for verification. An old MRI distortion phantom was modified to accommodate the gel cylinder. Advantage of this modification is that it avoids the use of metal post and pins in the vicinity of the dosimeter which causes artifacts while scanning. A X-ray CT scan was done on the phantom with cylinder positioned in the middle region. CT scanning parameters were: Tube Voltage – 120 KVP, Tube Current – 57 mAs, Slice thickness – 1.0 mm, FOV – 265 x 265 mm2. A treatment plan was generated in Leksell Gamma Plan TPS (LGP version 10.1) using CT images of the gel phantom. Using HU values and Electron density information CABP was activated. A single shot plan with third level dynamic planning option was generated using CABPMRI with following parameters were used for scanning: CPMG sequence with 8 TE values, FOV – 256, Matrix size – 256, TR – 5000 ms, slice thickness – 1.2 mm. Results: Gamma analysis of the verification showed a pass rate of more than 83 %. This is the first kind of study for three dimensional verification of dynamic planning using convolution algorithm in Gamma Knife Perfexion. Conclusion: We propose gel dosimetry as an essential dosimeter for verifying convolution algorithm in Gamma Knife. Further experiments required to validate the verification with close agreement.

**SP005.2 - Influence of Jaw Tracking in Intensity Modulated and Volumetric Modulated Arc Radiotherapy for Head and Neck Cancers – A Dosimetric Study**

**Authors:** Karthick Raj Mani1, Kh Anamul Haque2, Mohammad Anisuzzaman Bhuiyan1, Kolipillai Joseph Mariadas3

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**Aim:**

To Study the dosimetric advantage of the Jaw tracking technique in Intensity Modulated Radiotherapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT) for Head and Neck Cancers.

**Materials & Methods:**

We retrospectively selected ten previously treated Head and Neck cancer patients stage (T1/T2, N1, M0) in this study. All the patients were planned for IMRT and VMAT with Simultaneous Integrated Boost (SIB) technique to deliver a differential dose per fraction to the high, intermediate and low risk volume using a single plan. We intend to deliver 70 Gy to the high risk volume, 64 Gy to the intermediate risk volume and 56 Gy to the low risk volumes in 35 fractions. All
the critical structures were delineated which includes both parotids, spinal cord and both sub mandibular glands. Eclipse treatment planning system, version 11.0 (Varian Medical Systems, Palo Alto, CA), was used in this study. All the plans were planned with 6MV photons using Millennium 120 MLC. Both IMRT and VMAT plans were planned with and without jaw tracking by keeping the same constraints and priorities for the target volumes and critical structures for a particular patient. Plans were normalized at the target mean of the high risk volumes. All the plans were accepted with the criteria of parotid glands mean dose <25Gy and spinal cord maximum point dose <45Gy without compromising the target volumes. Target conformity, dose to the critical structures and low dose volumes were recorded and analyzed for IMRT and VMAT plans with and without jaw tracking for all the patients.

Results & Discussion:

Jaw tracking resulted in decreased dose to critical structures in IMRT and VMAT plans. But significant dose reductions were observed for critical structure in the IMRT Technique with jaw tracking compared to IMRT technique without jaw tracking. In VMAT with jaw tracking technique the dose reduction to the critical structure were not significant compared to the without jaw tracking technique due to relatively lesser monitor units. Gamma analysis showed greater than 97% of pixels were passed within 3mm distance and 3% dose criteria for all the plans.

SP005.3 - Evaluation of the eye lens dose according to patient setup errors in pediatric head CT examination

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According to the 2011 ICRP statement, the threshold in absorbed dose for the lens of the eye is now considered to be 0.5 Gy. Therefore, it is important to keep the eye lens doses during head computed tomography examination as low as reasonably achievable. In preliminary study, the surface doses became smaller with decreasing distance from the X-ray tube. Therefore, decreasing the distance from the lens to the X-ray tube (i.e. raising the bed position) is a simple and effective way to reduce the absorbed dose of the lens. However, the occiput doses became higher with increasing distance from the X-ray tube. In this study, the two lenses and the occiput doses associated with patient setup errors and head size were evaluated using phantoms developed for pediatric patients. The phantoms were made using flexible acrylic sheets in a cylindrical shape [diameters of 6 (premature baby), 8 (neonate), 10 (infant), and 12 cm (child)] and placed on the end of the CT bed. The bed position was raised from the center for each phantom size. The two lenses and the occiput doses at each setup were measured using radiochromic film. By raising the bed position, the lens doses decreased at all phantom sizes. However, the occiput doses increased at a complex manner according to the phantom size. The absorbed dose ratio of the two lenses and the occiput at φ8 cm phantom are shown in Fig. 1. In this study, raising the bed position is an effective way to reduce the absorbed dose of the lens. However, when the occiput was positioned at the center of the gantry aperture, the occiput dose peaked in all phantom sizes. In addition, the results indicated a complex dose distribution in pediatric head CT when taking into account the bed position (patient setup errors) and phantom sizes. Furthermore, beam slice width and pitch are significant factor in determining the maximum absorbed dose. To keep radiation doses during CT examination as low as reasonably achievable, it is important to clarify the influence of CT scanning settings on CT dose.

![Fig. 1. Absorbed dose ratio at φ8 cm phantom.](image)

**SP005.4 - Multi-Point Sources on Skin to Assess the Annual Effective Dose by Usage of TENORM added Pillow**

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Consumer products containing Technically Enhanced Naturally Occurring Radioactive Material (TENORM) have been distributed in our life. After the accident of Fukushima nuclear power plant, the law called as ‘Act on Safety Control of Radioactive Rays around Living Environment’ has been implemented to prevent the unnecessary radiation exposure to the public in KOREA. However, the appropriate method to effectively evaluate the exposed dose with TENORM added consumer product was not developed despite the law was into effect from July 2012. The aim of this study is to evaluate the exposed dose with the usage of TENORM added consumer product with Monte Carlo simulation. To assess the annual effective dose, the Monte Carlo method and computational human phantom was employed and the point source on the skin was suggested to effectively determine the various product shape and location.

For the assessment of effective dose with the radionuclide in a consumer product, Polygon-Surface Reference Korean-Man (PSRK-Man) phantom composed of high resolution polygons to represent the organs was developed. To represent the source location of the radioactive material in the product, polygons on skin under the product was selected and the source was generated in the weight center in each polygon. To validate the method defining the point sources on skin later than the realistic source distribution in the product shape and location, organ dose was compared with 1 MeV gammas isotropically emitted in the assumption of the pillow usage with Monte Carlo method using Geant4 tool kits.
Our simulation study shows that the multi-point sources defined on the skin indicate the conservative dose assessment than the sources in the product being modeled because of the close source definition to organs. For bone, skin, and muscle, the organ dose using modeling source was, however, higher than the point source with the increased effective angles. This indicates that increasing the source to organs distributed through the whole body distance could decrease the self-attenuation by other organs. The effective dose with the point source and modeled source was assessed as 5.56E-17 Sv/particle and 2.97E-17 Sv/particle, respectively.

The current study shows the potential method for the evaluation of effective dose by the TENORM added products by using the Monte Carlo method. The comparison study also showed that the various shape and usage location of products could be replaced with the point source on the skin. The data based for the exposed dose by whole the point source could enable the effective and convenient assessment of annual effective dose. This technique could also be used for the other field for radiation protection to calculate the effective dose.

Acknowledgment

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SP005.5 - Patient-Specific Quality Assurance of Respiratory-Gated VMAT Using a Programmable Cylindrical Respiratory Motion Insert for the ArcCHECK™ Phantom

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**Introduction:** The ArcCHECK™ phantom is a commonly used four-dimensional detector array for dose delivery verification of IMRT and VMAT. Although the isotropy of this device bodes well for ensuring accuracy for entrance dosimetry per control point, the composite 3D dose distribution may not be accurately represented for tumour sites influenced by respiratory motion. Motion management strategies, such as gating, often requires additional procedures and equipment to ensure accurate delivery. Here, we present a customized programmable moving insert for the ArcCHECK™ phantom that, in a single delivery, can verify both entrance dosimetry, while simultaneously verifying the delivery of respiratory-gated VMAT.

**Methods:** The QUASAR™ Cylindrical Respiratory Motion Phantom consists of a computer-controlled stepper motor used to move interchangeable cylindrical inserts inside a stationary sleeve placed within the bore of the ArcCHECK™ phantom (Figure 1). To demonstrate its effectiveness for patient specific QA, 4D-CT scans of 8 early-stage lung cancer patients previously treated with gated SBRT were used to characterize the tumour motion and was inputted into the programmable software used to drive an A1SL ion chamber insert. CT images of the ArcCHECK™ with the programmable insert were acquired at multiple static positions in 1mm increments.

Respiratory-gated VMAT plans were recalculated on the phantom scan corresponding to the amplitude of the tumour motion measured with 4D-CT. Each plan was delivered under static, moving (while non-gated), and moving (while gated) conditions. For each patient, standard ArcCHECK™ measurements were compared to the planned dose distributions using SNC Patient 6 software using standard gamma analysis with 5% threshold, 3% dose-difference, and 3mm distance-to-agreement and the measured dose to the A1SL chamber, located at isocentre, was compared to the planned dose.

**Results:** The pass rate for the static delivery ranged from 98.1% to 99.6%, suggesting a valid phantom setup for entrance dosimetry. The pass rate was not altered for any measurement delivered under motion conditions. A similar result was observed under gated VMAT conditions containing multiple beam holds and dose-rate ramp-up and ramp-down. For six patients, the measured dose to the A1SL ion chamber was within 3% of the planned dose. The maximum dose difference was 5.1% in one patient where the chamber was located in a large dose gradient.

**Conclusions:** Patient-specific respiratory-gated VMAT verification can be efficiently performed in a single delivery with the ArcCHECK™ phantom containing a moving cylindrical insert.

Figure 1. The QUASAR™ Cylindrical Motion Insert (with A1SL chamber) for the ArcCHECK™ phantom.
SP006 - Dosimetry in CT

TRACK 05: DOSIMETRY AND RADIATION PROTECTION

SP006.1 - Dosimetry and Radiation Protection
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It is an actual fact that the primary and most common application of radiation until today is in medicine. Furthermore, medical technology has taken a remarkable boost the last few decades both in patient therapy and medical diagnosis. Not only do we have a big variety of medical equipment but we can access all patient data so much easier than 10 or 20 years ago that is really spectacular. Evolution led us so quickly from soft copy to CD-ROM and now icloud that we sometimes ask ourselves how it was possible to work as we did 5 or 10 years ago. All this has resulted not only on a manifest increase in the number of procedures, but also an expansion into different areas of medicine and the creation of new medical specialties. Presently, complex radiation-based tools and techniques are used in most areas of modern medicine and by specialists who have differing levels of knowledge about radiation, dose and the risks posed to human health by ionising radiation.

Within this context, it is very important to use medical radiation technology with prodigious care due to the presence of ionizing radiation. To put the issue in perspective, the current annual collective dose estimate from medical exposure in the United States has been calculated as roughly equivalent to the total worldwide collective dose generated by the nuclear catastrophe at Chernobyl. Therefore accurate measurement of radiation dose is of utmost importance, not only for patients but also for members of the staff, specially due to the recent International Commission on Radiological Protection reduction in the dose limit for the eye lens of workers (from 150 mSv per year to 20 mSv in a year).

Dosimetry seems to play a fundamental role in the process of developing various radiation protection programs to fit the needs of radiation workers and members of the public, particularly as they relate to mitigating potential health risks from exposure to radiation. Specially due to the fact that there is broad discussion the last years on the possibility that radiation dose received by patients from modern diagnostic examinations can be at a level of significance for the induction of cancer across a population. Moreover, in a number of cases, in the acute damage to particular body organs such as skin and eyes.

The talk will cover the trends in dosimetry and radiation protection focused in diagnostic radiology, image-guided intervention procedures and nuclear medicine studies, illustrated by progress in science and practice of risk communication and changes in societal expectations, and examines challenges that will confront radiation risk communication in the future.

SP006.2 - Organ dose reduction while using in-house CBCT patient-specific protocols based on OSL dosimetry.
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Purpose/Objectives
In radiation therapy, dose contributions coming from planning and patient positioning images can seem negligible compared to the treatment dose. However, radiation-induced complications are numerous even at low dose. In order to diminish undesirable effects to the patient, one must concretely apply the ALARA principle and minimize dose to organs at risk (OAR) while not compromising treatment quality. In this study, appropriate adjustments to cone beam computed tomography (CBCT) imaging protocol parameters were performed. This was achieved after measuring the dose to organs in an anthropomorphic phantom filled with optically stimulated luminescent detectors (OSL). All these modifications lead to a significant dose reduction of at least 50% up to a reduction of 90% in comparison with the default protocol doses while still preserving a proper image quality for positioning.

Materials/Methods
Output measurements of the CBCT X-ray tube were performed at 100 kVp and 120 kVp. Measurements were based on the AAPM Task Group 61 protocol using a Farmer-type ionization chamber calibrated for the corresponding beam quality. Once the outputs were determined at the reference point, the correlation between OSL’s number of counts and the resultant dose was achieved. An anthropomorphic adult phantom with heterogeneous densities and 271 plugs for OSL detectors covering the whole body was used. Default scan protocols of the head and neck, breast, chest and pelvis were investigated. The mean dose and the maximum dose to the organs were collected over multiple scans to assure the reproducibility of the given method.

Results
The maximum dose to any given organ never exceeded 3.0 cGy for all the default protocols. For the particular head and neck cases, the maximum dose never reached more than 0.4 cGy. Radio-sensitive organs such as lungs, breasts, bone marrow, stomach and intestines received between 1.0 cGy and 2.0 cGy per scan. In the chest and pelvis protocols, the thyroid gland and the testis received more dose than the other organs (2.0 - 3.0 cGy) due to their proximity to the surface and the low attenuation of the beam before reaching the OSLs.

Conclusions
With the new modifications made to the default scan parameters, a considerable organ dose reduction of at least 50% can be achieved for every protocol without compromising image quality for patient positioning. With our in-house protocols, no organ received more than 1.5cGy per scan. These results are therefore in compliance with the ALARA principle. Also, a new ultra-low dose scanning protocol for the chest was introduced giving only 0.1 cGy to the lungs and 0.2 cGy to the heart and thyroid respectively. This significant dose reduction is desirable especially for young lymphoma patients.

SP006.3 - A novel tool for in vivo dosimetry in diagnostic and interventional radiology using plastic scintillation detectors
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Plastic scintillation dosimetry is now spreading in multiple areas of clinical practice either for quality assurance or in vivo dose monitor-
The study of the radiation dose distribution over the phantom’s eyeball was carried out using a Philips Allura Xper FD20/20 system (80 kV, 3 fps acquisition mode). Gafchromic XR-RV3 film was used to measure absorbed dose at positions corresponding to the surface of the cornea, under the cornea, under the lens, and on the retina of the eye.

**Materials and Methods:** CT images of head of 13 patients were successfully fabricated and used to evaluate eye lens dose during diagnostic fluoroscopy procedures.

**Purpose:** To fabricate an anthropomorphic phantom for patient’s radiation dose measurement during diagnostic X-ray procedures.

**Conclusion:** A custom made anthropomorphic head phantom was successfully fabricated and used to evaluate eye lens dose during diagnostic fluoroscopy procedures.

**Introduction:** Absorbed dose in CT exams can be ten times higher than in other common procedures of X-ray imaging and must
be monitored. Dosimetry in CT is still commonly made obtaining CTDI100 values, measured with a “pencil” chamber inside a CT phantom, in a single beam slice and no table movement. In helicoidal and multi-slice tomography with high number of rows, measured values of CTDI100 should underestimate accumulated dose at point z=0, as they don’t include the contribution of dose profile «tail», caused by scattering in the phantom (or tissue). In this sense, this work aimed to contribute to review the assessment of Dose in CT according to the methodology suggested by AAPM TG 111 [AAPM, Report 111, 2010].

**Methodology:** Firstly, we have used a Radcal 0.6 cc chamber, previously calibrated in CT standard beam qualities [IAEA, TRS 457, 2007] against a Farmer chamber, to measure dose profiles on a Toshiba Aquilion One scanner (HIAE), through several adjacent slices. Values of Equilibrium Dose free in air, Deq,ar, were obtained for various protocols and pitch values. In the second step, using a large CT phantom (Fig.1), values of central Cumulative Dose (DL(0)) were measured for different slice length values (L), for two different abdomen protocols, in order to evaluate the Equilibrium scanning length (Leq) and Equilibrium doses (Deq) (Fig.2). Finally, Planar Average Equilibrium Dose (Deq,p) was evaluated and compared with CTDIvol values displayed in the CT equipment.

**Results and Discussion:** In the survey of dose profiles, slice thickness was evaluated with 19-28% difference compared to the nominal value. It was also observed that Equilibrium Dose free in air increases as the pitch is reduced and that the values of equilibrium dose-pitch product free-in-air (p.DEQ, air) are constant. As expected, differences between Planar Average Equilibrium Dose and CTDIvol ranged between 30-37%.

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**SP007 - Biomedical Signal Quality Analysis**

**Track 09: Biosignal Processing**

**SP007.1 - Biosignal Processing**

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At the end of this presentation you will be able to:

1) explain the need for biomedical signal quality analysis
2) discuss the challenges in biomedical signal quality analysis
3) describe some of the advances in biomedical signal quality analysis

The democratization of technology is being fueled by technology that is decreasing in size, cost, and power-consumption, while the levels of computing power and interconnectivity are increasing. In healthcare, so called patient-empowering, information-leveraging (PI) technologies are drastically changing the paradigm of biomedical monitoring. Traditionally, biomedical monitoring is performed intermittently by a trained expert, under well-controlled conditions, whereas advances has made it easy for frequent or continuous monitoring; in addition, neither the monitoring environment nor the subject’s activity is controlled necessarily (e.g., monitoring can be performed in the home while performing normal activities of daily living). These technologies are not only non-invasive but also non-obtrusive; they can be wearable devices, or integrated into other devices or environments where they may remain unnoticed by the subject. Multi-sensor systems are being increasingly employed, some of which are also multi-modal. These systems may use sensors that are each of lower quality and lower cost, and may not be optimized for a given monitoring application; yet these multi-sensor systems may outperform a higher quality and higher cost individual sensor in terms of accuracy, robustness, and convenience. The rapid increase in biomedical monitoring has resulted in a large focus on “big data” in healthcare.

There has been considerable research and development effort in the acquisition of biomedical data and in data analytics to extract useful information from these data. In many acquisition systems, validation of the data in terms of quality typically requires a human. In data analytics, it is often assumed that data are of adequate quality for processing. When data are not of sufficient quality, this can result in erroneous conclusions including false alarms. For the fourth year in a row, the Emergency Care Research Institute (ECRI) identified alarm hazards as the top health technology hazard.

There is a pressing need for increased research on biomedical signal quality analysis. Biomedical signal quality analysis can be organized into four categories: 1) detection, observing the presence of contaminants in the signal, 2) identification, identifying the type of contaminant(s), 3) quantification, estimating the level of contamination, and 4) mitigation, removing or reducing the contamination. In some applications, simple detection may suffice, requiring only the ability to reject poor quality data. For non-expert users, identification of the contaminant type could be useful in providing feedback to remedy the acquisition setup. Biomedical signal quality analysis poses a variety of challenges, including large signal variability (inter- and intra-subject), contaminants that overlap in time and frequency with the signal of interest, and often a low prevalence of clinically significant events.
SP007.2 - Adaptive filter for eliminating baseline wander of pulse wave signals
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Recording and processing of arterial pulse signals are widely used in cardiology instrumental diagnostic systems. The arterial pulse signals are corrupted by physical and physiological interferences. Physiological interferences are happened due to the patient’s breathing and the effect of neurohumoral regulation factors and also the presence of low-frequency movement artifacts; these factors lead to the appearance of baseline wander: a nearly periodic low-frequency distortion of random nature. The stochastic nature of baseline drift in biomedical signals and also its broadband nature are the main reasons why new advanced methods should be developed for digital processing of the arterial pulse signal. In this article different baseline wander filtering methods were examined for pulse wave signal. A baseline drift correction method based on generating the reference signal of adaptive filter by using multi-resolution wavelet analysis of the original biosignal was proposed. This approach makes it possible to achieve the least distortions in processing pulse wave compared with other methods of eliminating baseline drifts. The effectiveness of proposed method, as well as other widely used approaches for filtering pulse wave signals such as approximation method, linear frequency filtering was studied.

Fig. 1 shows the fragment of arterial pulse signal with typical baseline wander (a); obtained estimation of the baseline wander (b); the pulse wave signal after application the new method of correction baseline wander proposed in this article (c).

![Graph showing baseline wander and correction](image)

SP007.3 - Efficacy of DWT denoising in the removal of power line interference and the effect on morphological distortion of underlying atrial fibrillatory waves in AF-ECG
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**Introduction:** Power line interference (50Hz) is a corruptive noise source which is commonly encountered when capturing body surface ECG signals. The purpose of this research is to assess the efficacy of Discrete Wavelet Transform (DWT) in removing mains noise by testing over thirty different wavelet functions. The four best performing wavelets were then further analysed to assess their effects on underlying fibrillatory waves which are present in atrial fibrillation patients.

**Methods:** 18 body surface ECG recordings of 1 kHz sampling frequency, which were corrupted by a range of mains interference levels (-10dB to 10dB) were simulated in MATLAB using an ECGSYN programme from PhysioNet. These signals then underwent a DWT denoising process which included 10-level decomposition, with full band cancellation of coefficients D1-D4, resulting in a significant attenuation of the added mains interference. The efficacy of the DWT denoising performance was assessed across the entire range of analysing wavelets and also compared to that of notch filtering, a technique which is widely used for mains interference suppression. The results were quantified and compared using three different performance parameters: Signal to Noise Ratio (SNR), Mean Square Error (MSE) and Signal Correlation Value (SCV). Additionally, we wanted to investigate the effect that the top performing wavelets would have on underlying fibrillatory waves which are present in atrial fibrillation electrocardiogram (AF-ECG), as certain key parameters of such waves have been shown to be useful in the characterisation and treatment of the arrhythmia. Five fibrillatory wave signals were extracted from real AF-ECG data using an average template subtraction method and were added to a range of mains corrupted simulated ECG signals. These signals were denoised using the top four performing wavelets and the underlying fibrillatory wave signal was recovered via the subtraction of the original ‘clean’ simulated ECG signal. Key parameters such as dominant frequency (DF) and total spectral power (TSP) of both the original and recovered fibrillatory wave signals were quantified and compared in order to assess whether or not the DWT denoising process was detrimental to fibrillatory wave characteristics.

**Results:** 12 out of 32 of the analysing wavelets tested outperformed a traditional notch filtering approach over all three performance indicators: SNR, MSE and SCV when averaged across the sample population. Four of the top performing wavelets were Daubechies ‘Db10’, Biorthogonal ‘Bior6.8’, DMeyer ‘Dmey’ and Symlet ‘Sym8’, with Db10 providing SNR, MSE and SCV values of 32.50, 5.13x10-5 and 0.9995 respectively. Fibrillatory waves were minimally affected by DWT processing with a 0% difference in DF and a 0.17% ± 0.25% difference in TSP across the study population.

**Conclusions:** DWT denoising can be an effective tool in the removal of unwanted 50Hz mains noise, where a range of analysing wavelets provide superior denoising performance when compared to traditional notch filtering. The process of DWT mains noise removal has negligible effects on the morphology or signal characteristics of underlying fibrillatory waves found in AF-ECG signals.

SP007.4 - Quantifying Blood-Oxygen Saturation Measurement Error in Motion Contaminated Pulse Oximetry Signals
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Oxygen saturation measurements from pulse oximetry (SpO2) can be unreliable in the presence of motion artifacts. While pulse oximetry is a crucial measurement in controlled environments, such as surgery or intensive care, its vulnerability to motion artifacts has slowed its adoption in wearable continuous monitoring devices. Measurement error can cause errors or delays in clinical decision-making. In remote monitoring applications, pulse oximeters should report measurement confidence along with SpO2 to help clinicians make decisions about the validity of alarm conditions. This paper seeks to relate signal quality to SpO2 measurement confidence.

In this study, clean photoplethysmograph (PPG) signals were collected from a pulse oximeter and contaminated with motion artifact. A range of linear combinations of signal and artifact were generated from collected SpO2 measurements. Two models based on Additive White Gaussian Noise (AWGN) were evaluated for their similarity to the motion artifact data. The first had identical noise on both red and infrared PPG signals; the second has uncorrelated noise. Both models successfully predicted negative measurement bias at low SNR, but only the second predicted the observed measurement variance.

![Graph showing SpO2 measurements](image)
Ambulatory electrocardiograms (ECG) can be used to monitor patients for myocardial ischemia. Low ECG signal quality, due to contaminants such as motion artifact, can lead to an increase in false alarms leading to alarm fatigue. The false alarms can be reduced by processing only ECGs of adequate quality, quantified by a signal quality index (SQI); contaminated ECG may be discarded. Four SQIs based on an estimate of the signal-to-noise ratio (SNR) were examined, where the mean, median, 25th percentile and minimum SNR were considered. ECG test data were retrieved from Physionet’s Long-Term ST Database; 30 minute segment of ischemic data and 30 minute segment of non-ischemic data were chosen from the record ‘s20031’. The record is sampled at 250 Hz and has a total of 2 unidentified leads. The SQIs were validated by contaminating 30 second segments of the ECG data with 30 seconds of motion artifact segments scaled at five levels from the record ‘em’ from the Physionet’s Noise Stress Test Database. The result is five copies of each ECG segment each with different calibrated SNR evenly distributed between -10 dB and 10 dB in steps of 5. For each channel of both the non-ischemic and ischemic data of the ‘s20031’ record, 300 segments were created, resulting in a total of 1,200 segments. Four SQIs were then generated for each of these 1,200 segments. The SQIs of each segment were compared to the calibrated SNR of both the non-ischemic and ischemic data of the ‘s20031’ record, and 30 minute segment of non-ischemic data were chosen from the record ‘s20031’. The record is sampled at 250 Hz and has a total of 2 unidentified leads. The SQIs were validated by contaminating 30 second segments of the ECG data with 30 seconds of motion artifact segments scaled at five levels from the record ‘em’ from the Physionet’s Noise Stress Test Database. The result is five copies of each ECG segment each with different calibrated SNR evenly distributed between -10 dB and 10 dB in steps of 5. For each channel of both the non-ischemic and ischemic data of the ‘s20031’ record, 300 segments were created, resulting in a total of 1,200 segments. Four SQIs were then generated for each of these 1,200 segments. The SQIs of each segment were compared to the calibrated SNR of the segment. A Pearson correlation coefficient was calculated between the SQIs and the calibrated SNRs for each of the cases (Fig. 1).

![Fig. 1 calculated Pearson correlation coefficient for SQIs and the calibrated SNRs for non-ischemic and ischemic data for channels 1 and 2](image)

It was found that a strong correlation (Pearson correlation coefficient $> 0.85$) was exhibited between the SQIs and the calibrated SNR for each segment with SQI based on 25th percentile exhibiting highest correlation. The strong correlation indicates that the SQIs are good representatives of signal quality.

SP007.6 - A simple algorithm for identifying artifact beats in long ECG recordings

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**Introduction**

The artifact beats in ECG recordings make diagnosis and monitoring of heart disease difficult and will increase the misdiagnosis rate. Clinically, it is time-consuming and labor-intensive to identify the artifact beats from long ECG recordings. Thus, there is a great need for developing an algorithm to automatically detect the ECG artifacts.

**Data**

The simulation data is used to determine the parameters in the algorithm. The independent data is the combinations of real ECGs of normal patients and patients with arrhythmia (such as atrial fibrillation, atrial flutter, ventricular premature beat, etc.) and the measured signals under the case of electrode loss. The sampling frequency is 250Hz and the total length is 2394.58s, in which there are the six segments of artifacts and the eleven segments of ECGs, in total 167.60s and 2226.98s respectively.

**Algorithm**

For a given ECG segment with the length of $L_s$, the three steps are carried out to identify its type using the novel algorithm.

**Step1:** Calculating the standard deviations of R-R interval (RRI) and R-peak amplitude in this ECG segment. If both parameters are synchronously greater than the two given thresholds (denoted by $ThrRR$ and $ThrRA$), the segment is judged as ECG artifact beats. Otherwise, go to the next step.

**Step2:** The ECG segment between 0.3*RRI at each R-peak before and 0.6*RRI at the R-peak after is selected as a template. If the length of a template is less than 100ms, the template is replaced by ECG segment of 700ms starting from 0.3*RRI at this R-peak before. The aim is to ensure each template contains at least three heartbeat cycles for detecting the rhythm.

**Step3:** The shift correlation is calculated between the given ECG segment and the template and the correlation function $r(i)$, $i=1,2,3,\ldots, L$ is obtained. The periodic wave peaks in the $r(i)$ can be used to reveal the rhythm of the ECG segment. Since the probability that three continuous wave peaks appears in $r(i)$ for the ECG artifacts is very small, the amplitude of the third wave peak of $r(i)$ is selected as the feature parameter discriminating the rhythm of the ECG segment. If this parameter is less than the given threshold (denoted by $Thrmax$), the ECG segment is identified as artifacts.

**Results**

When the $ThrRR$, $ThrRA$ and $Thrmax$ are set as 20, 10 and 0.75 respectively, the performance of the algorithm reaches optimal on the training data. The accuracy, sensitivity and positive prediction value of the algorithm on the independent data are 97.16%, 92.24%, 73.76% respectively, which are better than other related methods on the same data.

**Conclusions**

The logical structure and the computational complexity of the algorithm are simple and low respectively. The algorithm is sensitive to the artifact beats since of high sensitivity. Thus, it is suitable to be applied in the identification of artifact beats in long ECG recordings.
SP007.7 - Automatic Detection of Low-Quality Seismocardiogram Cycles Using the Outlier Approach  
Author(s): Vahid Zakeri1, Farzad Khosrow-Khavar2, Kouhyar Tavakolian3  
1Heart Force Medical Inc., Vancouver/BC/CANADA, 2Engineering Science, Simon Fraser University, Burnaby/BC/CANADA, 3Electrical Engineering, University of North Dakota, Grand Forks/ND/UNITED STATES OF AMERICA

In this study, an algorithm was developed to automatically detect the low-quality (LQ) cardiac cycles in seismocardiogram (SCG). The proposed algorithm extracts some features from the SCG signal, which are referred to as signal quality indices (SQIs), and computes the outlier points of each SQI. Our hypothesis was that the identified cycles (outliers) would include the LQ ones. To verify this hypothesis, the algorithm results were compared with the LQ cycles that were labeled manually by an expert in the field. The developed algorithm was tested on total 1697 cardiac cycles, and there was a great overlap between the computed outliers and the LQ cycles (84% of 248 LQ cycles were identified). The proposed algorithm is simple, efficient, and works in an unsupervised manner.

SP008 - Spinal Cord and Brain Injury Treatment  
TRACK 10: REHABILITATION MEDICINE, SPORTS MEDICINE, REHABILITATION ENGINEERING AND PROSTHESES

SP008.1 - A Validation Test of a Simple Method of Stride Length Measurement Only with Inertial Sensors and a Preliminary Test in FES-assisted Hemiplegic Gait  
Author(s): Takashi Watanabe1, Tasuku Miyazawa2  
1Graduate School Of Biomedical Engineering, Tohoku University, Sendai/JAPAN, 2Graduate School of Engineering, Tohoku University, Sendai/JAPAN

This study aimed to realize simplified gait evaluation system only using inertial sensors in order to support motor rehabilitation, healthcare and so on. In this paper, stride length measurement only with inertial sensors for the simple gait evaluation system was tested. First, a calculation method of the stride length was developed, in which acceleration and angular velocity signals of the foot were used. In order to calculate the stride length, the beginning and the ending of the foot movement during walking were detected by acceleration signal for determination of the integration period of motion acceleration of the foot. The motion acceleration was calculated from acceleration and angular velocity signals. The measurement method was evaluated in 10 m walking of 6 neurologically intact subjects attaching inertial sensors using stretchable band on their feet (shoes). Reference data for the stride were measured with portable walkways with embedded, pressure-sensitive sensors. The average values of error and absolute error of measured stride lengths were 0.38±4.77% and 3.36±3.04%, respectively. Correlation coefficient of the measured length with the reference data was 0.910 and the slope of the regression equation was 0.978. Then, stride lengths of a hemiplegic subject were measured in 10 m walking with and without FES-assisted foot drop correction. Although there was no difference in stride length between with and without the FES-assist, the calculated data from inertial sensor signals supported that the time for 10 m walking measured by therapists decreased when the subject walked with the FES-assist. It was expected that the stride length measurement only with inertial sensor would be practical, and it can be implemented easily.
SP008.2 - A novel Treadmill Body Weight Support system using Pneumatic Artificial Muscle actuators: a comparison between active Body Weight Support system and counter weight system

**Author(s):** Thuc V. Tran, Flavio Praticcio, Shin-Ichiroh Yamamoto

**Abstract:** In recent years, Treadmill Body Weight Support System has been developed and proved the improvement for patients who recover from Spinal Cord Injury. Passive and dynamic systems were shown their capacities to maintain unloading force in the vertical direction, however, there are no system considered that track the moving of the Center of Pressure trajectory during gait training. Our hypothesis is that tracking Center of Pressure trajectory, during gait training, could be more effective than the common system. This paper proposed a new active Body Weight Support system using Pneumatic Artificial Muscle actuators. An active model of new Body Weight Support system with the tracking model of the human center of pressure was developed. The validation tests experiments were implemented with three levels of unloading force 30%, 50% and 70% using new Body Weight Support system and counter weight system for comparison. The speed of the treadmill is set, for all the experiments at 2 km/h. Center of pressure trajectories are recorded for a normal random walk, for the counter weight system and for the Body Weight Support systems. The results showed that the center of pressure trajectory using active system was much fitter with center of pressure pattern of normal gait than counter weight system.

SP008.3 - A Serious Game for Training and Evaluating the Balance of Hemiparetic Stroke Patients

**Author(s):** Pedro Bertemes-Filho, Fabricio Noveletto, Antonio V. Soares, Marcelo D.S. Hounsell

**Abstract:** Stroke is the major cause of disabilities in adults and the second major cause of deaths worldwide. People that survive a stroke present deficits that affect their functional capacities and require rehabilitation for long periods. The use of digital entertaining games has shown to be a helping ally to the rehabilitation process, despite its therapeutic limitations. An alternative to these limitations is the development of games and control interfaces targeted the needs of patients, the so called Serious Games. The aim of this paper is to present the development of a Serious Game for training and evaluation of balance in hemiparetic stroke patients. An integrated biomedical system was, which consists of a balance board with inertial sensors instrumentation and a computer system that runs the game. The aim of the game, called myBalance, is to direct a ball to a target position according to the board signals. Various parameters of the game can be adjusted to comply with patients’ limitations. The game has a scoring system that extracts metric information regarding patients’ performance during gaming. Preliminary results indicate that the system (board and game) can be easily used for training and evaluation of patients’ balance. It was also showed that the game can be used as a metric system for clinical studies. Future works include comparing game scores to standard clinical scales for balance.

SP008.4 - fNIRS-based analysis of brain activation with knee extension induced by functional electrical stimulation

**Author(s):** Misato Ohdaira, Tomoko Kamisawa, Soichiro Morishita, Yinlai Jiang, Osamu Yamamura, Hiroshi Yokoi

**Abstract:** Patients suffering from paralysis due to aging, accidents, or brain injuries are increasing worldwide. Consequently, there is a compelling need for effective methods for the recovery of motor functions. The involvement of brain plasticity has been suggested effective and previous studies have reported that lost motor function and efficiency due to brain damage can be regained by repeatedly increasing and decreasing brain activation. Functional electrical stimulation (FES) has shown its effectiveness in the recovery of motor function. Brain activity usually decreases with the improvement of muscle control by FES. This study investigated the general ability of brain responses during rehabilitation with FES in order to elucidate the recovery mechanism. We monitored the brain activity of one healthy subject with fNIRS over a ten-day period (one experiment per day) during which the knee joint movement was induced by FES with different parameters. The subject was seated in the chair of a leg extension device (Fig.1). The measurement regions covered the primary motor cortex and the somatosensory cortex with transmitters and receivers shown in the right of Fig. 1. Receiver No. 5 in Fig. 1 was positioned on the Cz of the international 10-20 system. We stimulated his left quadriceps muscle with the FES device for 4 seconds. The results suggest that the observed increases and decreases of brain activity induced by FES are common (Fig.2). It is suggested that increasing and decreasing brain activation was evoked by long-term FES stimulation. Further research is needed to examine greater numbers of healthy subjects and patients suffering from paralysis to determine the optimum stimulation parameters for brain activation to involve brain plasticity.
Two healthy volunteers participated in a 4-hr experiment. Stimula

tion pulse, resulting in the need of unnaturally high stimula-
tion frequencies result in rapid fatigue, negatively impacting benefits
of stimulation rehabilitation. To address this issue, researchers have
“spatially distributed” and “sequentially” interleaved stimulation
pulses between multiple active electrodes (Spatially-Distributed-Se-
quential-Stimulation; SDSS; Figure 1A). SDSS allows muscle fibres
to be activated in an asynchronous manner, reducing the stimula-
tion frequency at each active electrode, while maintaining activation
of the muscle as a whole (Figure 1B). Although SDSS can improve
fatigue-resistance of isometric contractions, this method has not
been tested during non-isometric conditions.

Purpose:
To reproduce previous findings that SDSS can improve fatigue-re-
sistance of isometric contractions, and to extend this line of inquiry
to isokinetic conditions.

Methods:
Two healthy volunteers participated in a 4-hr experiment. Stimula-
tion (40 Hz; 0.3-s-on:0.7-s-off; 120-s total) was delivered to the
knee-extensors using SES and SDSS, in separate trials, to generate
isometric (0°/s) and isokinetic (180°/s) torque. Isometric and iso-
kinetic contractions were tested on separate legs in separate trials.
A rest period of 2-hr was provided between repeated testing of each
leg. Protocol order was randomized. Stimulation intensity was set to
generate ~40% maximum-voluntary-contraction.

Results:
Fatigue indices were calculated (final torque/initial torque) for iso-
metric (SES=0.37; SDSS=0.57; Figure 1C) and isokinetic (SES=0.36;
SDSS=0.39; Figure 1D) contractions.

Conclusion:
Previous findings that SDSS can improve fatigue-resistance of iso-
metric contractions were reproduced. However, the effect of SDSS
on improving fatigue-resistance may not be as pronounced during
isokinetic, compared with isometric, contractions.
SP008.7 - Motor Control Assessment using Leap Motion: Filtering Methods and Performance in Indoor and Outdoor Environments
Author(s): Jong J. Kim1, Dave A. Gonzalez2, Adam Mintz2, Eric A. Roy2, James Y. Tung3
1Mechanical And Mechatronics Engineering, University of Waterloo, Waterloo/CANADA, 2Kinesiology, University of Waterloo, Waterloo/CANADA

In this paper, we describe and evaluate a filtering method designed to remove the artifacts from hand/finger kinematics acquired using the Leap Motion controller (or ‘Leap’). We report two experiments evaluating this methods: 1) accuracy and precision compared to an established motion-tracking system (Optotrack) and 2) performance in indoor and outdoor environmental conditions. The main findings were that the filtered Leap finger output: i) compared well to motion capture systems in temporal accuracy and precision, ii) moderately well in spatial accuracy and precision, and iii) adequately in indoor settings, but not in outdoor conditions. These advances will inform further development of new tools to assess human motor control.

SP008.8 - Biceps brachii EMG signals: estimation of dipole sources
Author(s): Peyman Aghajamaliaval1, Pierre A. Mathieu2, Mickael Corinthios1, Michel Bertrand2, Jean Laurier2
1Génie électrique, École Polytechnique, Montréal/CANADA, 2Physiologie Moléculaire Et Intégrative, Institut de génie biomedical, Montréal/QC/CANADA

The biceps brachii (BB) was shown to be anatomically composed of up to 6 innervated compartments from which as many independent electromyographic (EMG) signal sources could be obtained. Extracting several signals from a single muscle would allow upper-limb amputees to produce several forearm/hand movements with a myoelectric prosthesis. While normal subjects were either sitting or standing-up, we investigated how to activate those compartments by using various right upper limb and hand positions. Five pairs of surface electrodes were put across the short head (SH) and 5 others pairs over the long head (LH) of the BB. Five seconds EMG signals were recorded during isometric contractions produced at a constant level. RMS value of each signal was obtained.

EMG signals where assumed to originate from dipole sources within the arm. A peel-off method served to search for up to 6 dipoles which were used as moving sources in a 3-D finite element forward model study (COMSOL). Arm was modeled either as a single or as 4 concentric cylinders (for skin, subcutaneous fat, muscle and humerus). Comparison was made between amplitude of the simulated and experimental signals.

Results for one seated subject are shown in Fig. 1. In column A, there are significant amplitude differences between some of the experimental signals and model predicted values. Differences were reduced in a second iteration during which dipole parameters are readjusted (column B). With a 4 layers model (column C), differences can be larger and it is also observed that some dipole positions are physiologically incorrect (i.e. in the fat layer). So, while the peel-off method provides a first estimate of the dipoles characteristics, the 4 layers model is necessary to do the proper dipoles readjustments that constrain the position of the dipoles to the muscular tissue.

SP008.9 - Validating a Solid-Static Single-Armed Male Prototype Tasked to Produce Dynamic Movement from the Shoulder Through the Preparation Phase
Author(s): Alicia M. Gal1, Adrian D.C. Chan1, Dean C. Hay2
1Computer System Engineering, Ottawa Carleton Institute for Biomedical Engineering, Ottawa/CANADA, 2Physical And Health Education, Nipissing University, North Bay/CANADA

The purpose of this study was to design, implement, and validate a methodology to determine baseline measures during the preparation phase (PREP) of seated weight-bearing locomotion. In order to evaluate this methodology this study investigated the external movement produced by the shoulder joint-centre of the upper limb through a seated downward poling motion. A solid-static anatomically correct prototype was designed to produce isolated dynamic movement about a human’s shoulder joint-centre; this particular investigation replicated the average male weighing 80kg having fixed elbow (135°) and wrist-stick (45°) angles, and dynamic shoulder start angles (-10°, 0°and +10° to the horizon). The prototype was tasked to produce PREP; a phase identified in seated locomotion produced through a double poling fashion. Trajectory and reaction forces created through PREP were evaluated using a standard Newton-Euler mathematical model in conjunction with a 3-dimensional motion capture system and force plate. Trajectory data concluded that the prototype was of reliable and valid mechanical design producing near identical curves for all trials individually as well as combined averages. Evidence also indicated that all trials displayed similar reaction forces, which produced torque in an anticlockwise direction about the shoulder. Since the prototype is solid and designed to mimic the male upper limb data can be used to describe minimal reaction forces onto the shoulder joint produced from PREP. Understanding external forces at baseline measures allows for valid assumptions to be made or dismissed concerning internal forces within the human body. Dynamic biomechanical analysis requires assumptions involving internal and external parameters when producing a movement. The addition of PREP to the seated propulsion cycle is unclear identifying the need to investigate the biomechanics produced through this phase; full arm extension to pick-plant. This study has developed an improved model of the upper limb during seated double poling.
SP009 - Patient Safety, Medical Errors and Adverse Events Prevention Related to Health Technologies and Incident Analysis and Management

SP009.1 - Technological Surveillance and Integrity Monitoring of Infusion Systems
Author(s): David Grosse-Wentrup, Uvo M. Hoelscher
Center For Biomedical Engineering And Ergonomics, Münster University of Applied Sciences, Steinfurt/GERMANY

Infusion therapy is a routine medical procedure. As errors can have potentially fatal consequences, monitoring of infusion systems is mandatory. At present, the technical monitoring of infusions is limited to only a few properties of the infusion system. This passes the demand for vigilance on to the clinical personnel and potentially leaves errors undetected.

By sending small pressure pulses through the interconnected infusion lines, a route map of the infusion system can be created. This map visualizes the connections of infusion lines including line lengths, connection points and connected infusion devices.

This way, errors in the infusion system setup, loosened connections, erroneous stopcock positions and thereby caused under-infusion or reflux can be automatically detected, indicated to clinical personnel, and subsequently corrected before causing harm to the patient.

SP009.2 - Evaluating Patient Safety Risks Related to Oral Chemotherapy: Evolution of a Human Factors Informed Failure Mode and Effects Analysis Framework
Author(s): Melissa Griffin1, Rachel Gilbert1, Larry Broadfield2, Andrea Cassano-Piche3, Anthony Easty1, Patricia Trbovich1,1Centre For Global Ehealth Innovation, University Health Network, Toronto/ON/CANADA, 2Cancer Care Nova Scotia, Halifax/CANADA, 3ibbme, University of Toronto, Toronto/CANADA

Chemotherapy is commonly used to treat cancer, which is the leading cause of death in Canada (PHAC, 2012). Chemotherapy treatment involves the use of complicated and flexible drug protocols to care for patients experiencing different types and stages of cancer. A variety of healthcare professionals, who practice in different locations, are involved in the delivery of chemotherapy. Traditionally, most intravenous (IV) chemotherapy is administered to patients in hospital settings, but more recently oral chemotherapy is being delivered in the home and community. Many patients, families, and providers prefer oral to IV chemotherapy for several reasons, including its perceived convenience (Liu, 1997). Manufacturers are facilitating this shift, with an estimated 25% of the 400 new medications currently in development being formulated as oral medications (NCCN, 2008).

IV and oral chemotherapy have comparable toxicity risks and the potential to cause serious harm when not managed properly. However, oral chemotherapy is associated with some unique challenges, such as access, adherence, and safe handling. Many of these challenges stem from a shift in responsibility for administering chemotherapy from healthcare professionals to patients and their families. With increased attention being paid to oral chemotherapy safety (Neuss, 2013), a Canadian provincial cancer agency approached HumanEra, a team comprised of human factors specialists, to analyze their current practices and identify any risks and opportunities related to oral chemotherapy from a human factors perspective.

Two human factors specialists collected field data using direct observations and semi-structured interviews. Healthcare professionals involved in providing patients with chemotherapy, such as staff in the cancer centre clinics and pharmacy, as well as a number of community pharmacies, were included during data collection. Process maps were created to describe chemotherapy-related processes from when lab work was done through to when chemotherapy was dispensed in the community.

Data were analyzed using a human factors informed failure mode and effects analysis (HF/FMEA) framework. This framework was developed iteratively, and is also presented in the upcoming Human Factors for Health Technology Safety book (Cassano-Piché, et al, in preparation). Unlike more traditional FMEA frameworks, the HF/FMEA framework guiding this assessment included three tests: the severity test, the hazard score test, and the single point weakness test; to prioritize which key failure modes to focus on for the remainder of the analysis, making the analysis more efficient. Using this framework, a total of 201 failure modes were identified, with 73% of those being key failure modes requiring further analysis. Although 147 failure modes were still prioritized as key failure modes requiring further attention and analysis (e.g., patient removes the incorrect number of pills from their bottle), the HF/FMEA framework allowed 54 failure modes to be set aside before time was invested identifying causes and recommendations for these lower priority risks (e.g., pharmacy assistant does not pick chemotherapy drug from shelf).

This presentation will provide an overview of the HF/FMEA framework and highlight results from applying this framework to oral chemotherapy processes in a Canadian province, to demonstrate how HF/FMEA can be used to improve healthcare safety.

SP009.3 - Alarm Management Study in Pediatric Special Care Unit
Author(s): Christopher J. Bzovey1, Paul Prowse2
1Clinical Engineering, Winnipeg Regional Health Authority, Winnipeg/MB/CANADA, 2Clinical Engineering, Winnipeg Regional Health Authority, Winnipeg/CANADA

There have been a number of critical incidents reported where improperly managed alarms contribute to alarm fatigue in clinicians resulting in patient harm or mortality. Numerous studies have been published in the United States; however there appears to be a lack of publications on alarm management investigation studies conducted within Canada.

The purpose of this work was to investigate the current state of alarm communication and management within the Pediatric Special Care Unit (PSCU). The investigation included an environmental assessment, a staff survey, and a review of the alarm event logs from several medical devices. The staff survey investigated current alarm management practices by analyzing self-reported effects of alarm fatigue experienced in the PSCU. The survey identified ventilators and patient monitors as most heavily contributing to alarm load. Alarm logs were collected from those devices.

The environmental assessment revealed that ventilators within the unit are connected to a latching nurse call system, which requires staff intervention to reset. Within 30-40 seconds after alarming, the alarm increases in volume and pitch resulting in greater distress for the staff and patients within the unit. The staff survey identified that the alarm load they experience has a moderate to high effect on their ability to provide safe patient care (Figure 1). Data collected from the patient monitors demonstrated a significant difference between the number of alarms during the day and night shifts (Figure 2).
and severity for each step. Results of the application of FMEA for the major process “treatment planning” are reported here. Hazard index given by the Risk Priority Number (RPN) is found to range from 4 - 270 for various processes and the severity (S) index is found to range from 1 - 10. The RPN values > 100 and severity value ≥ 7 were chosen to flag safety improvement interventions. Number of steps with RPN >100 were found to be 6, 45 and 59 for the three centers. The corresponding values for S ≥ 7 are 24, 21 and 25 respectively. The range of RPN and S values for each center belong to different process steps and failure modes (see table).

<table>
<thead>
<tr>
<th>Radiotherapy Center</th>
<th>Process Step</th>
<th>Potential Failure Mode</th>
<th>Potential Causes of Failure</th>
<th>S</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center I</td>
<td>Evaluate DVH</td>
<td>Minimum Dose At Target Not Evaluated</td>
<td>Lack of Standard Procedures</td>
<td>1-10</td>
<td>4-162</td>
</tr>
<tr>
<td>Center II</td>
<td>Proceed the Image Fusion</td>
<td>Imaging Not Fused Properly</td>
<td>Software Failures</td>
<td>1-10</td>
<td>7-270</td>
</tr>
<tr>
<td>Center III</td>
<td>Insert the Total Dose on TPS</td>
<td>Wrong Dose Inserted</td>
<td>Incorrect Prescription</td>
<td>1-10</td>
<td>4-245</td>
</tr>
</tbody>
</table>

These results show that interventions to improve safety is different for each center and it is associated with the skill level of the professional team as well as the technology used to provide radiosurgery treatment. The present study will very likely be a model for implementation of risk-based prospective quality management program for SRS treatment in Brazil where currently there are 28 radiotherapy centers performing SRS. A complete FMEA for SRS for these three radiotherapy centers is currently under development.

This work demonstrates that alarm load is a problem in the PSCU, and furthermore the intensity is dependent on the time of day. A committee has been established to discuss potential solutions for mitigating the alarm load. The success of this will be discussed during the presentation.

**SP009.4 - Failure Modes and Effect Analysis for Stereotactic Radiosurgery: a comparison among three radiotherapy centers in Brazil.**

**Author(s):** Flavia Cristina S. Teixeira, Carlos E. Dealmeida, Mohammad S. Huq
Lcr, LCR/UERJ, Rio de Janeiro/BRAZIL

Task Group 100 of the American Association of Physicists in Medicine recommended the adoption of prospective quality management techniques such as process mapping, failure modes and effects analysis (FMEA) and fault tree analysis (FTA) for analyzing clinical processes and for designing clinic- and site-specific quality management programs that are based on risk assessment. According to this approach, each facility determines the hazards and risks at their own facility based on their own processes and procedures. Appropriate quality control measures are then put in place to mitigate the risks associated with a given process. The goal of the present work was to evaluate the process maps for stereotactic radiosurgery (SRS) treatment at three radiotherapy centers in Brazil and apply the FMEA technique to evaluate similarities and differences, if any, of the hazards and risks associated with these processes. A team, consisting of professionals from different disciplines and involved in the SRS treatment, was formed at each center. Each team was responsible for the development of the process map, and performance of FMEA and FTA. A facilitator knowledgeable in these techniques led the work at each center. The TG100 recommended scales were used for the evaluation of hazard
SP010 - Biomedical Engineering in Nigeria: A Developmental Overview

Author(s): Kenneth I. Nkuma-Udah, Gideon I. Ndubuka, Kennedy O. Ejeta
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Biomedical Engineering (BME) activities in Nigeria can be said to have started in the 1970s during which collaborative efforts were made by engineers, medical doctors, pharmacists, physicists, technicians and other scientists. Although, the pace of development was hitherto slow, most efforts were in the area of training - short courses, continuing education or professional development. However, the coming of NIBE in 1999 has propelled a steady progress of BME activities in Nigeria. This is rightly so, because Nigerian BME professionals from 1999 started addressing issues concerning them as a professional group. BME activities in Nigeria was further given a big boost in 2007, when the first undergraduate programme in BME started in the Federal University of Technology, Owerri, Nigeria with NIBE contributing the foundation members of faculty. NIBE, which stands for Nigerian Institute for Biomedical Engineering, represents the BME profession and its members in Nigeria and in international organisations. Established in 1999 with the vision “to develop and advance the biomedical science, health and human well-being of Nigeria through modern technological approaches comparable to those obtainable in any developed country of the world”, NIBE has members largely of the various sciences and classical engineering disciplines from universities and hospitals as well as from other institutions/organisations. It has a membership list of over 2000 members, but financially active membership fluctuates between 100 and 200 depending on the BME activity of each year. NIBE is currently structured in 5 divisions - biological engineering; medical engineering; clinical engineering; rehabilitation engineering; and biomedical physics / allied sciences - to accommodate virtually every field in the sciences. It has its 1st annual BME conference in 2000. Since then it has organised 9 national biomedical engineering conferences and 6 national professional development courses in Nigeria. NIBE has published a newsletter, news@nibe since 2000; a professional journal, Nigerian Journal of Biomedical Engineering since 2001; and electronic mail news, e-nibe since 2003. In 2003, NIBE was admitted as the 50th member of IFMBE. The same year, she co-founded the African Union of Biomedical Engineering and Sciences (AUBES) in Ghana while some members were on a Medical Equipment Training. AUBES was established in order to integrate the effort of various African BME professionals and to expand cooperation on a continental basis. Since 2003, NIBE has made effort with AUBES to pioneer the development of BME in Africa. AUBES’s official inauguration and the 1st African Biomedical Conference scheduled to hold in 2005 in Nigeria was cancelled for logistic reasons. However, sustained effort is being geared towards its official inauguration in 2016 in Nigeria. The role of NIBE in developing BME in Nigeria is mainly as a membership group to develop resources for BME by evolving adequate training programmes for members, facilitating accreditation and certification of professionals practicing BME in Nigeria. NIBE is expected to continue to give its members a sense of belonging by becoming the mouth piece of BME professionals in Nigeria. All these development efforts should be a matter of concern for the international BME community.
cases, the biomedical engineers are recruited from abroad to either consult or work as permanent employees. Three training centres in the country have started biomedical engineering training. ECUREI started a biomedical technician diploma before the Ministry of Health initiated a diploma training with Kyambogo University 3.5 years ago. This diploma is supported by the Amalthea trust from the UK. Makerere University started a degree programme 3.5 years ago. With all this training happening, the technicians and engineers job roles have not yet been included in a lot of government hospitals with pay scales a big challenge to many aspiring technicians and engineers in the field.

Methods
A sustainable volunteering project was developed to improve skills of technicians working in seven hospitals. None of the technicians chosen for the project had any formal training in medical equipment management but were routinely involved with the repairs. The main objectives were to improve the process of procurement, repair and disposal of medical equipment by benchmarking with UK and other international standards. A volunteer Biomedical Engineer was recruited from the UK to work as a trainer and provide in-house mentorship to the technician for over 2 years.

The project was in collaboration with the Amalthea trust who provided intensive two weeks training in each year through Kyambogo University. Different parties, including the Ministry of Health, Commercial medical equipment providers and the professional association were always involved throughout the duration of the project. The volunteer also contributed to lecturing and improving the degree programme at Makerere University. Collaboration was formed with the Uganda Industrial Research Institute to replicate the work in other hospitals.

Four technicians were taken to the UK through the commonwealth professional fellowship programme to gain more on job experience.

Results
The technicians showed improved skills, knowledge and confidence about medical equipment management. There has been increased awareness of biomedical engineering profession through workshops and conferences. Inventories were developed using Microsoft Excel and they have been updated yearly since the beginning of the project. There has been increased confidence in the technicians by the clinicians about them handling the medical equipment. The link for the biomedical engineering volunteer between the hospitals and Makerere University means that the students have easy access and can always get feedback from real life scenarios. Some hospitals have set up biomedical engineering workshops and recruited biomedical technicians as a direct result of the project.

SP010.4 - Designing Biomedical Engineering Programs to Prepare for Medtech Industry
Author(s): Shankar Krishnan
Biomedical Engineering, WIT, Boston/MA/UNITED STATES OF AMERICA

The astounding arrays of inventions, innovations and implementations of technologies have resulted in a huge growth in the medical devices and systems worldwide. Medtech industry is instrumental in manufacturing complex medical devices and systems. A vital role is played by Biomedical engineering (BME) in research and development by creating advances in applications of multidisciplinary technologies which ultimately traverse towards improved and efficient health care delivery, which generates consistently increasing demands for biomedical engineers at the international levels. Consequently, the needs for biomedical engineers trigger corresponding requirements for training biomedical engineers, especially for the medtech industry. The responsibility of developing academic programs to train students to gain multidisciplinary knowledge and adequate expertise in research, design, development, manufacturing, operations, compliance and regulatory affairs is bestowed on the academic leaders who face numerous challenges. The objective of this paper is to determine the challenges and present potential solutions in the design of undergraduate biomedical engineering programs to prepare the students for meeting the existing and emerging demands of medtech industry.

The duration of a typical undergraduate BME program is four years in most American Universities. Major challenges are encountered while designing a comprehensive undergraduate BME curriculum within the available duration. Essential factors including the breadth and depth of BME coverage, distribution of relevant theoretical and practical aspects, and, course work, laboratory work, project work knowledge and skillset to fulfill the graduation requirements, in conjunction with appropriate preparation for career paths, are to be considered diligently in the overall design of the BME program. Foundations in mathematics, sciences and engineering are vital prerequisites to the core courses in BME. For achieving superior student outcomes pertaining to conducting experiments and carrying out projects, well-equipped laboratories and faculty mentors with related academic and industrial experience are essential. Additionally, a cluster of elective BME courses catering to the existing and emerging needs of the industry and employers must be incorporated in the curriculum. The aforementioned factors pose strenuous challenges in the BME program design.

A few model designs of BME programs are developed to overcome the challenges cited above. The curricula for the proposed models are formulated employing general structure, track-based structure, and emphasis-based structure. A preferred model is based on emphasis of medical devices and systems in the curriculum coupled with embedded internship or co-operative experiential learning modules to prepare for employment in medtech industry. Real life experiential learning thru placement at a medtech industry or a teaching hospital undoubtedly complements the knowledge and competencies acquired on campus. BME program directors should make special efforts to recruit and retain dedicated faculty and technical staff. Continuing support of resources are necessary for the successful execution of the academic programs. The curricula for the proposed models have been developed in different academic settings and implemented. Extensive experience in designing and directing multiple models for BME undergraduate education lends support to the success of carefully designed site-specific programs to prepare the students for the medtech industry involving medical devices and systems.

SP010.5 - BME vs CE vs HTM vs HbHTA vs EAM. What's in a Name and does it matter?
Author(s): Maden A. Poluta
Human Biology (bme Division), University of Cape Town, Observatory/SOUTH AFRICA

Background:
Technology is increasingly an essential component of effective healthcare delivery in diverse settings. Ensuring that healthcare technologies are optimally planned, assessed, acquired, implemented, managed and replaced is a complex process involving many stakeholders and players. While the adage “Don’t fix what ain’t broke” applies in the context of established practices in different jurisdictions, it is nevertheless important to consider where we stand collectively. Greater alignment, clarity of purpose and standardisation - as well as a common future vision - would support stakeholder engagement, demystify guidance to countries (especially those that
are resource-challenged), support capacity building and facilitate both achievement of critical mass in diverse settings and mobilisation of resources for related activities. This paper provides one perspective of the status quo and makes some suggestions for the way forward, with a focus on engineering/technical disciplines related to healthcare technologies.

**Issues:**

How can we address the lack of uniformity in both nomenclature and practice? For example, BME is often seen as synonymous with CE, but not universally so, and both are referred to by other terms.

What are the generic international classifications pertaining to BME and CE? (Ref: ISCO-08)

How can recognition to be given to the full range of engineering professionals: engineers, technologists and technicians? (Ref: Washington-, Sydney- and Dublin Accords of the International Engineering Alliance)

How different is HTM from Clinical Engineering, and both HTM and CE from the emerging fields of Hospital-based HTA and Engineering Asset Management, respectively?

What are the individual ‘value-adds’ and focus/impact areas for BME, CE, HTM, HbHTA and EAM, and is there merit in unifying/aligning these disciplines?

Figure 1 below shows how the disciplines/specialities addressed could combine in serving a common purpose, while recognising their specific roles and contributions to the overall process.

**Figure 1:** Optimised Life-Cycle management of Healthcare technologies, showing the contribution of supporting disciplines, specialities and fields.

**SP010.6 - Clinical Engineering Certification Program in the Americas**

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The American College of Clinical Engineering’s (ACCE) definition of a clinical engineer is a professional who supports and advances patient care by applying engineering and managerial skills to healthcare technology. One of ACCE’s mission statements is to define a body of knowledge on which the profession is based. Using the definition and the information received from a body of knowledge survey sent to over 500 practicing clinical engineers from around the world, in 1990 a clinical engineering certification exam was created.

The Healthcare Technology Certification Commission (HTCC) was formed to oversee the process and a Board of Examiners was formed to create the exam and test the candidates. The financial aspects of the certification process are managed by ACCE on behalf of the HTCC.

After several years it became apparent that the process could be adopted by other countries. In 1995 the Canadian Board of Examiners was formed and the CCE exam became a collaborative process between the Canadian and US Board of Examiners. In the meantime collaboration with several countries in South and Central America as well as the Middle East has been discussed.

The exam process includes three major components; the application, written exam and oral exam. The application process consists of the simple application, university transcript and three professional references. Through this the candidate must demonstrate they have sufficient clinical engineering experience to qualify to take the exam. The exam consists of 150 multiple choice questions distributed across CE topics in the same proportion as they appear in the body of knowledge survey results. The oral exam is a structured exam questioning the candidate on three separate real life clinical engineering scenarios.

The Board of Examiners publish an application and a handbook to guide the candidate through the process. These are available on the certification page of the ACCE website (www.accnet.org). This page also includes information on the CCE renewal process, recommended resources for use in preparing for the exam and a list of those currently certified. 221 certified clinical engineers are currently listed.

**SP010.7 - Biomedical Technology Online Courses for the Americas**

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Latin America and the Caribbean countries are rapidly expanding their healthcare technology usage. Physicians, patients and their families are understanding better the relevant influence of healthcare technology based on clinical, ethical, social, and economic health outcomes. Companies are eager to expand to this growing area, and donations from developed countries of new and used equipment continue.

In general, the regional status of Latin American and Caribbean countries includes: little medical device regulations, a high percentage of devices that are out of service, weak after sale device support with nearly all service from manufacturers or their representatives, a shortage of technical staff in hospitals, very limited maintenance budget, inadequate number of healthcare staff appropriated trained and limited technology management.

What is needed is training and education of staff at the hospital level in the various technologies used in healthcare. Education and training of clinical and technical staff interacting with medical technology enhances the effectiveness and safety of medical care.

Through a grant from the PAHO Foundation (formerly PAHEF), biomedical technology online courses were developed for clinical and technical staff. Online training via the Internet allows 24x7 accesses to training resources in an asynchronous fashion. Extensive use of web resources and simulations enhance the courses. The course topics include anatomy/physiology, engineering concepts, physiological monitors, cardiac therapy devices, ventilators, infusion technology, all imaging modalities, surgical systems, clinical information networks, and therapy devices. The initial English version has been taught in the USA since 2007. The courses were translated to Spanish and adapted for use in Latin America for use in 2008. Over 1000 students from 28 countries have taken the courses at the University of Vermont USA, Universidad CES in Colombia, Universidad Tecnológica Nacional - Facultad Regional Mendoza in Argentina, and Pontificia Universidad Católica del Perú.

In September 2014, the online courses were placed on the PAHO...
Virtual Campus for Public Health. The PAHO Virtual Campus for Public Health with over 100 courses offered currently has students from over 140 institutions enrolled from the Americas. The PAHO platform allows a broader range of students from the Americas to enroll in the courses especially those without the funds for university courses. Forty-eight students from twenty-one countries enrolled in the twenty-four week English and Spanish courses – Introduction to Biomedical Technology. Course assessments and evaluation will be available following the end of course on April 24th and will be presented at the WC2015. Future plans are for translation of the courses to Portuguese and adaptation to Brazil, and additional educational offerings on healthcare technology planning and management.

SP011 - Overview of Gender Roles in Medical Physics in North America

TRACK 18: GENDER, SCIENCE AND TECHNOLOGY

SP011.1 - Gender, Science and Technology: The Role of Women in Medical Physics

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The role of women in the field of medical physics has been steadily increasing over time. Data obtained from the AAPM shows that the women comprise an increasing percentage of the overall membership. In the late 1960s, less than 10% of the membership was female, however this has been steadily increasing and in 2014, 21% of the full membership is female and 29% of the overall membership (including student members) is female. If this trend continues at the same rate, by 2044 we would expect equal representation of males and females in the field. It is important to not only evaluate the membership, but also the engagement of women within the active membership and leadership positions within the field and professional society. AAPM staff assisted in mining the membership database for statistics on gender representation in the society membership, engagement in the AAPM, presentations at the annual AAPM meeting, and AAPM leadership. Full membership was used as the gender baseline as student members are not allowed to serve on committees, however they do present at the annual meeting. Engagement in the AAPM was classified as membership on an AAPM committee, which has the structure of 3 councils (Professional, Educational, and Science) under which there are several committees, subcommittees, working groups, and task groups. Presentations at the annual meeting were evaluated based on authorship, first author presenting a poster, first author presenting at the podium (oral), session moderators, invited speakers, and invited speakers in the educational, professional, and scientific track. Presentation data was obtained over the past 5 meetings (2009-2014). Leadership in the AAPM is defined as members of the Board of Directors (nominated by a committee and elected by the full membership or elected from a local chapter), membership on the Executive Committee (nominated by a committee and elected by the full membership), and President (nominated by a committee and elected by the full membership). Gender representation in distinguished awards given by the society was also evaluated.

Of the AAPM membership currently serving on a committee, working group, or task group, 21% are female, the same ratio of women in the AAPM membership. Further evaluation of ‘very active’ members, defined as membership in 5 or more committees, found that this representation is maintained, with 20% of very active members being female.

Evaluation of the past 10 AAPM annual meeting shows that of the over 60,000 authors of AAPM abstracts, 16% were female. 20% of the 6,794 poster presentations were given by women and 18% of 6,947 oral presentations were given by women. Abstracts acceptance and placement in a poster or oral session (highest scored abstracts) are based on single blind reviews (authors’ names are known to the reviewers). Session moderators are selected by the scientific program committee and of the 451 moderators over the past 10 years, 16% were female. The AAPM Meeting Coordination Committee invites speakers for educational, professional and scientific sessions. Over the past 10 years, 17% of the invited speakers in educations sessions have been female, 23% in the professional
The current Board of Directors for AAPM is comprised of 46 individuals, 10 of whom are female (22%). Historically, of the 18 Secretaries of the AAPM, 2 have been women (11%) and 7 of the 15 Treasurers have been women (47%). There have been 57 presidents of the AAPM society, 3 of whom have been women (5%). The first female president of the AAPM was in 1982, the last 2 in 2007 and 2009. Of the 897 awards bestowed by the AAPM, 9% have been awarded to women. The William D. Coolidge Award recognizes ‘an AAPM member for an eminent career in medical physics. It is the highest award given by the AAPM’ and has only been awarded to one woman, in 1977.

These trends show promising inclusion of women in medical physics. The increase in the number of women pursuing careers in medical physics is evident by the steady increase in the percentage of women making up the membership. It is encouraging to see that this rate of women entering the field is also matched by active engagement in the society (through membership on committees) and emerging in leadership, as seen in membership of the Board of Directors, however not yet matched at the presidential level.

Learning Objectives:

1. Highlight the role of women in Medical Physics.

2. Evaluate the engagement of women in the American Association of Physicists in Medicine.

3. Understand gender related issues in science and technology fields.

**SP011.2 - Biography of Women in Medical Physics: Maryellen Giger, Ph.D.**

**Author(s):** Maryellen L. Giger  
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My brothers and I were first-generation college and were raised with the importance of education. Following the completion of my Bachelor’s Degree in Mathematics, Physics, and Health Sciences from the Illinois Benedictine College, I studied Physics at the University of Exeter, earning a Master’s Degree. This experience led me to the University of Chicago to study Medical Physics, where I earned my PhD in 1985. I continued my tenure at the University of Chicago becoming faculty in 1986 in the Department of Radiology. At the University of Chicago, I have served as Director of the Advanced Imaging Program in the Cancer Research Center, Director of our CAMPEP-accredited Graduate Program in Medical Physics, and Chair of the Committee on Medical Physics. I am currently the A. N. Pritzker Professor of Radiology/Medical Physics and Director of the BSD Imaging Research Institute at the University. My passion for medical physics began while working summers during college at Fermi National Laboratories where I assisted in the beam diagnostic group and the neutron therapy group. I have also served as President (and Chairman of the Board) of the American Association of Physicists in Medicine, Board member of SPIE, and Editor-in-Chief of the SPIE Journal of Medical Imaging. I am a Fellow of AAPM, AIMBE, and SPIE. I was honored to be elected to the National Academy of Engineering and to be named by the International Congress on Medical Physics as one of the 50 medical physicists with the most impact on the field in the last 50 years. I feel that my most significant scientific achievement was providing leading contributions to the field of computer-aided diagnosis. I have more than 170 peer-reviewed publications (over 300 publications), more than 20 patents, and mentored over 100 graduate students, residents, medical students, and undergraduate students. Also, my husband and I have raised our four children through various trips to AAPM, SPIE, and other scientific meetings. The best part of my “job” is when my student becomes a colleague. I look forward to sharing my experience at the World Congress.

**SP011.3 - My STEM story: from Martinique in the Caribbean to Quebec City, through France and Vietnam**

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It is always a bit intimidating to be asked to come forward to talk about one’s personal life, experiences and career path. Someone said stories can move people and inspire them. That is for big stories, I would say. My aim would be just to send seeds in the wind and who knows? May be one will bear fruits? So to start, I am a medical physicist born and raised in Martinique, a French region in the Caribbean. I have a biomedical engineering background with a master in medical technologies from Toulouse Paul Sabatier University, and a specialization in radiation physics and imaging. Two long-term internships in Toronto had a major impact on my following choices and did actually prove to influence all the rest of my career path until my current job position in Quebec City. But that is a long story that I cannot tell in a few words, because I would have to start with the very beginning: my thirst for knowledge of the human body and its biology and my first interest in physics with the moon and astronomy. To this I have to add, the meeting of important role models and mentors to whom I could always refer and who could share their own experiences with me. Also I could tell you about my years of training at the Curie Institute, at the Gustave Roussy Institute and my first position as a junior medical physicist at the Georges Pompidou European Hospital in Paris and also about an experience within the experience working in Vietnam. But more importantly I would like to emphasize on the challenges and obstacles that I overcame. I will also share some strategies that worked for me so that you too can be convinced that the only limits are the ones that we imposed to ourselves. And finally, since stories without actions are meaningless, I will speak about an initiative here today.

**SP011.4 - My strategies for living (and enjoying) academic research**

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During the completion of my Bachelor’s degree in Physics at the University of Toronto, I became interested in Medical Physics, which led me to pursue a Master’s in Medical Biophysics from the University of Toronto. I completed my PhD in Medical Biophysics from the University of Western Ontario, where I focused on novel x-ray imaging techniques. I was awarded a Post-Doctoral Fellowship by the Medical Research Council of Canada, which I completed at Stanford University. Following my fellowship, I joined the faculty at Stanford School of Medicine, where I am currently a Professor (Research) of Radiology. I have had the honor of receiving the Young Investigator’s Award from the American Association of Physicists in Medicine, and the Greenfield Award for Best Paper published in Medical Physics. I have published over 100 peer reviewed articles and I am currently the PI on two NIH funded grants. At each stage of my career I have been fortunate to have mentors who have provided sage advice and guidance. I look forward to an exciting World Congress and the opportunity to share my experience in the Gender, Science, and Technology Track.
SP011.5 - Early exposure to science leads to fulfilling career in medical physics
Author(s): Renee X. Larouche
Radio-oncologie, CHUM - Hôpital Notre-Dame, Montreal/Canada

I have a happy and fulfilling career working in the field of clinical medical physics for almost 13 years. Although I love my work, finding the perfect balance between work, family life, and volunteering is not an easy task to accomplish. After working in two community radiation oncology clinics, one in Canada and the other in the USA, I finally settled in Montreal. I am now currently employed at the Centre hospitalier de l’Université de Montréal (CHUM- Notre-Dame hospital) in the department of radiation oncology. My general interests are in safety and risk management as well as the implementation of more robust processes in the clinic. Since 2012, I am the Deputy Chief Examiner for the Canadian College of Physicists in Medicine (CCPM). This opportunity allows me to meet a number of young medical physicists from all across Canada.

My life experience in the world of sciences has been very positive. I have received encouragement, worked in nurturing conditions and have had great role models. I was exposed to physics at a very young age when a neighbor who was a physicist recognized my interest in science and nurtured it. In high school, I enrolled in a special science program. This constructive early exposure to science kept me motivated.

We were only three female students majoring in undergraduate physics. The gender issue had never been so obvious. The small number of women did not impact my sense of belonging. Although I felt lonely at times, I wanted to be a physicist just as much as anyone else in that classroom. Fortunately, I met a group of young women enrolled in science or engineering programs and we found ourselves together. The gender issue had never been so obvious. The small number of women did not impact my sense of belonging. Although I felt lonely at times, I wanted to be a physicist just as much as anyone else in that classroom. Fortunately, I met a group of young women enrolled in science or engineering programs and we found ourselves together. This was a great time in my life: in fact, a friend I made through WISE women enrolled in science or engineering programs and we found ourselves together. This was a great time in my life: in fact, a friend I made through WISE.

As a graduate student in medical physics, I realized that confidence plays a major role when expressing your ideas. Indeed, more importance was given to oral expression during exams than when I was an undergraduate student: I had never experienced the somewhat daunting situation of being questioned by a panel of examiners orally before. I will always remember the stress and fear associated with these exams, but I found that being well prepared and organized was key and is still the solution in my case. I keep this in mind when preparing oral exams for the CCPM.

Fear is often a hurdle for someone to attain his or her potential: fear of not succeeding, fear of ridicule or fear of rejection. The truth is that you are letting yourself down when deciding not to try. Getting out there, pushing yourself is how you are able to develop and, looking back, be proud of what you have accomplished.

SP013 - MRI: Methods

SP013.1 - Numerical Simpson’s Rule for Real Time and Accurate T2* maps generation Using 3D Quantitative GRE
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Introduction: Quantitative T2* maps can be generated using different approaches, the golden standard being the nonlinear least square (NLLS) exponential signal decay fitting technique. It can also be generated using a logarithmic linear fit (LLF). However, the above mentioned methods based on curve fitting are time consuming and their use in real time challenging. NumART2* approach introduced by Hagberg et al. (2002) computes in real time the T2* but remains echo spacing and signal noise dependent. In this work, we propose an alternative approach relying on Simpson’s rule integration that generates in real time accurate T2* maps even in the presence of large echo spacing and high noise value.

Materials and Methods: We propose a method based on Simpson’s rule for integrating the temporal signal decay. Instead of a linear approximation (e.g. NumART2*), Simpson’s rule combines trapezoidal and midpoint rules to better interpolate the signal decay between echoes. To test our hypothesis, we used simulated brain MRI data (MNI, Canada) and 20 in vivo scans performed on a 3T Magnetom Trio (Siemens Healthcare, Erlangen, Germany) using the following parameters: Echoes/GRE/α/TR/TE1/ΔTE/size=32/Bipolar/8°/47/1.23/1.23ms/136×136×112. An offline generation of T2* maps was realized using LLf, NLLS (expo) and NumART2*. The maps were evaluated and compared in terms of signal echo spacing and image noise level.

Results and Discussion: In the presence of small echo spacing (ΔTE/T2*<0.2), the T2* maps were well generated by all methods, with a slight overestimation when using NumART2*. When ΔTE increases (ΔTE/T2*>0.2), NumART2* tends to overestimate the T2* values, although accuracy is well maintained by the other methods. These results can be explained by the quadratic interpolation of signal decay between the echoes that Simpson’s rule uses to approximate the area under the signal decay rather than a linear approximation that NumART2* uses. For low noise levels (<15%), all methods provide highly accurate results. NumART2* starts to diverge when the noise level becomes significant (>15%), while Simpson’s rule, linear and NLLS fit remain insensitive to added noise. Simpson’s rule combines two approximations, namely the midpoint and trapezoidal rules, to compute the signal integral. This combination enables to approximate well the signal decay between two echo points using a smooth quadratic interpolation even in the presence of high noise level, and as such, provides accurate T2* maps.

Conclusion: We proposed an alternative T2* maps generation which relies on Simpson’s rule to approximate the geometric area under the signal decay. The method allows rapid whole brain mapping of T2* with a high accuracy even in the presence of large echo spacing and high noise level.
SP013.2 - Optimization of Pulse-Triggered fMRI Measurement Delay with Acoustic Stimulation

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The purpose of the study was to examine whether improvement of activation maps of auditory cortex and brainstem nuclei is possible when the delay between the cardiac induced pulse signal and the measurements is optimized. Subsequently, the comparison of the height of brain activity obtained for different stimuli- classical and rock music. In five healthy, right- handed volunteers (the mean ages 25.4 ± 2.8 years old), musical stimuli were presented binaurally in a block design. Evaluation was performed using 'Matlab' and 'SPM-8new' software with statistical threshold p< 0.001 (auditory cortex, AC) and p< 0.01 (brainstem). Our results suggest that the manipulation of the trigger delay (TD) time changes the degree of activation in auditory cortex and brainstem nuclei. Detection of auditory cortex was in 16% (TD=0), 30% (TD=200), 8% (TD=400) and 9% (TD=800) higher than without cardiac gating examinations, and correspond to the 41 and 22 Brodmann areas. The 3-selected slices volume included the medial geniculate bodies (MGB), lateral lemniscus nuclei (NLL), superior olivary complex (SOC) and cochlear nuclei (CN). The height of activation depends on duration of trigger delay. Therefore, using various TD time proves that it is possible to increase ability to detect activation in subcortical auditory structures - another method to reduce image signal variability, which was caused by brainstem motion. Examinations with rock type of music bring better than classical.

SP013.3 - Improvement of Pseudo Multispectral Classification of Brain MR Images

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Introduction: Several advanced applications using morphological MRI frequently require segmentation of the imaged volumes. The accurate interpretation of information pertaining to investigation of brain alterations relies on accurate and reproducible brain tissue classification. Different approaches based on thresholding, cluster analysis, a priori information about anatomy and Bayesian classification have been proposed. However, many of them fail when classifying specific regions with low contrast between tissues. In this work, we introduce an enhanced method to classify brain tissue by combining a pseudo-multispectral color transformation (PMC) and improved K-mean clustering. The proposed approach is compared with FSL classification (FMRIB, Oxford, UK).

Materials and Methods: Gray and binary color spaces are commonly used by image processing methods. However, the contrast between brain tissues in some regions is very low e.g. cerebellum(WM and GM interfaces). Consequently, methods fail and wrong classifications might occur. To overcome this problem, the first step consists, after skull stripping, in transforming the T1-MPRAGE data to multispectral data containing 3 different images CIE-XYZ. To better separate neighboring values in WM, GM interfaces, normalized 3-channel data values are weighted by root square function (RSF). RSF minimizes low contrast region brain tissue overlapping. In the second step, an enhanced iterative and non-deterministic K-mean clustering is applied for image classification. The number of K-clusters is initially set to be maximal; the algorithm repeats classification with decreasing K until convergence. Subsequently, gap criterion, used to evaluate the optimal number of clusters, is calculated. Optimal K-cluster is then estimated. In addition, GM, WM and CSF centroid distribution templates are estimated beforehand using more than 70 human and a couple of simulated data. Based on these parameters, brain tissue classes computed earlier are corrected and reassigned to the new optimal classes. To evaluate our approach, we used 4 numerical brain atlas templates where GM, WM and CSF volumes are known beforehand (ground truth). In addition, 10 clinical MRI studies scanned on a 3.0T Skya (Siemens Healthcare, Germany) using T1-MPRAGE sequence with the following parameters: flip/TE/TR/TI=100/4/9.7/20ms. These data sets were classified using PMC and then compared with FSL classification.

Results and Discussion: The numerical brain tissues are classified using the enhanced PMC algorithm with a high accuracy (90% for WM, 101% for GM and 108% for CSF) against FAST-FSL (85% for WM, 119% for GM and 86% for CSF). Silhouette plot indicates that PMC better separates clusters compared to FAST-FSL classification even in presence of low CNR and partial volume effect. The clinical studies show that the proposed approach is faster and more accurate, especially in region with low CNR e.g. cerebellum artery vitae where the WM and GM are better delineated.

Conclusion: It can be concluded that enhanced PMC classification provides a fast and accurate brain tissue classification. This approach overcomes the low CNR and partial volume effect present in some brain regions, e.g. cerebellum artery vitae and near the temporal lobe region and seems to be promising for clinical and research applications.

SP013.4 - Image reconstruction of RF encoded MRI signals in an inhomogeneous B0 field

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Introduction: Conventional Magnetic Resonance Imaging (MRI) use a uniform main magnetic field (B0) to polarize the sample being imaged. Non-homogeneity in the B0 field leads to image distortion. In practice it is impossible to have a perfectly homogeneous B0 field so shim coils are used to remove the inhomogeneity of the field. However, shim coils and other B0 homogeneity requirements result in expensive and heavy MRIs. To produce truly portable MRI equipment, the requirements for homogeneity of the B0 field could be removed. When used with TRansmit Array Spatial Encoding (TRASE) [1] to encode information instead of using traditional B0 gradient coils an MRI with an inhomogeneous field could be portable [2]. The TRASE method encodes spatial information through the use of spatially varying B1 transmit phase fields. The feasibility of the reconstruction of TRASE signals under B0inhomogeneity from a mathematical perspective was investigated.

Method: TRASE signals were simulated for a discrete Shepp and Logan mathematical phantom inside a TRASE RF coil set, composed of a combination of circular Maxwell and Helmholtz coils, in an inhomogeneous B0 field. The field assumed was \( B_0(x,y) = A x^2 + B y^2 + C \) where \( A = 0.1, B = 0.2 \) and \( C=0.08 \). The simulated TRASE MRI signals were reconstructed using a regularized least squares reconstruction method. The signal from the phantom \( p \) can be written in matrix form, with appropriate re-indexing of the collected signal data points, as \( S = [T] p \). The image may then be reconstructed using constrained least squares technique. Here a regularized least squares reconstruction was done by adding Tikhonov regularization as \( R = \text{argmin} \{ \langle [T] R - S \rangle^2 + \mu \| R \|^2 \} \), where \( \mu \) is a regularization parameter, \( \| \) is the identity matrix and \( R \) gives the approximate solution for \( p \).
**SP014 - Bone Mechanics**

**SP014.2 - Improved Semi-automated 3D Kinematic Measurement of Total Knee Arthroplasty Using X-ray Fluoroscopic Images**

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Accurate measurement of 3D dynamic kinematics of total knee arthroplasty (TKA) is very important for evaluating the outcome of surgical procedures and for improving the implants design and clinical outcome. In order to achieve 3D kinematic analysis of TKA, 2D/3D registration techniques, which use X-ray fluoroscopic images and computer aided design (CAD) model of the knee implants, have been applied to clinical cases. However, in previous study, these techniques have needed time-consuming and labor-intensive manual operations in some process, and particularly the process of the manual initial guess poses of the CAD model for each X-ray image was problem for practical clinical applications. In this study, we propose an improved method for semi-automated 3D kinematic measurement of TKA using X-ray fluoroscopic images. The proposed initial pose estimation method of the model is based on the use of a transformation with feature points extracted from each X-ray image using speeded up robust features algorithm. In order to ensure the validity of the proposed method, in vivo experiment using X-ray fluoroscopic images of 4 TKA patients during knee motions was performed. As a result of experiment, 3D pose of the model for all X-ray images except for the first frame was automatically stably-estimated, and the success rate (X-ray frame number within error of 1mm / 1 degree relative to all X-ray frame number) for the femoral and tibial component were 83.7 % and 73.5 %, respectively. In addition, the success rate with the proposed method was higher than a conventional method. Consequently, the present method was thought to be very helpful for practical clinical applications.

**SP014.3 - The influence of screw length and stiffness on the tibial mechanical environment in ACL reconstruction**

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**Introduction & Objective**

Anterior cruciate ligament (ACL) reconstruction is the primary treatment for the ACL injury in orthopedics. However, the post-operative graft laxity has been frequently reported, which would cause knee instability and osteoarthritis in long-term [1]. The interference screw is the popular implant for the graft fixation. It may change the surrounding mechanical environment, induce the undesirable bone remodeling, and lower the graft fixation strength. Therefore, this study aimed to quantify the influence of the screw on the distribution of stress energy density (SED), which correlated with the bone remodeling.

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**Fig. 1:** 128 *128pixel phantom and reconstructions. (a) Phantom. (b) Reconstructed image from a TRASE coil in a homogeneous B0 field. (c) Reconstructed image from a TRASE coil in an inhomogeneous B0 field.

**Results/Conclusion:** Fig. 1 shows regularized least squares inversion of simulated signals from a TRASE coil in an inhomogeneous B0 field. The result is comparable to the reconstruction from a signal generated in a homogeneous B0 field. This is the first step in showing that TRASE in an arbitrary B0 field is possible. The next steps include simulations via the Bloch equations to model the effect of inhomogeneities on the flip angles attained.

Methods
The finite element model of single-bundle ACL reconstruction was developed. The SED distributions in tibia under the compressive, valgus, and rotational loadings were applied. The influences of the screw length and stiffness on the post-operative SED were calculated.

Results & Discussion
The compressive loading played an predominant role among the three loadings. Under the compressive loading, the SED beneath the screw shaft was decreased, whereas the SED above the screw shaft was increased. Extremely high SED occurred near the screw head and tip.

Increasing the screw length would potentially promote the bone healing at the proximal part of the tunnel, yet aggravate the SED alteration at the distal part. Using a screw modulus approaching to the bone could reduce the undesirable SED alteration.

Conclusion
In ACL reconstruction, using a long screw with the modulus approaching to the bone could provide a beneficial mechanical environment for the post-operative rehabilitation.

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References

SP014.4 - A new method for determining the effect of follower load on the range of motions in the lumbar spine
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In this study, a new method of applying follower load in finite element (FE) model of lumbar spine was presented. The effect of follower load on the range of motions (ROM) in lumbar spine was also investigated. A three-dimensional nonlinear FE model of lumbar spine (L1-S1) has been developed and validated. Connector elements between each pair of endplates were created to apply follower load. The endpoints of each connector were close to the center of endplate. The follower load of 0N, 500N, 800N, 1200N were respectively applied to explore their influence on the motion response of lumbar spine to the moment of 7.5NM in three principle planes (extension, flexion, right bending, left bending, right torsion, left torsion). The results showed that the direction of follower load was almost along with the curvature of spine and induced very small segmental motion. The follower load made the ROM of lumbar spine slightly increase in extension, while produced the decrease in ROM in other five moments. This stiffening effect became more obvious with an increase in the follower load. The largest percent decrease in motion of lumbar spine due to pre-load was in left torsion (47%), and then right torsion(42%), right lateral bending (21%), left lateral bending(20%), flexion(11%).
Conclusions. Beta Enhancers show to be a complementary tool to improve the BNCT of very superficial tumors cases, without significant perturbation of the primary neutron beam used for the treatment.

SP015.2 - Nanoparticle Enhanced Radiation Therapies: Is There a Synergy with Chemotherapies?

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**Introduction**

Nanoparticles can enhance the radiation dose, but have exhibited cytotoxicity, which is highly dependent on the ability of nanoparticles to penetrate the cell membrane and accumulate within the cell. Both radiation enhancement and nanoparticle uptake is regulated by the nanoparticle surface characteristics, their size and chemical composition. The goal of this study is to identify the individual and combined synergistic toxicity of radiation therapy and chemotherapy with gold nanoparticles (GNPs). The existence of a synergy would enable the radiation dose and the systemic dose from chemotherapy drugs to be reduced, thereby reducing side effects. Local treatment efficacy, through the synergistic coupling with nanoparticles, would be enhanced.

**Method**

For the human colon adenocarcinoma (LoVo) cell line, the clonogenic survival response was determined for a 50 kVp beam produced by a Pantak and a 6 MV beam produced by a Varian Novalis linear accelerator, for the chemotherapy drug 5-fluorouracil (5-FU) and for GNPs of diameter 4 nm for a range of concentrations. The GNPs were manufactured using precipitation method and stabilised with PEG. The therapies were combined in pairs to identify individual synergies first, then all three (radiotherapy, nanoparticles and chemotherapy) were combined to establish cumulative effects.

**Results**

Radiation doses for both energy beams and concentrations of GNPs and 5-FU were chosen such that in combination a paired total loss in cell survival was predicted on the basis of no synergistic effects to be of approximately 50%. The doses used were 1 Gy (kV radiation), 2 Gy (MV radiation), 0.5 µg/mL 5-FU and 50 µg/mL GNPs. It was found that the cells are more sensitive in the kV beam than in the MV beam for the same dose (Figure 1A & 1B), the result of differences in LET. The 5-FU and GNPs at very low doses appear to cause an increase in clonogenic survival however this is not statistically significant.

**Conclusion**

The nanoparticle toxicity was measurable but small and was concentration dependent. The response to kV radiation produced a greater decrease in survival than MV radiation. The 5-FU response was determined and 50% survival was approximately 1 µg/mL. These results lay the groundwork for synergistic effects. In vivo studies will confirm the translation of our findings.

SP015.3 - Change in Hounsfield Units due to lung expansion as a predictor of LAD and heart displacement in patients undergoing deep inspiration breath hold for left sided breast cancer

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**Aim:** Deep inspiration breath hold (DIBH) is a cardiac sparing technique for patients with left sided breast cancer undergoing external beam radiotherapy. Little work has been published on patient-specific quality assurance for DIBH. This study aims to assess the relationship between change in lung Hounsfield Units (HU) that occurs between a free breathing (FB) CT scan and deep inspiration breath hold (DIBH) scan and the displacement of the heart and left anterior descending (LAD) coronary artery from the radiation target volume.

**Methods:** Ten consecutive left sided breast cancer patients underwent a FB and a DIBH CT scan. A single clinician contoured the heart and LAD for all patients. The mean lung HU were sampled over a 2 cm (length) area spanning across the lung on the coronal plane above the diaphragm. For assessment of heart and LAD displacement, a line was drawn on the axial slice using the CT software between the medial and left lateral ball bearings to define a region of interest (reference line), which typically would correspond to a high dose region. The distance of the anterior aspect of the LAD, as well as the amount of heart present from this line was measured on both scans.

**Results:** The heart and LAD displacement measured from the reference line as a function of the relative change in HU is shown in Figure 1 and 2, respectively. Displacement was found to increase with relative change in HU for the left lung. There was no significant correlation with the right lung.
Materials & Methods — The cation-exchange resin, Amberlite IR-120 (Sigma Aldrich, USA) which is commercially available in large beads (620-830 μm), was crushed and sieved into size of 20-40 μm and labelled with 1 g of 152SmCl3 salt prior to neutron activation. Therapeutic activity of 3 GBq 153Sm was aimed based on the standard activity used by the 90Y SIR-Spheres. The samples were irradiated in 1.494 x 1012 n.cm².s⁻¹ neutron flux for 6 h. Characterization of the microparticles, gamma spectroscopy, and in-vitro radiolabelling studies were carried out and compared to a commercially available resin readily made in 20-40 μm, Fractogel EMD SO3⁻ (S) (Merck, Germany).

Results — Fourier Transform Infrared (FTIR) spectroscopy of Sm-Amberlite microparticles showed unaffected functional groups within the resin, following size reduction of the beads. However, the microparticles were irregular in shape as shown by the electron microscope. The radioactivity achieved after 6 h of neutron activation was 3.104 ± 0.029 GBq. The specific activity per microparticle for 153Sm-Amberlite and 153Sm-Fractogel were 55 Bq and 49 Bq, respectively. Gamma spectroscopy data showed that no radioactive impurities were detected in 153Sm-Amberlite samples but there was a detectable amount of 24Na in the 153Sm-Fractogel samples. Furthermore, Energy Dispersive X-ray (EDX) spectroscopy of Sm-Fractogel showed presence of chlorine impurity but no significant impurities were observed in 153Sm-Amberlite samples. Radiolabelling efficiency of 153Sm-Amberlite tested in distilled water and blood plasma were excellent (99.9 and 96.9%, respectively) whilst 153Sm-Fractogel showed lower labelling efficiency (82.3 and 92.9%, respectively) over a test period of 48 h.

Conclusion — Despite the irregular shape due to mechanical grinding of the resin, 153Sm-Amberlite formulation showed excellent radiolabelling efficiency and no impurities were detected during the labeling and neutron activation processes. In comparison, the presence of chlorine and 24Na in Sm-Fractogel formulation as well as its lower radiolabelling efficiency make it less suitable to be used for radioembolization of the liver tumour.

Conclusion — 153Sm-Amberlite microparticles presented suitable characteristics for liver radioembolization as an alternative to 90Y. It has advantage over the 90Y for being able to do post-procedure imaging to estimate treatment efficacy. Dosimetric study needs to be carried out to estimate radiation dose contributed by the gamma radiations from the 153Sm. Further animal studies are also needed to verify its in-vivo distribution, and biochemical stability.
models for EBRT treatment dose calculations obsolete, in most clinical situations. For pregnant patients however, the abdominal anatomy is routinely excluded or shielded, during the acquisition of the treatment planning CT, and therefore cannot be included in out-of-field dose calculations.

This study therefore aimed to take existing anatomical models of pregnant women, currently used for radiation protection and nuclear medicine dose calculations, and adapt them for use in the calculation of fetal dose from external beam radiotherapy (EBRT).

The models investigated were ‘KATJA’, which was provided as an MCNPX geometry file, and “RPI-P6”, which was provided in a simple, voxelized binary format. In-house code was developed, to convert both models into an ‘egsphant’ format, suitable for use with the BEAMnrc and DOSXYZnrc Monte Carlo codes. The geometries and densities of the resulting phantoms were evaluated and found to accurately represent the source data.

As an example of the use of the phantoms, the delivery of a cranial EBRT treatment was simulated using the BEAMnrc and DOSXYZnrc Monte Carlo codes and the likely out-of-field doses to the fetus in each model was calculated. All sources of out-of-field dose (radiation leakage from the linac head, scatter of the primary beam from the linac head and the intervening air, and scatter of the primary beam within the patient) were included in the simulation.

The results of these calculations showed good agreement (within one standard deviation) between the doses calculated in KATJA and PRI-P6, despite substantial anatomical differences between the two models. For a 36 Gy prescription dose to a 233.2 cm³ target in the right brain, the mean doses calculated in a region of interest covering the entire uterus were 1.0 +/- 0.6 mSv for KATJA and 1.3 +/- 0.9 mSv for PRI-P6.

This work is expected to lead to more comprehensive studies of EBRT treatment plan design and its effects on fetal dose in the future. The novel codes developed for this study may also be used to produce EBRT Monte Carlo simulation files from other radiation safety models, including pediatric patients of various ages.

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**SP016 - Image Guided RT: Part 1**

**TRACK 04: RADIATION ONCOLOGY**

**SP016.1 - 18F-NaF PET/CT-directed dose escalation in stereotactic body radiotherapy for spine oligometastases from prostate cancer**

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**Purpose:** To investigate the technical feasibility of SBRT dose painting using 18F-NaF positron emission tomography (PET) scans guidance in patients with spine oligometastases from prostate cancer.

**Materials/Methods:** Six patients with 15 spine oligometastatic lesions from prostate cancer who had 18F-fluorine PET/CT scan prior to treatment were retrospectively included. GTVreg was delineated according to the regular tumor boundary shown on PET and/or CT images; and GTVMATV was contoured based on a net metabolically active tumor volume (MATV) defined by 60% of the SUVmax values on 18F-NaF PET images. The PTVs (PTVreg and PTVMATV) were defined as respective GTVs (plus involved entire vertebral body for PTVreg) with a 3-mm isotropic expansion margin. Three 1-fraction SBRT plans using VMAT technique along with 10 MV flattened filter free (FFF) beams (Plan24Gy, Plan24-27Gy, and Plan24-30Gy) were generated for each patient. All plans included a dose of 24 Gy prescribed to PTVMATV. The Plan24-27Gy and Plan24-30Gy also included a simultaneous boost dose of 27 Gy or 30 Gy prescribed to the PTVMATV, respectively. The feasibility of 18F-NaF PET-guided SBRT dose escalation was evaluated by its ability to achieve 100% of the prescription dose to cover at least 90% of the PTV volume while adhering to organs-at-risk (OARs) dose constraints.

**Results:** In all 33 SBRT plans generated, the planning objectives and dose constraints were met without exception. Plan24-27Gy and Plan24-30Gy had a significantly higher dose in PTVMATV than Plan24Gy (p < 0.05), respectively, while maintaining a similar OARs sparing profile.

**Conclusion:** Using VMAT with FFF beams to incorporate a simultaneous 18F-NaF PET-guided radiation boost dose up to 30 Gy into a SBRT plan is technically feasible without violating normal tissue tolerances. The relationship between local control and normal tissue toxicity during 18F-NaF PET-guided dose escalation in SBRT should be validated in clinical trials.

**SP016.2 - Evaluation of a lung tumor autocontouring algorithm for intrafractional tumor tracking using 0.5T linac-MR: phantom and in-vivo study**

**Authors:** Jihyun Yun, Eugene Yip, Zsolt Gabos, Keith Wachowicz, Satyapal Rathee, B Gino Fallone

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We developed an autocontouring algorithm for intrafractional lung-tumor tracking using linac-MR, and evaluate its performance with phantom and in-vivo MR images.

A pulse-coupled neural network is the main component of the algorithm responsible for tumor contrast improvement from its surrounding anatomy (normal lung, blood vessels). Prior to treatment, an expert user needs to contour the tumor and its maximum anticipated range of motion in pretreatment MR images. During
treatment, however, the algorithm processes each intrafractional MR image and automatically generates a tumor contour without further user input. The algorithm is designed to produce a tumor contour that is the most similar to the expert’s one.

To evaluate the algorithm in our linac-MR environment (0.5T MRI), a motion phantom and four lung cancer patients were imaged with 3T MRI at ~4 frames per second, and the images were degraded to reflect the image quality characteristic of lung tumor MR images at 0.5T. During scanning (~3 minutes), the phantom was driven according to four different 1-D motion patterns (sine pattern with 4 cm amplitude, 4 seconds period + three lung tumor motion patterns), and the patients were in free breathing. Each of these pseudo-0.5T images was autocontoured using our algorithm. In each test image, the Dice’s coefficient (DCE) and Hausdorff distance (HD) between the expert’s manual contour (ROIstd) and the algorithm generated contour (ROIauto) were calculated to measure their similarity, and their centroid position difference (Δdcentroid) was calculated.

Our algorithm successfully contoured the shape of a moving tumor from pseudo-0.5T MR images. Example images are shown in Fig. 1, and the autocontouring accuracy is summarized in Table 1. From the in-vivo study, we achieved 87–92% of contouring agreement and centroid tracking accuracy of 1.03–1.35 mm. These results demonstrate the feasibility of lung tumor autocontouring in our laboratory’s linac-MR environment.

Table 1. Summary of contour shape fidelity and centroid position accuracy

<table>
<thead>
<tr>
<th>Mean(SD)</th>
<th>DCE</th>
<th>HD (mm)</th>
<th>Δdcentroid (mm)</th>
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</thead>
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<tr>
<td></td>
<td>Max/Min</td>
<td>Mean(SD)</td>
<td>Max/Min</td>
</tr>
<tr>
<td>Phantom</td>
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<td>0.97/0.93</td>
<td>2.82(0.39)</td>
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<td>0.97/0.94</td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
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<td>0.97/0.93</td>
<td>2.68(0.29)</td>
</tr>
<tr>
<td>Patient</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>3.38(0.95)</td>
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<td>4</td>
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<td>0.98/0.83</td>
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</tr>
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</table>
SP016.3 - Multi-modal image registration for MR-guided radiotherapy workflow based on detection of features in a customized stereotactic body frame

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Introduction
Shuttle-based MR-guided radiation therapy with separate MR imaging and treatment devices requires both reproducible patient immobilization and robust multi-modal image registration. In the MR-guidance study [1] currently conducted at our institution a customized stereotactic body frame (CSBF) was developed to facilitate image registration. The aim of this work is to develop an algorithm for fast detection of features in the CSBF in order to support image registration for assessment of patient setup alteration.

Methods
The CSBF is equipped with a long (600mm) and a short (80mm) hose (inner diameter 2mm) filled with contrast agent. The former is bent in its middle at an angle of 28.07° surrounding the latter which is centered horizontally (see Fig. 1). Image data of one patient from the MR-guidance study cohort has been selected for evaluation. Besides the treatment planning CT, Cone-Beam CTs (CBCTs) and their corresponding T2 weighted MR images (MRIs) from 16 fractions were used. To identify lines representing the hoses in the images, a probabilistic Hough transform on thresholded gradient image slices is performed in posterior-anterior direction. Detected line pairs oriented towards each other most akin to a notional isosceles triangle formed by a straight line representing the short hose and two lines representing the tapering ends of the long hose are further analyzed. The image data is traversed along the triangle’s edges in search of local intensity maxima. Principle component analysis of the detected maximum intensity distribution enables refinement of the detected lines. Eventually, line intersections are re-calculated and used for landmark-based rigid registration.

Results
Evaluation of the algorithm was performed by registration of the detected points from each MRI and CBCT with interactively placed reference points in the planning CT. For the 16 MRIs the mean root mean square registration error (RMSRE) was 0.78mm and for the 16 CBCTs 0.97mm. Additionally, each MRI was matched to its corresponding fraction CBCT resulting in a mean RMSRE of 0.65mm. Registration results were also assessed qualitatively by visual inspection (see Fig. 1).

Conclusions
An algorithm for multi-modal detection of characteristic features in a CSBF was developed. Accurate results and robust performance on 32 image data sets were achieved. The benefits from incorporating this algorithm, as a preprocessing step, for patient position correction will be evaluated in future research.

Acknowledgements
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References

SP016.4 - A phantom study of impact of probe metal artifact in planning dose for ultrasound-guided radiotherapy

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Image guided radiotherapy (IGRT) is gaining popularity in radiation oncology. Among different IGRT imaging modalities, ultrasound (US) is portable, affordable, and non-ionizing. To monitor the abdominal organ motion during IGRT, we previously developed a probe holder to reproduce the simulation probe position during treatment. However, the metallic parts inside the probe caused artifacts in the CT images (see Fig. 1). This work quantifies the influence of metal artifacts on the treatment plan.

A CIRS Triple Modality 3D Abdominal Phantom (model 057A) including kidneys, lung, and liver, with six tumors inside the liver was scanned using Phillips Brilliance Big Bore CT both with and without the probe in place. A passive arm was used to hold the probe with minimum pressure applied to avoid any phantom deformation. The CT scan without the probe was used for treatment planning in Pinnacle 9.8. Six tumors with distance 60–127 mm to the probe and organs at risk were contoured. Individual plan was made for each tumor. All tumors were prescribed to receive 4000 cGy dose in five fractions. Two VMAT partial arcs avoiding the US probe were
Objectives: This software tool was built to handle reference CT (rCT) and MR (rMR) images from treatment simulation as well as guidance CBCT and MR (gMR) images from daily image guidance. Key design goals include: (i) support various data formats such as DICOM CT, DICOM MR, DICOM spatial registration objects; (ii) provide communication and data flow between different imaging, treatment and storage devices; (iii) perform accurate and robust image registration; (iv) provide a user-friendly graphical interface for users to manipulate data and assess registration quality; and, (v) output couch coordinate shift information to correct patient position for treatment.

Methods: We designed the software to import reference CT and MR images as well as guidance CBCT and MR images from the Mosaic Data Director (MDD), accurately register the guidance MR image to the reference MR, and export couch correction information to the Varian external interface to drive the couch to the correct position. Furthermore, we have developed storage capability to save all patient data, images, and registrations as a DICOM secondary capture, which allows us to re-examine the case and study the MR-guidance performance over time.

Results: All image data from the simulated workflow were successfully loaded into our software tool. Registration of the reference MR to the guidance MR was successful with resulting mean squared errors (MSE) for the four phantom shifts of 0.23 mm, 0.40 mm, 0.11 mm, and 0.10 mm. Registration of the corresponding CT images was also successful with resulting MSE of 0.35 mm, 0.21 mm, 0.33 mm, and 0.26 mm. Couch corrections were generated based on the registration information and exported. Finally, each test case was saved as a DICOM file and stored within the database.

Conclusions: In this study, we demonstrated the successful implementation of a comprehensive image-guidance tool for the MRgRT system in the 3D Slicer platform. We plan to use this tool to study the MRgRT system’s performance in guiding patient positioning based on soft tissue contrast and develop novel applications to enhance the clinical value of MR-guidance in radiation therapy.

| Table 1: The PTV volume, tumor distance to probe, mean PTV dose and PTV dose difference between two plans for six tumors in the liver. |
|---|---|---|---|---|---|---|
| tumor1 | tumor2 | tumor3 | tumor4 | tumor5 | tumor6 |
| PTV volume [cm³] | 7.26 | 2.97 | 7.84 | 3.11 | 2.48 | 2.30 |
| Tumor distance to probe [mm] | 87.2 | 87.9 | 61.0 | 60.4 | 145.2 | 127.8 |
| mean PTV dose to plan with probe [cGy] | 4126 | 4182 | 4134 | 4093 | 4153 | 4240 |
| mean PTV dose to plan without probe [cGy] | 4142 | 4151 | 4121 | 4088 | 4157 | 4245 |
| mean PTV dose difference [%] | 0.39 | -0.73 | -0.31 | -0.10 | 0.08 | 0.11 |

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**SP016.5 - Software development for image guidance on the magnetic resonance-guided radiation therapy (MRgRTTM) system**

**Author(s):** Wenya Xia¹, Stephen L. Breen², An Wang², David Jaffray²

¹Radiation Physics, Princess Margaret Hospital, Toronto/Canada.
²Radiation Medicine, Princess Margaret Hospital, Toronto/ON/Canada.

**Background:** The magnetic resonance-guided radiation therapy (MRgRT™) system utilizes a moveable MRI system to provide image-guidance in a linear accelerator (Linac) vault. By exploiting the superior soft tissue contrast available with MR-guidance, our goal is to provide more accurate patient positioning based on internal soft tissue. To implement cone beam CT (CBCT) and MR guidance effectively, we developed a novel software tool using the 3D Slicer platform.
Figure 1.
SP017 - Calculational Techniques in Therapy Dosimetry

TRACK 05: DOSIMETRY AND RADIATION PROTECTION

SP017.1 - Dosimetric Effect of Beam Angle on the Unflattened and Flattened Photon Beams: A Monte Carlo study

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1Princess Margaret Cancer Center, Toronto/Canada, 2University of Michigan Health System, Ann Arbor/United States of America

This study compared the variations of depth and surface dose on beam angle between the unflattened and flattened photon beams. Monte Carlo simulation based on the EGSnrc code was used in dose calculation. Phase-space files of the 6 MV photon beams (field size = 10 X 10 cm²) were generated with and without the flattening filter based on a Varian TrueBeam linear accelerator. Depth and surface doses were calculated in a water phantom with angles of the photon beams turning from 0° to 90°. Our results showed that compared to the flattened photon beam, the unflattened beam had a higher dose in the build-up region but lower dose beyond the depth of maximum dose. With the Monte Carlo beams cross-calibrated to the machine monitor unit in simulations, dose ratios of the unflattened to flattened beams were in the range of 1.6 – 2.6 as shown in Figure 1 with beam angles varying from 0° to 90° in water. In addition, higher surface doses of about 2.5 were found with beam angles equal to 0° and 15°. However, surface dose deviation between the unflattened and flattened beam became smaller with an increase of beam angle. Using the photon fluence incorporated to the monitor unit, variations of depth and surface dose on the beam angle were investigated and compared. For the unflattened and flattened photon beams, the surface dose and range of depth dose ratios (unflattened to flattened beam) decreased with an increase of beam angle.

Fig. 1: Relationship between the dose ratio (unflattened to flattened photon beams) and depth.
Results:
The Monte Carlo calculated dose rate constant $\Lambda$ of the $^{125}$I in water was found to be 0.992 $\pm$ 0.025 cGyU$^{-1}$ h$^{-1}$. Radial dose functions of the new source model based on point and line source approximations were calculated at distance ranging from 0.1 to 7 cm. Moreover, $g_L(r)$ was measured in Plexiglas phantom material using TLD chips. In addition, the 2D anisotropy function, $F(r,\theta)$, were calculated and measured in both Plexiglas and water phantom.

Conclusions:
The results of these investigations show an agreement of about ±7% between the measured and simulated data in Plexiglas. The statistical uncertainty of MC within ±5% relative to the previously published data for different brachytherapy sources. Based on the results, the Monte Carlo simulated dosimetric parameters of the new $^{125}$I source in water are recommended for their clinical applications.

SP017.3 - Assessment of RayStation treatment planning algorithm to calculate dose in the presence of lung tissue

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Purpose: To investigate the accuracy of RayStation treatment planning algorithm to calculate absorbed dose when the photon beam is disturbed by attenuation or lateral scatter of lung material.

Materials:
A farmer type ion chamber was placed in the center of 30x30x20 cm$^3$ water phantom with a 5 cm lung material slab at 3 cm form the chamber when the beam was perpendicular to the lung slab and at 1 cm from the chamber when the beam was parallel to the lung slab. A SSD=100cm PDD curve was also measured placing a Gafchromic EBT2 film in the interface of the solidWater-lungSlab with the lung slab parallel to the beam and starting at 10 cm depth. Measurements were taken for 6 and 18 MV photon beams and for 10x10, 5x5 and 3x3 cm$^2$ field sizes. The ratio of the dose with and without the lung slab is reported.

Results:
The ratio of the measured dose with and without the lung slab (Dlung/Dsw) is within 1% of that ratio calculated by RayStation algorithm for all energies and field sized used when the beams are parallel and perpendicular to the lung slab (table 1). The PDD curves measured with gafchromic film with and without the presence of lung slab agree with those calculated by RayStation algorithm within the uncertainty of the measurements (figure 1), which is within 3%.
Conclusion:

RayStation dose calculation algorithm takes into account inhomogeneity corrections. It models attenuation of the beam and lateral scatter within 1% of points measured with ion chambers. PDD curves in the presence of lung material also agree with gafchromic film measurements within the uncertainty of the measurements. Therefore, RayStation has an acceptable algorithm to correct dose from photon beams perturbed by lung tissue.

SP017.4 - Improving the efficiency of charged particle transport in magnetic fields in EGSnrc

**Author(s):** Victor Malkov, David W.O. Rogers

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Image Guided Radiation Therapy (IGRT) technologies aim to improve the accuracy of the delivery of radiation with the hopes of decreasing damage to healthy tissues and sensitive organs. Synergistic MRI-Radiation therapy machines are a developing technology that can provide improved tumour tracking during treatment to help accommodate for patient motion or unaccounted for bodily changes over the full course of treatment. Porting the advantages of MRI technology into IGRT comes with the cost of introducing a magnetic field around the patient while a radiation beam is present. This magnetic field (MF) causes curvature in the charged particle trajectory, and can lead to significant variations in dose distributions, particularly at tissue-air interfaces, and lead to changes in the dose response of detectors. Our aim is to evaluate our implementation of the influence of the MF in the EGSnrc Monte Carlo code system, and deliver a detailed study of the increased computational requirements of our code. Monte Carlo (MC) codes have become a staple in radiation treatment planning systems, and are extensively used in radiation dosimetry and Medical Physics research. The EGSnrc code, a popular general purpose MC package used in Medical Physics, previously supported charged particle transport in magnetic fields, but in the transition from EG4 this feature of the code went untested. Our implementation is based a framework similar to the one originally proposed by Bielajew, but have introduced a higher order integration algorithm for the condensed history mode and made use of the single scatter algorithm in the EGSnrc code. To properly handle region transitions, additional changes were made related to the boundary crossing algorithm. These alterations lead to a reduction in the total required computational time compared to the previous implementation since larger step sizes can be taken during the simulation. These improvements prove crucial since the original theory required strict step size reduction which can lead to two to 30 fold increases in computation time as compared with the 25% to 50% increases with the current algorithm. The presented results will highlight ion chamber calculations as a function of magnetic field strength and step size constraints to demonstrate the importance of proper selection of system parameters to obtain accurate solutions. These results will be of particular benefit for groups looking to make use of the EGSnrc code or another MC package for calculating dose distributions in the presence of magnetic field. The improved computational efficiency of the presented code reduces the need for large computational facilities, making it a valuable research tool for investigating the effects of magnetic fields on radiotherapy treatments.

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<tr>
<th>Lung slab perp to the beam</th>
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<td>field size (cm²)</td>
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<td>5 MV</td>
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<td>1 MV</td>
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<td>0.5 MV</td>
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<tr>
<td>0.2 MV</td>
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Table 1. Ratio of the measured dose in solid water with and without the lung slab related to the same ratio calculated by RayStation treatment planning algorithm.

SP017.5 - Accurate Monte Carlo dose calculations for permanent implant prostate brachytherapy: first results from a large scale retrospective study

**Author(s):** Nelson Miksys¹, Eric Vigneault², Luc Beaulieu³, Rowan Thomson⁴

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Recently, the joint AAPM-ESTRO-ABG-ABS TG-186 report endorsed Monte Carlo (MC) dose calculations for brachytherapy as they are more accurate than the traditional TG-43 water-based paradigm. MC dose calculations require accurate patient-specific computational models often derived from post-implant CT images. We have explored issues related to the accurate modelling of the patient geometry by investigating algorithms to mitigate seed artifacts in addition to comparing detailed schemes for mapping image CT numbers to tissue type and mass density in the MC models. Here, we present our advanced MC patient-specific modelling approaches and initial dosimetric results of the first large retrospective MC dose calculation study (of approximately 1000 patients).

The EGSnrc user-code BrachyDose is employed for MC dose calculations of clinical prostate brachytherapy. Seed artifacts are mitigated by applying a metallic artifact reduction (MAR) algorithm to post-implant CT images. Artifact- mitigated images are used to derive MC phantoms by applying one of several tissue assignment schemes (TAS) mapping voxel CT number to tissue composition and mass density. MC-calculated dose distributions and clinical dose metrics for the target and OARs (organs-at-risk) are compared to each other (between different MAR and TAS models) and to TG-43 water-based calculations.
Materials and methods

The bremsstrahlung dose component in electron beams arises from four main sources considered in our model: scattering dual-foils, collimator jaws, applicator’s scrapers and insert of cerrobend. We have neglected the bremsstrahlung generated in the patient. Our model consists in two main parts: in the first part, we calculate the angular energetic fluence distribution for every bremsstrahlung photon source, using an existing model based on a multi-scattering theorem. In the second part, we calculate the relative number of pixels irradiated by the primary electron beam in every bremsstrahlung photon source. All programmings were executed by Matlab. All detailed information about the geometry, material composition, and size of each component have been provided by the manufacturers. Most of the data on the electrons interactions with matter are based on ICRU-1984 data. Measurements of bremsstrahlung dose component were achieved with TLD-700 powder thermoluminescent dosimeters, from 0 cm to 70 cm from the beam central axis, at a depth of 10 cm in a water phantom for a Varian 2300C/D Linac, operated at 6,9,12 and 18MeV.

Results

We demonstrate that out-of-field bremsstrahlung dose is essentially produced by applicator’s scrapers, while the out-of-field bremsstrahlung dose generated in scattering dual-foils can be neglected. In-field bremsstrahlung dose comes essentially from scattering dual-foils, which represents 70%-80% of total in-field bremsstrahlung dose. Our modelling results show a very good agreement between calculated and measured values, in-field and out-of-field. The average difference between calculated and measured values is less than 10%, which represent a very small difference in absolute dose.

Conclusion/perspective

Our approach can be used to provide a good representation of bremsstrahlung dose distributions in all healthy tissues for any applicator size and type and for any electron beam energy used in high-energy electron beam therapy.
The current state-of-the-art in radiotherapy (RT) is precision fractionated irradiation of tumors, with intended sparing of the surrounding normal tissue. To achieve this, highly accurate methods to aim radiation beams with complex static or dynamic shapes have been developed. In addition, various forms of anatomical and functional imaging (e.g., CT, PET, MR) have been integrated with the irradiation technology to achieve accurate targeting and dose verification. This integration was achieved using complex treatment planning software. These innovations are largely responsible for improved cancer treatment outcomes in recent years, rather than an improved fundamental insight in radiation response of normal and cancer tissues.

To gain more fundamental insight, and also to allow investigating the combination of radiation and other cancer agents, recently much progress was made towards developing advanced small animal combined irradiation/imaging platforms. The recent availability of small animal image-guided precision radiotherapy devices (Fig 1) in a growing number of centers is currently revolutionizing preclinical research. Researchers now can perform SmART (Small Animal RadioTherapy) research with devices that combine precise irradiation with high-resolution imaging in one system; the concept of image guided RT (IGRT). The essential components of a SmART research platform are: precision animal positioning, precision irradiation with small photon beams, onboard CT imaging and onboard bioluminescent imaging, all in the same coordinate system. In addition, an accurate treatment planning software for small animals, SmART-Plan, was developed at our institute. We recently added inverse planning capabilities to SmART-Plan to improve workflow and standardization of preclinical studies.

Several preclinical trials have been initiated at our institute. As an example, we used precision image-guided irradiation of the upper right lung lobes of 76 C57BL/6 adult male mice, with doses of 0-20 Gy. We used image registration and image analysis in this longitudinal study to establish a dose response for radiation-induced lung fibrosis. It was found that the mice were more resistant for high doses of irradiation preclinical studies are reported. This is one of the first studies where accurate irradiation and image analysis are used on such a scale. Many other experiments are being performed or planned now.

The final aim is to identify those combined novel treatments that have the best chance of success for clinical translation. In this work, we will report on the progress of the research in this new field at our institute.

SP018.2 - Longitudinal MRI evaluation of whole brain radiotherapy on brain metastasis development and dormancy in a mouse model
Author(s): Donna H. Murrell, Niloufar Zarghami, Michael D. Jensen, Ann F. Chambers, Eugene Wong, Paula J. Foster
Medical Biophysics, Western University, London/ON/CANADA

A major challenge in breast cancer treatment is its ability to metastasize – commonly to liver, lung, bone, and brain – thereby complicating detection and therapy. When cancer cells arrive at distant sites, they may experience different fates: (1) death, (2) proliferation creating metastases, or (3) dormancy (remaining viable but non-proliferative).

This work uses high-resolution anatomical and iron-labelled cellular MRI techniques developed in the Foster lab (Heyn et al., Magn Reson Med, 2006) to monitor cancer cell fate in the brain during metastasis progression. We combine this with image-guided micro-irradiation techniques developed in the Wong lab (Jensen et al., Med Phys, 2013) to investigate the growth of brain metastatic breast cancer and concurrent responses of metastases and dormant cancer cells to whole brain radiotherapy (WBRT).

Two animal experiments were performed (n=24): (1) ‘Late’ WBRT delivered when MRI-detectable tumours had developed; this is similar to the case of clinical diagnosis, or (2) ‘Early’ WBRT given following initial cancer cell arrest in the brain, prior to tumour growth.

‘Late’ WBRT was able to halt tumour growth. At 11 days post-therapy, the average volume of a treated tumour was significantly smaller than untreated (p<0.01); however, the number of MRI-detectable tumours did not decrease and some tumours continued to grow.

‘Early’ WBRT was more effective than ‘late’ and was able to eradicate nearly all tumours [C]. The number of metastases and total tumour volume in treated brains were significantly less than untreated (p<0.05). There was a reduction in the number of MRI signal voids from solitary iron-labeled cancer cells) over time; however, there was no significant difference between groups at any time point. Signal voids from non-viable cells are cleared from the brain; therefore, residual signal voids observed here are potentially viable dormant cells. This suggests dormant cancer cells can persist and are potentially viable, even if WBRT is delivered very early and has eliminated the tumour burden. Further investigation of the dormant cell population is warranted as these may respond to future proliferation signals and contribute to cancer recurrence.
SP018.4 - Tissue characterization using dual energy cone beam CT imaging with a dedicated small animal radiotherapy platform  

**Author(s):** Patrick V. Granton¹, Guillaume Landry², Mathieu Gaudreault³, Frank Verhaegen⁴  
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**Purpose**  
There is a growing number of preclinical image-guided high-precision conformal irradiation devices tailored to small animal geometries. Typically, 225kVp is used as the treatment photon energy. A potential error in the dose prescription lies in the dose calculation phase where there is uncertainty in the tissue composition. Dual-energy CT (DECT) provides estimates of the effective atomic number (Z_{eff}) and relative electron density re when two CT images are acquired at different energies. As Z_{eff} describes tissue composition, DECT of small animals could yield 1) information on the adequacy of approximating mouse tissues by tabulated human compositions and 2) improved tissue assignment for Monte Carlo-based dose calculation algorithms. The goal of this work was to optimize the selection of kVp-pairs, and investigate a recent DECT algorithm for robustness, accuracy, and precision using a dedicated small animal irradiation platform.

**Materials**  
Two mouse-sized phantoms, one acting as DECT calibration and the other as DECT validation, were custom-made from inserts of the...
identified and delineated on CT data obtained from each one of the implanted tumours. Volume reconstruction was performed on each injection site (Figure 1c-e), in order to quantify Au NP diffusion. At t = 2h (n = 3), 1 day (n = 4) and 8 days (n = 8), the tumours were harvested and radioactivity-counted. An organ biodistribution study was also performed (liver, spleen, kidneys, lungs). In 8/11 animals, the total activity retention in the tumours was higher than 80% of the total activity in the animal (93.2% ± 7.7%). After 8 days, the % of total activity retained in the tumours, was (92.0% ± 12.1%). Liver activities higher than 20% of the total animal activity were found in 3 animals, indicating that, in some injection and tumour conditions (e.g. vascularization of the tumour, interstitial fluid pressure), a fraction of Au NPs is taken up by the vasculature and immune cell processes, ending up in the organs associated to the reticuloendothelial system (liver, spleen). In resume, 

103Pd:Pd@Au-PEG NPs were efficiently synthesized (rapidity, reaction yield, colloidal stability, NPs concentration, purification), injected in prostate cancer tumours, and efficiently visualised in CT. In the perspective of clinical applications, the liver and spleen Au NP uptake must be adequately controlled by using either a polymeric or a molecular cancer cell targeting strategy to secure the retention of NPs in tumours.

Gammex (RMI467) and CIRS (062MQA) electron density calibration phantoms, respectively. The phantoms were imaged using a preclinical irradiator (XRAD225Cx, PXI) for a series of kVp settings (40-100) in increments of 10 kV. The exposures were adjusted to yield air kerma equivalent imaging dose of 30 cGy for each kVp. Images were decomposed into Zeff and re for each kVp pair and compared against referenced values. The best energy pair was chosen on the basis of accuracy and noise for both Zeff and re. The experimental DECT imaging was compared against simulations using a CT software package (imaSim) with different amounts of image noise. DECT imaging of a dead mouse, plasticized mouse, and a human heart was performed and assessed.

**Results**

The 40-80 kVp pair was identified as the optimal DECT protocol, yielding a mean errors of 0.9 ± 2.6% on Zeffand 0.8 ± 1.8% on re; simulation results were similar.

**Conclusion**

We have implemented DECT for an optimal small animal imaging protocol, enabling tissue characterization for dose calculation of preclinical radiotherapy studies. Using known tissue-like materials for the DECT calibration are important aspects in achieving accurate DECT imaging.

**Figure 1 (A,B) Photos of the calibration and validation phantom; (C,D,E,F) Simulated and experimental images of the validation phantom; (G,H) Zeff and re images of the calibration phantom. The average noise within the CT images was 15HU.**

**SP018.5 - Low-dose prostate cancer brachytherapy by injections of radioactive gold nanoparticles (103Pd:Pd@Au NPs)**

**Author(s):** Myriam Laprise-Pelletier, Diane Djoumessi, Jean Laguex, Marie-France Côté, Marc-André Fortin

Axe Médecine Régénérative, Centre de recherche du centre Hospitalier Universitaire de Québec, Québec/CANADA

Here we report on the development of a new approach for low-dose prostate cancer brachytherapy, based on the injection of radioactive 103Pd:Pd@Au NPs. Photons emitted by the radioisotope palladium (103Pd; photon energy : 20.1 and 23.0 keV), interacting with gold distributed in the vicinity of and inside cells, are expected to lead to higher energy deposition compared with conventional low-dose brachytherapy. A rapid (~4h), one-pot procedure was developed to synthesize ultra-small 103Pd:Pd nanoparticles (radioactive precursor: 103PdCl2, MDS Nordion, Canada), followed by encapsulation with gold (Figure 1a-b; nanoparticle diam.: ~ 40 nm). Thus-obtained core-shell nanoparticles were stabilised with biocompatible polyethylene glycol (NH2-PEG-SH), purified and concentrated by centrifugation. The tumour retention of 103Pd:Pd@Au-PEG NPs was studied in a PC3 prostate cancer xenograft model (n = 11). For this, the NPs were labeled with a moderate (sub-therapeutic) labeling activity level (4 μCi 103Pd/mmol Au; 2 μL/ injection). The animals were CT-scanned immediately after implantation, then at time-points (1 and 8 days). The 103Pd:Pd@Au NPs injection sites were clearly
SP019 - Nanobiosensors and Nanotheranostics

SP019.1 - Synthesis and evaluation of C595 mAb-conjugated SPIONs nanoprob for specific detection of Prostate cancer 

Author(s): Mohammad Abdolahi1, Sophie Laurent1, Lionel Larbanoix2, Corine Sermeus2, Sebastien Boutry1, Robert N Muller2
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Introduction: Carcinoma of the prostate is the most frequent diagnosed malignant tumor in men and is the second leading cause of cancer-related death in this group. Despite the efficacy of local therapy (surgery or radiation therapy) for treating localized disease, the cure rate is highly dependent on the stage of disease at the diagnosis and early detection of prostate cancer is key to designing effective treatment strategies. However, in its early stages, PC rarely causes symptoms and the majority of men diagnosed with advanced PC at the time of diagnosis. New detection methods are needed for prostate cancer, particularly for metastatic disease, in order to provide patients the best possible staging and treatment. The objective of the present study is to locate primary tumors or distant metastases using MRI with contrast agents targeted specifically to cancer cells. We take advantage of the fact that many types of prostate cancer cells express high levels of mucin 1 (MUC1) oncoprotein on their cell surface. The imaging strategy is to use superparamagnetic iron oxide nanoparticles (SPIONs), attached to an antibody that directly target MUC1, to specifically enhance the contrast of MUC1-expressing prostate cancer cells. The use of antibody-conjugated MRI contrast agents to specifically target cancer cells has been demonstrated previously for some other cancers. Here, we demonstrate an MRI contrast agent targeted specifically to the MUC1-expressing prostate cancer cells.

Methods: A number of cell lines were chosen for MRI experiments: DU-145 cells, which express a high level of MUC1, and LNCaP cells, which do not express MUC1. Conjugation of Mab C595 (anti MUC1) to commercial SPIONs (Micromod, 20 nm diameter) was achieved by using a heterobifunctional linker, sulfo-SMCC. LNCaP and DU-145 cells incubated with conjugated SPIONs. In vitro and in vivo imaging was performed in a 7 T MRI system.

Conclusions: Results of this study showed that through functionalization of SPIONs by C595 monoclonal antibody specific binding of the SPIONs to the MUC1-expressing cells is achievable. With development of this and similar imaging specific vehicles, more effective and detailed diagnosis of prostate cancer through high concentrations of SPIONs at the tumors site is possible.

Fig1. T2-weighted imaging of LNCaP cells (3×10^6) after 2h incubation with SPIO-C595 nanoprobe (Left) and DU145 (Right) at Fe concentration of 0, 5, 10, 20, 40, 80 µg/ml (The vial in the middle is PBS alone without any contrast agent).

SP019.2 - Magnetic Resonance Nanotheranostics of Guerin’s Carcinoma 

Author(s): Valeri E. Orel1, Thamos Mitrelias2, Marina Tselepi2, Eugeny Kruchkov1, Alexander Rykahlskiy1, Andry Romanov1, Tatjana Golovko1, Crispin H.W. Barnes1, Igor Shchepotin1
1Medical Physics & Bioengineering Research Laboratory, National Cancer Institute, Kyiv/UKRAINE, 2Cavendish Laboratory, University of Cambridge, Cambridge/UNITED KINGDOM

We proposed a new technology of nanotheranostics that is combination of magnetic resonance therapy and chemotherapy during moderate hyperthermia below 40 °C inside tumor with diagnostics by magnetic resonance imaging. As nanotheranostics agent the multifunctional magnetosensitive nanocomplex consisted of nanoparticles containing Fe3O4 with diameters < 50 nm and antitumor drug doxorubicin was used. The synthesis of multifunctional magno-sensitive nanocomplex was performed in a magnetomechanical reactor. We conducted a detailed imaging study of transplanted Guerin’s carcinoma in rats during treatment with magnetic nanotherapy. We showed that treatment with magnetomechano-chemically synthesized magnetosensitive nanocomplexes based on Fe3O4 nanoparticles conjugated with the antitumor agent doxorubicin and followed by irradiation with local electromagnetic irradiation resulted in a better outcome than treatment with conventional doxorubicin or treatment with magnetic nanocomplexes without electromagnetic irradiation. An analysis of magnetic resonance images obtained over time showed that the application of local electromagnetic irradiation did not alter the position of magnetic nanocomplexes in the tumor.

SP019.3 - Effects of Fluorescence Gold Nanoclusters on Anti-oxidation and Anti-aging by Cell Model 

Author(s): Walter H. Chang1, Wen Hsiung Chan1, Nai Ruei Cyue2, Cheng-An J. Lin2
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We have developed gold nanoclusters (Au@DHLA, Diameter = 2nm) with red - NIR fluorescence and excellent biocompatibility as novel bioprobes. Moreover, we further found that Au@DHLA is not only a promising probe for cell labeling but also has the anti-oxidative stress properties and further improved cell viability. These novel findings indicate that Au@DHLA has a potential to reduce senescence and apoptosis. We observed the interaction of Au@DHLA with mouse osteoblasts, fibroblasts, and hepatocytes. Au@DHLA has been found to have rapid and efficient cell uptake into the mouse cells, although the toxicity analysis of mouse osteoblasts, fibroblasts and hepatocytes of the tolerance variation are not the same, but it is confirmed that Au@DHLA for mice cells has a good biocompatibility. In the experiment, we utilized the hydrogen peroxide that induced the increase of the oxidative stress of the mice cells then stained it with the dye (DCF-DA) and flow cytometry is used to observe Au@DHLA. We found the results of the intracellular oxidative stress in mice were reduced and the collagen detected in fibroblast production in the known Au@DHLA does not affect the production. In detecting the ability of Au@DHLA of calcification experiments, we found that the low concentrations of Au@DHLA do not affect the ability of osteoblast calcification. We also found hepatocytes can generate the cholesterol, however Au@DHLA does not affect the hepatocytes. These study results demonstrated that
Au@DHLA has high potential to be developed as nanomaterials with anti-oxidation, anti-apoptosis and anti-aging properties for the application in medical research, aesthetic medicine, and regeneration medicine.

SP019.4 - Nanoparticle-aided Radiotherapy for Retinoblastoma and Choroidal Melanoma

Author(s): Yucel Altundal1, Erno Sajo1, G. M. Makrigiorgos2, Ross Berbeco2, Wilfred Nawa2
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This work investigates the dosimetric feasibility of employing gold nanoparticles (AuNPs) or carboplatin nanoparticles (CNPs) to enhance radiotherapy (RT) treatment efficacy for ocular cancers: retinoblastoma (Rb) and choroidal melanoma (CM), during kV-energy internal and external beam radiotherapy. The results predict that substantial dose enhancement may be achieved by employing AuNPs or CNPs in conjunction with radiotherapy for ocular cancer using kV-energy photon beams. Brachytherapy sources yield higher dose enhancement than the external beam in kV energy range. However, the external beam has the advantage of being non-invasive.

SP019.5 - Nanoparticle enhancement of radiation dose: experimental confirmation using scintillation dosimetry

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1School Of Physics, University of Sydney, Sydney/AUSTRALIA, 2Radiation Oncology, Chris O’Brien Lifehouse, Sydney/AUSTRALIA

Nanoparticles of high atomic number enhance the radiation dose delivered and therefore are potentially useful in radiation therapy. The effects of beam energy and nanoparticle size on dose enhancement have been modelled using Monte Carlo and the response of cells has been measured in-vitro. However, for different cell-lines a range of responses has been observed, which are not always consistent with the Monte Carlo predictions. The aim of this study is to provide a direct measurement of the dose enhancement that is independent of the cytotoxicity of the particles or the manner in which cells take up the particles.

A composite was made using commercially available liquid scintillator (BC430 or BC 498) and gold nanoparticles (diameter 30nm, Nanopartz Inc). The scintillation light emitted during irradiation was used to evaluate the enhanced dose from the photoelectrons emitted from the nanoparticles. The samples were exposed to radiation beams with a range of energies (50kV, 75kV, 100kV, 125 kV, 180kV and 280kV). Some of the emitted light was absorbed by the nanoparticles and this effect was corrected for. The scintillation light was coupled into a PMMA fibreoptic and transferred to a photo multiplier tube (PMT) for readout. The PMT was calibrated to dose after subtracting the background signal consisting of Cerenkov, fluorescent and stray light. A theory was developed using photon absorption cross sections taken from the NIST XCOM database (Berger et al 1998).

SP019.6 - Graphene Plasmonics as Promising Platform for Highly Sensitive Plasmonic Sensing

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Surface plasmon resonance (SPR) is the collectively oscillating charge densities at the interface between thin metal film and dielectrics in resonance with the incident light. SPR-based sensors have emerged as a versatile tool for the label-free and real-time biomolecule sensing during the recent two decades. However, it has been recognized that the sensitivity has yet to be improved to allow for single molecule detection. Incorporation of additional plasmonic nanostructures onto SPR sensor chip is one of the most promising strategies. The use of graphene in conventional plasmonic devices was suggested by several theoretic research studies. Plasmons in graphene were also intensively investigated by some researchers and tight confinement, tunability and long propagation which make graphene as a promising material for SPP-based optical nanodevice applications were reported. It is required to enhance the light-matter interaction for the actual applications despite of relatively high light absorption of single layer graphene. In this regard, the use of graphene in conventional plasmonic devices has been suggested. However, the existing theoretic studies are not consistent with one another and the experimental studies are still at the initial stage. To reveal the role of graphenes on the plasmonic sensors, we deposited graphene oxide (GO) and reduced graphene oxide (rGO) thin films on Au films by layer-by-layer self-assembly method and their refractive index (RI) sensitivity was compared for the first time in SPR-based sensors. The deposition of GO bilayers with number of deposition L from 1 to 5 was carried out by alternative dipping
of Au substrate in positively- and negatively charged GO solutions. The fabrication of layer-by-layer self-assembly of the graphene films was monitored in terms of the SPR angle shift. GO-deposited Au film was treated with hydrazine to reduce the GO. For the rGO-Au sample, 1 bilayer sample showed a higher RI sensitivity than bare Au film, whereas increasing the rGO film from 2 to 5 layers reduced the RI sensitivity. In the case of GO-deposited Au film, the 3 bilayer sample showed the highest sensitivity. The biomolecular sensing was also performed for the graphene multilayer systems using BSA and anti-BSA antibody.

SP020 - Biomedical Modeling

SP020.1 - Respiratory parameters have different patterns in imposed-inspiration and imposed-expiration within a closed pneumatic circuit in rats

Author(s): Fabio G. Aoki1, Marcelo H. Valenga1, Thiago G. Rodrigues1, Paulo F.G. Cardoso2, Rogerio Pazetti2, Henrique T. Moriya1

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Computer-controlled research ventilators for small animals (SAV) are often used to assess the respiratory mechanics’ parameters such as resistance and elastance of the respiratory system in animal models of disease. In commercially available SAVs, it is common to obtain such parameters with the forced oscillation of a given volume of air into respiratory system with a quasi-sinusoidal pattern in a closed pneumatic circuit (i.e. both the injection and the removal of gas during the piston movement). We hypothesized that obtaining the respiratory mechanical parameters with the linear single-compartment model (LSCM) during the forced inspiration and forced expiration (when calculated together) is not sufficient to explain the physiology of the respiratory system exposed to high doses of bronchial agonist. In order to verify this, male Wistar rats (n = 5) were anesthetized, orotracheally intubated, mechanically ventilated at 90bpm (or 1.5Hz) with a tidal volume of 10mL/kg, and a positive end-expiratory pressure (PEEP) was set at 3cmH2O. The ventilation was performed in a commercial mechanical ventilator (flexiVent, SCIREQ Inc., Canada) and the animals were infused with a saline solution (PBS), followed by 3 increasing doses (3, 30 and 300mg/mL) of the bronchial agonist methacholine (MCh). Respiratory parameters were calculated by the LSCM. Pressure and volume data, calibrated and corrected by a proprietary software, were analyzed using a computational routine. The full quasi-sinusoidal signal data was compared to inlet and outlet of air from the lungs separately. The data obtained showed that the difference among the three signals (i.e. whole signal, imposed-inspiration, and imposed-expiration) is pronounced at the higher dose (MCh 300mg/mL). Data from imposed-inspiration alone seem to better reflect the respiratory mechanics when a large dose of bronchial agonist is used.

SP020.2 - Autonomic and cardiovascular responses to food ingestion and gum chewing in healthy young subjects

Author(s): Kyuichi Niizeki, Tadashi Saitoh

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Objective: Our previous study has demonstrated that in humans mental stress exerts an influence on the oscillations of respiratory sinus arrhythmia (RSA), inducing incoherent phase lag with respect to breathing in addition to a decrease in the amplitude of RSA1. It was suggested the enhanced sympathetic nerve activity during stress may modulate the transduction property of cardiac vagal efferent nerve. However, whether coherent oscillations of RSA could be altered by other physiological condition has not been shown. We hypothesized that dietary behavior may induce strong cardio-respiratory synchronization, because that the digestive organs are innervated by parasympathetic nervous system. In this study, we examined cardiovascular responses to eating solid food and chewing a tasteless gum, with special reference to whether the phase coherency of RSA is altered by dietary behavior.

Methods: After 5 min of rest, 14 subjects were asked to eat solid meal [maple flavored Calorie Mate (CM) ] at their own pace, which
was followed by 5 min postprandial recording. We also examined the separate effects of mastication on cardiovascular variables by chewing a tasteless gum (GM). We measured ECG by means of wireless electrocardiogram, beat-by-beat blood pressure (BP) by means of Finapres, and breathing activity by inductance plethysmography. The R to R interval (RRR) of ECG wave and respiratory movement signals were sampled with a frequency of 10 Hz. These signals were further band-pass filtered with the frequency range 0.1~0.5 Hz. Instantaneous phases and amplitudes of RSA and respiration were continuously calculated by Hilbert transform, and then phase coherence (λ) between RSA and respiration was computed. Beat-to-beat stroke volume (SV) was determined by the pulse-contour method. Cardiac output (CO) was SV times heart rate (HR). To assess autonomic activation, the low- and high-frequency components of heart rate variability (HRV) were computed by applying a fast Fourier transform by the Welch method.

Results and Discussion: From rest to CM, transient increase in BP and decrease in RRI were observed. A transient decrease in the latency between OAEs and ABRs were further compared. System of auditory propagation pathway, the OAEs and ABRs were the integrity and coherence. Based on the integrated detection results, the testing conditions might be changed, lacking of proofs to ensure simultaneously. When comparing the features between the signals, we suggest that phase coherence analysis of RSA could provide a sensitive measure for evaluating cardiac autonomic influences on dietary behavior compared to the conventional frequency analysis of HRV.

Reference


SP020.4 - Numerical Optimization Performance of a Perfusion Kinetic Modelling Algorithm using Volumetric DCE CT

Author(s): Igor Svistoun1, Catherine Coolens1, Catherine Coolens1

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Introduction: Dynamic-contrast enhanced (DCE) CT imaging is increasingly being used to quantify tissue vascular and functional properties for treatment response assessment by its combination with tracer kinetic modeling. However, clinical kinetic parameter results have been shown to be highly dependent on measurement input and analysis method. Implementing the parameter estimation algorithm involves many design decisions including choice of: data processing sampling rate, continuous-to-discrete system mapping approach and numerical optimization algorithm. As such a simulation framework was designed to investigate the effects of those choices, as well as effects of measured signal aliasing and noise on the accuracy and speed of the parameter estimation.

Methods: A widely-used 2-compartment model (modified Tofts) was chosen which describes the dynamic perfusion properties of a contrast agent using 4 parameters: Ktrans - transfer from blood plasma into extracellular extra-vascular space, Kep - transfer from extracellular extra-vascular space back to blood plasma, Vb - whole blood volume per unit tissue. To account for separation between injection and measurement site, a time delay τ must be added. The 4-parameter estimation from the measured data requires numerical optimization. A test framework was developed where an experimentally derived population-average arterial input function and randomly sampled parameter sets [Ktrans , Kep , Vb , τ] were used to generate tissue curves. Knowing the ground truth values, 5 numerical optimization algorithms were investigated using multiple starting points from a quasi-random set: sequential quadratic programming (SQP), downhill simplex (Nelder-Mead), pattern search (PS), simulated annealing (SA), and differential evolution (DE). This was repeated for two error function evaluation approaches – finite impulse response (FIR) and infinite impulse response (IIR) approximations of extended Tofts model and the impact of these approaches on speed and accuracy evaluated for sampling rates of 1, 10 and 100 Hz. DE algorithm was implemented on a GPU for speed improvement testing since processing even a modest area of 128x128x200 voxels would require days on the CPU.

Results: SQP, Nelder-Mead and DE produced good results on clean and noisy input data outperforming SA and PS in terms of speed and accuracy. During calibration, the best 3 algorithms did not exceed absolute error 9.4e-6% for any parameter. When run on typically aliased and noisy (sigma=6HU) data average absolute % errors were: Ktrans=11.96%, Kep=8.2%, Vb=25.7%, τ =3.6%. On average SA and PS took 1 and 2 orders of magnitude, respectively, slower to converge. We found IIR to approximate the model much better at sampling rates 10 times lower than those required for FIR approximation i.e. when upsampling same data and processing with FIR at 10Hz the average absolute error drops from [4.3%, 1.7%, 16.0%, 1.4%] to [4.3%, 1.7%, 6.6%, 0.3%] for each parameter. CUDA_DE runtime averaged at 3e-2 sec/voxel – a speed improvement of 199x over CPU_DE.

Conclusion: Evaluation of different optimization algorithms, sampling and noise scenarios indicated a preferred implementation of CUDA_DE. This will be extended to a clinical version with real-time analysis capabilities with ex-vivo kidney perfusion data presented at the meeting.

SP020.3 - Characteristic Analysis and Modeling for Signals of Auditory Propagation Pathway

Author(s): Qin Gong1, Xiaolin Li2, Tao Zhang3, Xi Chen1

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Otoacoustic Emissions (OAE) and Auditory Brainstem Response (ABR) play important roles in the processing information of the auditory perception. Most previous studies only measured one signal simultaneously. When comparing the features between the signals, the testing conditions might be changed, lacking of proofs to ensure the integrity and coherence. Based on the integrated detection system of auditory propagation pathway, the OAEs and ABRs were measured simultaneously in normal subjects under different intensities and frequency of click and tone burst stimulation. The model to simulate the TEOAEs latency-frequency function was built up, and the latencies between OAEs and ABRs were further compared.
**SP020.5 - Validation of a Sympathovagal Balance Model to Evaluate Autonomic Function in Rats Using Time-Frequency Analysis**

**Author(s):** Rui Fonseca-Pinto¹, Lucília N. Diogo², Silvia V. Conde², Emilia C. Monteiro², Maria P. Guarino²  
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The Autonomic Nervous System (ANS) activity can be evaluated in humans by using Heart Rate Variability (HRV) analysis through classical spectral analysis, and more recently by the use of newer techniques by time-frequency analysis. We have previously shown that Blood Pressure (BP) changes felt in HRV spectrum can be assessed and possibly isolated using a hybrid methodology in which HR and BP (in particular diastolic blood pressure) are mixed to produce an instantaneous variation energy plot reflecting the sympathetic and vagal autonomic activity, in other words, the ANS modulation on Heart Rate and Blood Pressure.

In this work we test the same approach in rats with the objective to validate the use of this methodology using continuous Blood Pressure recordings to evaluate the ANS changes.

Data were obtained in 20 rats by using telemetry probes implanted in the abdominal cavity and connected to the abdominal aorta for continuous BP and HR recordings in control situation and also in response to stimuli that change the autonomic response such as chronic intermittent hypoxia and drug administration.

The results showed that this hybrid methodology allows the evaluation of autonomic nervous system balance and can be used in laboratory and eventually in clinical settings to evaluate disautonomies.

**SP021 - Public Health, Active and Healthy Aging**

**TRACK 13: INFORMATICS IN HEALTH CARE AND PUBLIC HEALTH**

**SP021.1 - Informatics in Health Care and Public Health**

**Author(s):** Leandro Pecchia  
School Of Engineering, University of Warwick, Coventry/UNITED KINGDOM

**Learning objectives:**

Attenders non experienced in the study of falls will be introduced to the main challenges of this field and will be able to discriminate, interpret and classify interventions for: risk of falling assessment, fall detection, fall prediction and fall prevention.

Attenders will learn how physiological monitoring has been used to assess the risk of falling in the next few months.

Attenders will learn how physiological monitoring has been used to predict falls due to postural hypotension in the next few minutes.

**Abstract**

Falls are a major problem of later life, causing loss of independence and quality of life for senior citizen and their families. Falls are difficult to prevent, because caused by complex and dynamic interactions between hundreds of intrinsic (subject specific) and extrinsic (circumstance dependent) risk factors.

Multifactorial interventions seem to be most effective approaches to prevent falls, and includes simultaneously exercises, training, multifactorial home assessments, home safety interventions (i.e. elimination of specific risks) and vitamin supplementations. However, inform these interventions with accurate information about the risk of falling in the next few hours, days or weeks is needed in order to make those interventions more cost-effective and sustainable.

Several technologies have been proposed to support or inform these interventions. Many focused on fall detections using wearable sensors (mainly accelerometers and gyroscopes); unobtrusive sensors (i.e. cameras, Kinect, microphones) or ambient sensors (i.e. infrared or pulse-Doppler radar systems to detect motion or to monitor the ambient response to falls as floor vibrations). Fewer studies aimed to detect falls while happening in order to predict the impact (pre-impact fall prediction) and eventually reduce harms (i.e. inflating airbags). Some studies proposed technologies for the risk of falling assessment, using body-worn kinematic sensors or heel and toe clearance measurements.

However, recent studies proved that there are specific circumstances in which the probability of falling is much higher, especially in-door. For instance, the 30% of indoor falls happen while rising from beds or chairs and the risk of falling in specific hours of the day increases significantly.

This talk will present the preliminary result of two studies investigating for the first time how physiological monitoring and biomedical signal processing can support fall prevention intervention by assessing the risk of falling in the middle term (few weeks) and predicting in the short term (few minutes before) falls due to specific circumstances (i.e. rising from bed or chair). Two case studies will be presented in which Heart Rate Variability (HRV) was used to predict falls or to assess the risk of falling, proving that:
HRV resulted systematically depressed in fallers;

subjects with a depressed HRV showed a significantly increased relative risk of falling in the next few months;

monitoring the HRV in the 5 minutes before standing-up it is possible to predict postural hypotension, which is the main cause of falls happening while rising.

Finally, the preliminary attempts to integrate those predictive modeling in wearable and unobtrusive monitoring applications for falls prevention will be discussed.

SP021.2 - Monitoring Information System of Aedes Aegypti Reproduction
Author(s): Heleno S. Morais¹, Oziel S. Santos¹, Mateus A. Rocha¹, Tâssila Catarina S. Almeida¹, Lurdhes M. Brasil², Gerardo A. Idrobo³

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Aedes aegypti is a mosquito and main transmitter of dengue disease. Dengue is a viral disease that can only be transmitted to Humans by the bite of infected mosquitoes with the virus of the disease. It usually manifests in three clinical types, one of which can lead to death. The classical dengue, is classified as a febrile illness of mild to moderate intensity; dengue hemorrhagic fever, more severe than the last one, it comes to changes in blood clotting of the infected person; and dengue shock syndrome, very rare form, but can be fatal if not treated in time. Furthermore, Aedes aegypti transmits diseases like yellow fever, and it also has fully capacity to transmit chucunghua fever. Due to the fact that it is a fatal disease and the eradication of Aedes Aegypti is practically impossible, it is very important monitoring and control of Aedes Aegypti reproduction. The monitoring and control processes are still precarious when it comes to mosquito eggs counting technology collected through ovitraps vane in breeding sites. Because this processes are performed manually by experts using magnifying glass and tweezers. This paper presents a mechanism to make these processes faster and more efficient, it is a hardware / software interaction mechanism capable of capturing microscopic images of ovitraps vane and from an image processing software automating the counting of eggs contained in the vanes and in the future through geoprocessing inform the locations of higher reproduction of Aedes aegypti in a given region.

SP021.3 - Design and Functionality of a Meta-Reporting Tool within a Medical Devices Vigilance System
Author(s): Antonios Deligiannakis¹, Nikos Giatrakos¹, Aris Demitzakis²

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Medical Devices (MDs) are an important factor related to the quality of healthcare that patients receive. Although regulations have been applied and standards are imposed on MD manufacturing, faulty behavior incidents (referred to as adverse events) are frequently observed and reported by various organizations, such as FDA[1] and EUDAMED[2]. Given these reports, which include information about MD products associated with an adverse event, national healthcare authorities have the duty of examining whether listed products match the equipment of administered institutions and of contacting them with information about the potential risks that admitted patients (or users) may encounter. Subsequently, the individual healthcare institutions should cross-check, appropriately maintain, or even withdraw the potentially hazardous MD that they own.

To facilitate healthcare authorities promptly notifying institutions under their organizational chart about potentially hazardous devices, we have designed and developed a meta-reporting, web-based tool as a part of the MEDEVIPAS system. Our tool automatically generates meta-reports of matches of adverse event reports to inventoryed MD equipment and to disseminate these meta-reports to institutions in a user-friendly format, conceivable by non-expert (medical or paramedical) users, such as administrative hospital employees. Our tool receives as input information about MD inventories and crawled reports of adverse events. An entity matching algorithm is executed, matching medical devices in reports with those in MD inventories (and computing a matching score in each case) using the manufacturer, model and serial number of a MD, upon the insertion of new reports of adverse events (or of new MDs) in the system. From that point forward, our meta-reporting tool, which is the focus of this paper, provides the necessary functionality to registered users.

Meta-reports are created and made available to registered institutional users via a web application, in a tabular format. The meta-reports display information about potentially affected medical devices of each user, along with data from a related adverse event report, the matching score, etc. This information can also be provided in printable format using the web application. Email alerts are also created and forwarded to their registered accounts automatically upon the detection of a possibly matching device. The alerts are displayed prominently at our web-based tool and remain active until institutional users confirm that they became aware of the cited situations. Our tool also exploits user feedback on the validity of provided meta-reports, which is then incorporated in the entity matching algorithm to increase its accuracy performance (properly modifying the matching score of matched records). Apart from providing meta-reports, analysis capabilities are embodied in our tool in the form of aggregate statistics per MD manufacturer, MD group and registered institution.

Keywords: Medical Device, Vigilance, Adverse event, Reporting Tool

Acknowledgment: This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program “Education and Lifelong Learning” of the National Strategic Reference Framework (NSRF) - Research Funding Program: Thal. Investing in knowledge society through the European Social Fund.


SP021.4 - Evaluation of the Impact in the Physical Condition of School Age Children Exposed to an Intervention of Exergaming in Montemorelos Mexico
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School Of Engineering, Montemorelos University, Montemorelos/ MEXICO

The current epidemiological situation of overweight and obesity in Mexico has been extensively documented and analyzed. Studies define the situation as a metabolic and inflammatory disease, of chronic course, multifactorial and with high impact on public health.

For the treatment of this multifactorial phenomenon, strategies have been proposed focused in the promotion and health education of the
target audience, seeking at medium- and long term, to prevent and eventually achieve the reduction of this epidemic situation. The school age population is particularly at high risk, with consequences ranging from psychological areas, school performance and organic malfunctioning that could emerge during the lifetime of the individual.

The overweight and obesity appears to be related to environmental factors such as sedentary lifestyle. The improvement of the physical condition through physical activity is a challenge in these new generations.

Considering the sociological features of school age population (6-12 years), their general technological familiarity implied in this age group and their tendency toward virtual interactions, an initiative of using video game platforms was designed performed, in order to promote physical activity (Exergaming). In addition, an evaluation of the impact in the physical condition on the participants through standardized anthropometric and physical performance tests was made, via pre and post testing. Results shows that there is a significant difference in variables related to flexibility, strength and body composition in a such a way, that opens the possibility to consider this type of virtual tools as an option for physical training in school age children.

SP020.5 - Using the EIP on AHA monitoring tool for the early technology assessment of a planned device to predict in-hospital falls in the elderly

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In-hospital falls can lead to severe health consequences for the individual and are associated with substantial cost to health and care systems and it is estimated that up to one third of all in-hospital falls happen straight after standing up from a bed or chair. It is possible that a sudden drop in blood pressure shortly after rising is causative for many of these falls and a recent observational study suggested that the blood pressure after standing up can be predicted with high accuracy based on the ECG registered during the five minutes before rising (82.5% accuracy; false positive 10%; false negative 7.5%). This study aims to inform the design of a device that could warn patients about the immanent risk of falling based on a drop in blood pressure after rising in an early assessment of the health and economic outcomes of such a technology. The monitoring and assessment tool for the European Innovation Partnership on Active and Healthy Ageing will be used in order to predict the potential impact of such a device on the number of falls and subsequent health outcomes as well as the impact on healthcare utilisation. The tool rests on a three-state Markov process (including baseline health status, deteriorated health status (i.e. a fall) and death), which allows estimating the probability of patients having a post-fall event with severe health consequences. Health states will be valued using EQ-5D data from the literature and resource use will be estimated based on the documented consequences of falls in a UK hospital setting. The probability of a fall following a sudden drop of blood pressure and the likelihood to prevent a fall through an alarm triggered by such a drop in blood pressure during standing up will be elicited from a group of falls experts with various backgrounds, including participants of the EIP on AHAs Action Group A2 on falls prevention. Key drivers of health and economic outcomes of the planned intervention will be assessed through extensive sensitivity and scenario analyses. With this study we will not just be able to assess the potential impact of a planned warning device for the prevention of in-hospital falls, but also the value of the EIP on AHA monitoring tool for the early evaluation and the pre-market assessment of new and innovative health technologies.

SP021.6 - An innovative Decision Support System (DSS) for patients with Inflammatory Bowel Disease (IBD)

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In IBD, investigators have suggested a possible role of various infective agents and recent epidemiological studies and veterinarian reports have reconsidered the pathogenetic role of some microbes and/or related vectors to the potential pathogenesis of some human disease. The etiopathology of IBD still remains unknown. The combined use of lifestyle surveys associated with blood samples and relevant clinical registers seems the best methodology to identify possible links between genetic predisposition, disease occurrence and natural course of the disease.

Such a system will help understand the natural course of the disease, study the predisposing factors and related genes and determine early clinical, genetic and immunological predictors of outcome and response to treatment. We build an efficient personal-ized web-based platform, in order to manage medical data, using efficient data mining and knowledge extraction techniques. Various variables already defined and determined for which associations are searched within the recorded datasets, discover interesting inter-relation and extract new knowledge from multiple and heterogeneous archived data that reflect everyday lifestyle and medical information, examine the results of previous therapeutic regimens and obtain quantitative explanations of the observations and generate efficient reports with intelligent data visualization.

We create an innovative clinical DSS, an efficient web-based platform, which incorporates 2 modules: Data Repository and Knowledge Discovery/Statistics module. The Data Repository module is a centralized data repository for annotation data (clinical, demographic and experimental data), sample source and handling information, processing and quality assurance information, as well as inventory and process flow data. In the front end, it will provide tracking, data query, report generation, process management functions, data handling as well as statistics, data mining and knowledge extraction capability (Knowledge Discovery and Statistics module incorporated in the back-end of the system). Moreover, the module will contain a Data Representation module that will handle the presentation of the extracted knowledge from the patients' data.

For the Data Repository module, a secure database has already been developed. For old patients, medical data from almost 600 patients, using their hard-copy medical records, have already been digitized. Blood sampling has already been achieved in 294 new patients and 234 healthy volunteers, while the results of the genetic and natural course of the disease.

In combination of clinical, environmental and laboratory data in IBD. In IBD, investigators have suggested a possible role of various infective agents and recent epidemiological studies and veterinarian reports have reconsidered the pathogenetic role of some microbes and/or related vectors to the potential pathogenesis of some human disease. The etiopathology of IBD still remains unknown. The combined use of lifestyle surveys associated with blood samples and relevant clinical registers seems the best methodology to identify possible links between genetic predisposition, disease occurrence and natural course of the disease.

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For the Data Repository module, a secure database has already been developed. For old patients, medical data from almost 600 patients, using their hard-copy medical records, have already been digitized. Blood sampling has already been achieved in 294 new patients and 234 healthy volunteers, while the results of the genetic (susceptibility gene polymorphisms) and serological (inflammatory and serological prediction markers) study are recorded in the database. Several knowledge discovery techniques have been applied in the Databases, giving more than satisfactory results.

Building such a system, for the first time in Greece, will contribute even more to IBD knowledge and research as the proposed sys-

tem will create a unique multidisciplinary combined database with combination of clinical, environmental and laboratory data in IBD. In addition, as IBD is regarded to be a multifactorial disease, we hope to better define some factors that clearly predispose to certain IBD phenotypes and IBD disease course. Finally, we hope that the computer-
ed platform will enrich our experience and will contribute towards a better IBD education and training in our medical, nursing and labora-
tory personnel and serve as a model and a basis for research in other chronic gastrointestinal and/or inflammatory diseases.

ABSTRACTS | IUPESM 2015 WORLD CONGRESS ON MEDICAL PHYSICS & BIOMEDICAL ENGINEERING
SP022.1 - Biomedical Engineering in Nigeria: A Developmental Overview

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Biomedical Engineering (BME) activities in Nigeria can be said to have started in the 1970s during which collaborative efforts were made by engineers, medical doctors, pharmacists, physicists, technologists and other scientists. Although, the pace of development was hitherto slow, most efforts were in the arena of training - short courses, continuing education or professional development. However, the coming of NIBE in 1999 has propelled a steady progress of BME activities in Nigeria. BME activities in Nigeria was further given a big boost in 2007, when the first undergraduate programme in BME started in the Federal University of Technology, Owerri, Nigeria with NIBE contributing the foundation members of faculty. Established in 1999 with the vision “to develop and advance the biomedical science, health and human well-being of Nigeria through modern technological approaches comparable to those obtainable in any developed country of the world”. NIBE is currently structured in 5 divisions - biological engineering; medical engineering; clinical engineering; rehabilitation engineering; and biomedical physics / allied sciences - to accommodate virtually every field in the sciences. It had its 1st annual BME conference in 2000. Since then it has organised 9 national biomedical engineering conferences and 6 national professional development courses in Nigeria. In 2003, NIBE was admitted as the 50th member of IFMBE. The same year, she co-founded the African Union of Biomedical Engineering and Sciences (AUBES) in Ghana while some members were on a Medical Equipment Training. The role of NIBE in developing BME in Nigeria is mainly as a membership group to develop resources for BME by evolving adequate training programmes for members, facilitating accreditation and certification of professionals practicing BME in Nigeria.

SP022.2 - Modernising Scientific Careers – a new scheme for the education and training of physicists, engineers and other scientific staff in the UK National Health Service

Author(s): Keith Ison, Chris Gibson, Sarah Peel, Sue Hill

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Modernising Scientific Careers (MSC) is a UK-wide government initiative to address training and education of the NHS healthcare science workforce (2011). MSC provides a flexible career pathway to meet current and future health system needs via a single coherent training framework across 50,000 healthcare scientists of all disciplines including medical physicists and clinical engineers.

MSC covers all career stages, and the associated training and education programmes incorporate both academic and workplace-based training. Early training is broad based with greater specialisation in the more advanced programmes. The intent is to develop a skilled yet flexible workforce with sustainable education and training funding. It is already being developed to cover Medical Physics Experts and public health scientists.

The MSC career pathway has four stages and qualifications (2014a):

- Assistant and associate training – vocational qualifications for scientific support roles

- Practitioner Training Programme (PTP) – BSc for healthcare science practitioners

- Scientist Training Programme (STP) – Masters for clinical scientists

- Higher Specialist Scientific Training (HSST) – five year doctoral level programme for consultant clinical scientists (2014b)

The presentation will outline evidence-based approaches to trainee selection, progress monitoring and assessment and also report initial outcomes. MSC is competency-based and scientists and engineers often approach competencies in a linear fashion, breaking complex real-world scenarios into discrete tasks with defined right answers that do not fully reflect clinical reality or capture all necessary learning. In progressing from academic achievement to professional competence, we propose that trainees should be encouraged to document real workplace processes, acknowledge and reflect on uncertainty, and develop strategies to respond appropriately. These documents would encourage all staff to consider reflective practice as integral to professional competence.


Competencies and Expectations of the Candidates, as They Came Allotted Time. However, We Faced Many Challenges in Terms of the That All Residents Undergo the Same Learning Modules During the Qualified Medical Physicists. The Structure of the Program Is Such Certified Physicists with the Objective of Graduating Clinically Established at Our Institution. The Program Is Supervised by Board Center, Riyadh/Saudi Arabia

<table>
<thead>
<tr>
<th>Program</th>
<th>Education Programme</th>
<th>Duration</th>
<th>Entry Requirement</th>
<th>Level</th>
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<td>Doctoral level (DClin-Sci / PhD)</td>
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**SP022.3 - Medical Physics Residency Program in Developing Countries: Lessons, Challenges and Solutions Learned from a Regional Pilot Training Program**

*Author(s):* Shada Wadi-Ramahi, Waleed Al-Najjar, Belal Mofthah

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A regional 2-year structured program in medical physics was established at our institution. The program is supervised by board certified physicists with the objective of graduating clinically qualified medical physicists. The structure of the program is such that all residents undergo the same learning modules during the allotted time. However, we faced many challenges in terms of the competencies and expectations of the candidates, as they came from different countries in the region. MSc level candidates exhibited varying levels of academic competencies, and the clinical expectation varied by country; From conventional treatments using Co-60 to state-of-the-art treatments on linacs. Challenges faced include how to cover various academic deficiencies, which required time-consuming per needed lectures, another major challenge was how to transition Co-60 users into linac users while dealing with other residents who wanted to advance more in linac-based techniques. A third major challenge was how to evaluate the various competencies achieved at the end of the 2 years, given the starting level and background, of course many other challenges presented themselves during the years. In this paper, we present a detailed description of our residency program, the modules it contains and expected competencies, then we discuss in more details the challenges we faced given the heterogeneous mix of the residents and the solutions that evolved, and still is evolving, to overcome these hurdles. Residency programs covering many countries, in which one cannot control education levels, have to evolve and adapt in order to produce useful results. A one-size-fits-all formula found in North America, for example, will fail if copied as is and implemented in developing countries.

**SP022.4 - International Union of Biological Sciences**

*Author(s):* Nils Chr. Stenseth

Université Paris Sud XI, IUBS, Orsay/FRANCE

The International Union of Biological Sciences (IUBS) was established in 1919. IUBS is presently composed of 27 National Members and 80 Scientific Members. The role of IUBS is to promote the study of biological sciences, to initiate, facilitate and coordinate research and other scientific activities necessitating international, interdisciplinary cooperation, to ensure the discussion and dissemination of the results of cooperative research, particularly in connection with IUBS scientific programmes. IUBS sponsors the organization of conferences and also scientific programmes. The current IUBS programmes are dealing with climate change, bionomenclature, Disaster and biodiversity, and also a case study on Bees and Coffee.

The bio-cluster meeting will be a good opportunity to discuss how the different bio-unions programmes and activities could interact for the benefit of our community. On the other hand, it is important to develop our interaction with ICSU and with its programme Future Earth. The bio-cluster of ICSU should discuss and propose ways to improve our participation in this important ICSU programme.

**SP022.5 - Promoting the public image of Medical Physicists and Biomedical Engineers**

*Author(s):* Michael Cheng

Biomedical Engineer, Ottawa/ON/Canada

This paper focuses on the alert raised by the IUPESM President that “In many developing countries, there are no physicists or engineers in clinical settings; in developed nations, physicists and engineers are losing their positions in hospitals.” The author offers his personal viewpoints derived from the past 30 years in more than 30 developed and developing countries around the world working on medical device regulations and management issues. The conclusion proposed collaborative summit brainstorming.

Despite their technical talent and devotion to their work, most medical physicists (MP) and biomedical/clinical engineers (BME/CE) have less skills in promoting themselves to the public. I think this phenomenon is a weakness that needs to be addressed. We know that industries and some politicians will hardly succeed if they do not make themselves known to the public. The professions must seek ways to promote their public image. I will describe two domains where the merits of the MP and BME/CE are huge but under recognized by the public: 1. MP, BME/CE are principal builders of healthcare technology; 2. MP and BME/CE play vital roles in patient safety.
with medical devices in healthcare facilities. Then, I will propose outreach to developing countries with references to simple knowledge transfer tools described in two education sessions offered by this Congress WC2015. Lastly, I will suggest examples of opportunities for research to help emerging global health issues, and opportunities to develop personal medical technologies to empower personalized medical care and encourage patient responsibility. A full paper is also submitted with this abstract; the descriptions in the full paper also make references to four other submissions (see below) to this Congress WC2015.

In order to promote the public image of MP and BME/CE, the hurdles to overcome are complex; therefore an appropriate strategy to “market” their huge contributions to global healthcare should be a key topic for collaborative summit brainstorming called by the President.

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SP022.6 - The Utilization and Design of Doorless Mazes for Medical Linear Accelerator Rooms In Ontario, Canada
Author(s): Joseph J. Szabo
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Medical linear accelerator rooms in typical cancer centres use mazes for radiation protection, but these are usually short and straight and still require a heavy shielding door at their entrance. Especially for treatment energies higher than 10 MeV the purpose of the door is to attenuate both photons and neutrons that have scattered down the maze, as well as capture gamma rays created by neutrons in the concrete walls, ceiling, floor, and ultimately in the door itself. This radiation must be dealt with to secure the therapy staff working in the control area near the room entrance. Depending on the length of the maze, the door may have to attenuate scattered photons, moderate fast and intermediate neutrons, and finally attenuate capture gamma rays. This requires often massive and cumbersome doors, which usually consist of an initial layer of lead to attenuate the scattered photons and the maze generated capture gamma rays, followed by another layer of quite thick, highly hydrogenous material such as borated polyethylene, to moderate fast and intermediate energy neutrons into low energy thermal neutrons, which then are effectively captured by the boron, while only releasing capture gamma rays of a relatively low energy (0.473 MeV). A final layer of lead at the outside of the door is used to block these capture gamma rays. All this is usually quite heavy, resulting in a door that is 10’s of centimeters thick and thousands of kilograms in weight, often requiring tracks and motors to operate, which makes it quite expensive. Also, moving such a heavy door is usually slow and since the door is likely opened and closed more than hundred times a day, it is prone to wear, requiring expensive continuous maintenance. And in the event of a breakdown a manual technique for opening must be available. All this can be avoided if one uses a longer maze. In 1991 the author designed a maze that required no door at all. This maze was first put into clinical use in the city of Kingston and was the first maze without a door in the province of Ontario. After the successful implementation of this design, it was utilized in all new clinics and many of the older clinics in all of Ontario. In addition, it has been used elsewhere in Canada as well as in parts of the United States. However, in other parts of the world the doorless bunker is still not very well known. This paper is a review of the extent of the use of this design as well as detailed instruction on how to build it to minimally take up real estate by use of multiple bends and strategically placed polyethylene and borated polyethylene panels to reduce the neutron flux well before it reaches the maze entrance. Calculation methods and measurements from the radiation survey for the most recent construction will be shown. In that case the results were so good that the author was actually concerned that his survey meters were not functioning.
**SP023 - Quantitative Imaging: Part 1**

**SP023.1 - Improving quantitative functional imaging with dynamic contrast enhanced studies using a linearized Johnson-Wilson model approach**

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**Background**

The standard two compartment (2-C) model, consisting of vascular and tissue compartments, is frequently used to fit tissue time density curves (TDCs) from dynamic contrast enhanced (DCE) CT or MR studies. However, the compartmental assumption for the vascular space means that the finite vascular transit time is ignored. As image acquisition speed increases beyond 0.5 Hz, parameters estimated by fitting the tissue TDC with the two 2-C model without accounting for the finite vascular transit time could be biased. Also, 2-C model is unable to estimate blood flow (F), it estimates Ktrans instead, which is the flow extraction efficiency product. On the other hand, fitting tissue TDC using the Johnson-Wilson model with the adiabatic approximation (aaJW) will provide estimates of both Ktrans and F that are independently important for investigations of tumor associated angiogenesis. Current applications of the aaJW model use non-linear curve fitting methods to estimate Ktrans and F. These methods are prone to be trapped in local minima while searching for the optimal fit to the tissue TDC resulting in erroneous estimates of model parameters.

**Purpose**

To develop a method to linearize the fitting of DCE tissue TDC with the aaJW model and compare the method’s sensitivity to model parameters and covariances of estimated parameters with non-linear fitting methods.

**Method**

Linearization of 2-C model fitting of tissue TDC has been published before but no attempts to-date have been made for linearization of aaJW model fitting. The method we developed to linearize aaJW model fitting of the tissue TDC is based on time integrals of the arterial TDC (Cp(t)) and the tissue TDC (Q(t)). The stability of the linear and non-linear fitting methods were analyzed using sensitivity analysis which calculated the changes in the fitted tissue TDC with changes in the model parameters or sensitivity functions of both fitting methods. The sensitivity functions were used to estimate the covariances of the estimated parameters for both methods.

**Results**

The equations for tissue TDC fitting with the aaJW model are:

Non-linear: \( Q(t) = F \cdot [D(t-to) - D(t-to-W)] + K1 \cdot Cp(t-to-W) \cdot \exp(-k2 \cdot t-to-W) \)

Linear: \( Q(t) = F \cdot [D(t-to) - D(t-to-W)] + K1 \cdot D(t-to-W) + F \cdot k2 \cdot [E(t-to) - E(t-to-W)] \cdot k2 \cdot G(t) \)

where * is convolution operator, to is the delay between Q(t) and Cp(t), W is the vascular transit time, K1=Ktrans, k2 is backflux rate constant, D(t) is the integral of Cp(t), E(t) is the integral of D(t) and G(t) is the integral of Q(t). The sensitivity functions for the linear fitting method were ~ 5 times larger than those of the non-linear fitting method resulting in the covariances of estimated parameters from the linear fitting method > 1.3 times less than those of the non-linear fitting method.

**Conclusions**

Unlike the non-linear fitting method, the linear method estimates model parameters at the unique global minimum sum of squared deviations between the fitted and the measured tissue TDC. More importantly, the covariances of the estimated model parameters are significantly less for the linear method than the non-linear method. This would lead to more precise quantitative functional maps from DCE studies and more reliable diagnosis.

**SP023.2 - Early tumor Response assessment using volumetric DCE-CT and DCE-MRI in Metastatic Brain Cancer Patients**

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**Introduction:** Early change in tumour vascularity following stereotactic radiosurgery (SRS) is a potential biomarker of response. Dynamic contrast enhanced (DCE) MRI is often used to interrogate perfusion but has known limitations to accuracy and precision. Progress in CT technology now allows for volumetric acquisition with 4D temporal dynamic analysis (TDA) of perfusion. As such, DCE-CT presents as a standard for tracer-kinetic validation. This study aims to compare DCE-MRI analysis against DCE-CT support with 4D temporal dynamic analysis (TDA) of perfusion. As such, DCE-CT presents as a standard for tracer-kinetic validation. This study aims to compare DCE-MRI analysis against DCE-CT support.

**Methods:** Patients with brain metastases (total of 14 tumours) treated with SRS as part of REB-approved clinical trials underwent volumetric DCE-CT (Toshiba, Aquilion ONE) and DCE-MRI (IMRIS 3T Verio, Siemens) scans at baseline then 7 and 21 days post-SRS. DCE-CT parameters were: 80kV, 100mAs, 1sec interval and 0.468x0.468x1mm. VFA T1 quantification and DCE MRI acquisitions used 3D-FLASH with matching echo times (1.86 msec), repetition times (4.8 msec), and geometric features (1.15x1.15 mm in-plane resolution, 40 slices at 1.5 mm each). DCE-MRI used a 20° flip angle, and 45 frames were acquired every 5.8 sec. Voxel-based whole brain TDA was performed on both DCE-CT and DCE-MRI data using in-house software. Perfusion, permeability and Area-under-the-Curve (Ktrans, Ve, AUC) were assessed within each tumour at every time point using the Modified Tofts model and a linear regression analysis which calculated the changes in these parameters over treatment. Correlation between these vascular parameters and treatment response, evaluated as stable or reduction in tumor volume was assessed.

**Results:** At Day 21 only one tumor had a volume that remained larger than at baseline while the other tumors showed a decrease in volume of (mean of 53.6 +/- 31%). **DCE-CT:** 3 of 8 stable or responding tumours revealed a Ktrans reduction of 44.6 +/- 36.6% (p=0.056) at Day 7 post-BS while 10 out of 13 responding tumours had a reduction in Ktrans of 26.0 +/- 16.6 % by Day 20 (p < 0.01). Only one of the non-responding tumours showed a decrease in Ktrans at Day 7 while none did at Day 20. **DCE-MRI:** 7 of the 8 stable or reducing tumours revealed a Ktrans reduction of 17.4 +/- 16.6% (p<0.05) at Day 7 post-BS while 10 out of 13 responding tumours had a reduction in Ktrans of 24.0 +/- 20.3 % by Day 20 (p < 0.05). MRI results showed weak overall correlations with DCE-CT at either Day 7 (R2=0.16) or Day 20 (R2 = 0.21) for Ktrans. AUC changes did not correlate significantly with either time point or modality.

**Acknowledgement:** This research was fully funded by the Canadian Cancer Society (Geriatric Cancer Research Project).
Conclusions: This is the first study evaluating perfusion parameters acquired by same-day volumetric DCE CT and DCE MRI in a cohort of metastatic brain patients. The weak correlation between MRI and CT results may reflect issues such as sensitivity to arterial input, tumour type, definition of response, and edema that are under further investigation. These early results show Ktrans reduction at day 20 may predict for eventual tumor response post-SRS.

**SP023.3 - Diffusion tensor imaging is correlated with quantitative histology in surgically-resected hippocampi of epilepsy patients**

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**Introduction**

Hippocampal sclerosis (HS) is the most common pathology seen in mesial temporal lobe epilepsy (MTLE) patients, and studies have shown a relationship between the pattern of sclerosis and post-surgical outcomes (seizure freedom and memory impairment). Thus, predicting these pathological sub-types pre-operatively can play a significant role in pre-surgical management of TLE patients. Diffusion tensor imaging (DTI) has shown to be a sensitive marker of microstructural changes but the precise relationship of diffusion markers with HS subtypes is not well known. The current study aims to assess these relationships by comparing pre-operative imaging with quantitative markers of neuropathology from histology of the tissue resected after surgery.

**Methods**

Patients (N=15) undergoing temporal lobectomy were recruited for this study and imaged pre-operatively in a 3T MRI using a research protocol that included diffusion tensor imaging (41+6 directions, 2.5mm isotropic resolution). Tissue was resected en-bloc and prepared for histological processing. Histology slides were cut, stained with H&E, NeuN (neuronal marker) and GFAP (glial marker) for quantitative histology assessment. Hippocampal subfields (CA1, CA2/3, CA4/DG) were manually segmented in the pre-operative MRI and histology slides, and spatial correspondences were found using our validated MRI-histology image registration pipeline. Automated histology image processing was performed to extract maps of neuron density, size, and gliosis, and were correlated against mean diffusivity (MD) and fractional anisotropy (FA) of the corresponding slice.

**Results**

Histological data for two subjects were discarded due to insufficient tissue to assess delineate the subfields, thus correlations were computed with 13 patients. Mean diffusivity (MD) in the end folium (CA4/DG) was significantly correlated with the number of neurons in CA4 (r=-0.833, p<0.001) and the size of neurons in CA4 (r=-0.841, p=0.039). An increase in the extracellular space could explain the significant increase in MD in samples which contained fewer neurons or neurons with smaller average size.

**SP023.4 - Evaluation of fully automatic volumetric GBM segmentation in the TCGA-GBM dataset: Prognosis and correlation with VASARI features**

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**Background:** Reproducible definition and quantification of imaging biomarkers is essential. We evaluated a fully automatic MR-based segmentation method by comparing it to manually defined sub-volumes by experienced radiologists in the TCGA-GBM dataset, in terms of sub-volume prognosis and association with VASARI features.

**Methods:** MRI sets of 67 GBM patients were downloaded from the Cancer Imaging archive. GBM sub-compartment were defined manually and automatically using the Brain Tumor Image Analysis (BraTumIA). Spearman’s correlation was used to evaluate the agreement with VASARI features. Prognostic significance was assessed using the C-index.
Additionally, auto-segmented sub-volumes showed higher correlation with the manually delineated volumes (range ($r$): 0.65 – 0.91).

Results: The auto segmented sub-volumes showed high agreement with the manually delineated volumes ($r$: 0.65 – 0.91). Additionally, auto-segmented volumes showed higher correlation with the VASARI features ($r = 0.35, 0.50$, and 0.59; manual $r = 0.29, 0.50, 0.43$, for percentages of contrast-enhancing, necrosis and edema, respectively). The relative contrast-enhancing volume and the post contrast abnormal volume (necrotic core + contrast enhancing region) showed the highest C-index (0.73 and 0.72), comparable to manually defined volumes ($p = 0.22$ and $p = 0.07$, respectively). The non-enhancing region defined by BraTumIA showed significantly higher prognostic value (CI = 0.71) than the tumor-associated edema (CI = 0.60), both of which could not be separated by manual delineation.

Conclusion: BraTumIA tumor sub-compartments showed higher correlation with VASARI data, and equivalent performance in terms of prognosis compared to manual sub-volumes. This method can enable more reproducible definition and quantification of imaging based biomarkers and has a large potential in high-throughput medical imaging.

SP024 - Breast CAD and New Breast Imaging Techniques

SP024.1 - Modelling Breast Cancer Tissue via Analysis of WAXS Signatures

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A wide-angle x-ray scatter (WAXS) method to quantify the composition of cancerous tissue is described. The modeling of cancerous tissue is accomplished by analysis of the differential linear scattering coefficients $\mu_s$ of fibro glandular (fib) $[\mu_s,\text{fib}]$, cancerous breast tissue ($\mu_s,\text{cancer}$) and water ($\mu_s,\text{h2o}$). A model assumed that cancer consisted of fib and a volume of cancerous cells. Most of the scattering properties of the cells can be attributed to water since cells are composed primarily of water. In this work, the volume of cancerous cells was approximated by a volume of water. A two basis function method was used to estimate the $\mu_s$ of cancer, namely $\mu_s,\text{cancer}(x) = \text{afib} \cdot \mu_s,\text{fib}(x) + \text{ah2o} \cdot \mu_s,\text{h2o}(x)$ [Eq. 1], where $\mu_s,\text{fib}(x)$ and $\mu_s,\text{h2o}(x)$ are the basis functions, afib and ah2o are coefficients. The variable $x = (1/\lambda) \sin(\theta/2)$ is the momentum transfer which combines dependence of scatter on x-ray wavelength ($\lambda$) and scatter angle $\theta$.

A system of 78 equations corresponding to $x$ values ranging from 0.80 to 3.2 nm$^{-1}$ was constructed. The coefficients afib and ah2o of this overdetermined system were calculated via least-squares using the singular value decomposition (svd) method. The coefficients were also used to estimate fractional volumes $v$ of fib (afib) and h2o (vh2o), namely $v_{\text{fib}} = \text{afib}/(\text{afib} + \text{ah2o})$ and $v_{\text{h2o}} = \text{ah2o}/(\text{afib} + \text{ah2o})$.

These $v$ values were then used to estimate another more meaningful $\mu_s$ estimate of cancer given by $\mu_s,\text{cancer}(x) = v_{\text{fib}} \mu_s,\text{fib}(x) + v_{\text{h2o}} \mu_s,\text{h2o}(x)$ [Eq. 2]. For one set of diffraction data, afib = 0.23, ah2o = 0.73, $v_{\text{fib}} = 0.24$ and $v_{\text{h2o}} = 0.76$ and for the other set afib = 0.83, ah2o = 0.31, $v_{\text{fib}} = 0.73$ and $v_{\text{h2o}} = 0.27$. For the first set of data both $\mu_s$ estimates (i.e. Eqs. 1 and 2) matched the measured $\mu_s$ cancer well whereas for the latter only the $\mu_s$ via Eq. 1 provided a reasonable match. The modeling of cancerous tissue via analysis of WAXS signals is an interesting method to learn more about the characteristics of cancer. It was not surprising to see differences in predictions when using different WAXS data for breast tissue since they were different in the first place. The different results obtained justify the needs for more studies on the acquisition of WAXS signals of breast tissue. The presence of fat tissue could have affected the WAXS signals. In a future work, a WAXS fat subtraction protocol will be implemented in order to measure the $\mu_s$ coefficients of fib and cancerous tissue without the effects of fat. The measurements of $\mu_s$ for cells will also be done. Such data will help in characterizing the make-up of cancer and help determine the potential diagnostic use of WAXS.

SP024.2 - Analysis of 80 kV WAXS Measurements with a CdTe Breast Biopsy Diffractometer

Author(s): Nancy Mcdonald, Robert J. Leclair

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The wide-angle x-ray scatter (WAXS) signatures of breast tissue may provide an additional source of diagnostic information in the realm of breast diagnostics. Measurements to test the ability of exploring a larger momentum transfer $x$ space with a custom built breast biopsy CdTe diffractometer were performed. 80 kV 3.2 mm diameter beams of 3 min duration interrogated 5 mm diameter, 2 to 5 mm thick samples of polymethyl methacrylate (PMMA) and polycarbonate as well as a 5 mm thick water sample. Scattered spectra $N_s(E)$
were detected at θ=6° with a 25 mm² x 1 mm thick CdTe detector. A 3 mm diameter aperture placed 4 cm above the detector yielded a solid angle of detection Ω = 4.9×10⁻⁵ sr at the sample center. The probed x range was from 0.3 nm⁻¹ to 3.38 nm⁻¹. Linear differential scattering coefficients μ were calculated via a semi-analytical model and compared qualitatively with μ calculated using coherent form factors and incoherent scatter functions from the literature. Because of the use of a higher kV beam, the effects associated with florescence escape and hole tailing in the CdTe crystal were investigated via the application of a detector response function. The incident spectrum N0(E) was estimated via application of the scatter model N0(E). The μs and compared qualitatively with μs scattering coefficients μs

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Breast Cancer is the most common cancer in women worldwide. As mammographic double interpretation is not possible everywhere, and with the number of cases rising in addition to time and cost constraints, the development of Computer Aided Detection (CAD) systems with high sensitivity and high specificity is important. Mammographic breast density refers to the prevalence of fibroglandular tissue as it appears on a mammogram and it is an important breast cancer factor risk. Furthermore, breast density may mask abnormalities and/or lower the sensitivity of mammography. The development of density specific CAD systems coupled with automated breast density classification may alleviate the problem by achieving high sensitivity and specificity for certain breast density classes. Women with high breast density may seek supplementary screening – in addition to mammography. Amplitude-Modulation Frequency-Modulation based features have been successfully used to characterize mammographic breast density and to automatically classify mammograms into one of the four Breast Imaging Reporting and Data Systems (BI-RADS) mammographic breast density classes.

This work, presents initial results on the use of multi-scale Instantaneous Amplitude (IA), Instantaneous Phase (IP) and Instantaneous Frequency (IF) information from Amplitude-Modulation Frequency-Modulation (AM-FM) decomposition for the classifications of Regions of Interest (ROIs) from low density mammograms to either normal or cancerous/malignant. A Gabor filter-bank using eight orientations and six different frequency scales is applied for AM-FM demodulation. Dominant component analysis is used for the evaluation of IA, IF and IP at each frequency scale. The IA amplitude reflects local image intensity variations, e.g. edges, with different spatial scale variations reflected in different frequency scales whilst the IF measures local frequency content. First and second order statistical features are evaluated on each of the normalized histograms of the components across the different scales and are used for characterizing the ROI. Support Vector Machines (SVMs) are used for ROI classification.

All mammograms from the Mammographic Image Analysis Society Database that are classified as fatty are used for the development and the evaluation of the presented CAD system. Regions of different size - segmented using block processing from the mammograms classified as normal-, and the ROIs that hold biopsy proven malignancies (well defined masses, speculated masses, other ill-defined masses, architectural distortion and asymmetry but not calcifications) are used for training the SVM classifier. The SVM with RBF kernel is investigated using tenfold cross validation in order to identify the best parameters. The developed CAD system achieves accuracy over 80%, with sensitivity over 85% and specificity over 75% for all types of masses. The prediction results, achieved using the SVM classifier, are very encouraging. Similar CAD systems using different AM-FM with additional texture features will be developed and evaluated specifically for other mammographic density classes.

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SP024.3 - AM-FM features for the classification of Regions of Interest towards the Development of a Breast Cancer Density Specific Computer Aided Detection System

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SP024.4 - Single Scatter Signals during Dual Detector Volume-of-Interest Breast Cone-Beam Computed Tomography: A New Source of Diagnostic Information?

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Dual detector breast volume-of-interest (VOI) cone-beam computed tomography (CBCT) is a technique that uses two scans to generate higher quality details of a VOI. A full field scan is acquired at low exposure with a flat panel detector whereas a high resolution scan of the VOI is acquired with a high resolution CMOS detector at higher exposure. The data obtained at lower exposure/resolution is used in conjunction with the higher quality VOI data to reconstruct images. The effects of scattered x rays on details within the VOI are reduced by this technique. In this work it is proposed that during the high resolution scan it could be beneficial to also use the flat panel detector to capture some scattered photons from the VOI for diagnostic purposes. Simulations were performed to assess the potential use of the single scatter that could be captured during the high resolution scan. A 14 cm diameter 10.5 cm long cylinder with an embedded 2 cm diameter spherical lesion was considered. Fibroglandular (fib) and water spheres were chosen to represent benign and cancerous lesions. The following percent mass compositions for the cylinder were considered: 80(fib):20(fat), 60:40, 50:50, 40:60, and 20:80. The distance from the source to isocenter was 58 cm and from the isocenter to detector plane 28 cm. Using a 60 kV beam with an HVL of 3.7 mm Al, energy integrated signals (EIS) were computed for each of the 300 × 300 1 mm² pixels. In normal full field breast CBCT, a typical mean glandular dose of 6 mGy is used. In this work, the VOI scan had an exposure 4× higher than that of the regular full-field CBCT. The incident cone beam irradiated the smallest VOI which included the spherical lesion. The EIS due to scatter (EISs) from the VOI were calculated for both fib and water lesions embedded in the different cylinder compositions. Since contrast reversal occurred across the detector, the information content was increased by adding pixels selectively. Pixels including signals from primary photons were not included in the summations. The variances in pixel signals were based on the propagation of Poisson noise in ideal energy integrating pixels. The signal-to-noise ratio in terms of EISs for malignant versus benign lesions within cylinders of the same composition were on the order of 20 thereby suggesting potential usefulness of the x-ray scattered photons. A problem
that needs to be addressed, however, is that there were significant variations in signals as a function of cylinder composition for a given lesion type. A study which includes a method to estimate the composition of the main phantom will be conducted.

SP024.5 - Investigating automatic techniques in segmentation accuracy of masses in digital mammography images
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Many procedures have been developed to aid in the early detection and diagnosis of breast cancer. In this context, Computer-Aided Diagnosis (CAD) schemes were designed to provide to the specialist a reliable second opinion. In such schemes there is a complex step which corresponds to the segmentation since good structures classification is dependent on the features extracted from the segmented images. In this work we propose the use of several methods of automatic segmentation of breast lesions, such as: watershed, fuzzy c-means, k-means, Self-Organizing Map (SOM), Enhanced Independent Component Analysis Mixture Model (EICAMM) and level set. In order to evaluate which of them could provide more accurate results in segmenting breast masses segmented images were compared with those manually delimited by an experienced radiologist. Ten quantitative measures were obtained from the images. These segmentation techniques were applied on different types of lesions, including images corresponding to dense breasts. From the evaluation the level set technique has proved being more effective for the images set used to testing all the methods. It has registered a higher overlap rates in relation to the image segmented by the specialist as well as low rates of under and oversegmentation, reflecting in the high accuracy and low false-positive and error rates.

Step 3. If MI converges, end the registration process for the nth IR image.

Fig. 2 shows the well registration results between the 1st IR image and the nth IR image.

SP024.6 - The Automated Marker-Free Longitudinal IR Breast Image Registration Algorithm
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Longitudinal IR image registration is a very difficult task in general because it is impractical and unlikely to keep markers attached on a body surface of a subject for weeks or even longer. To overcome this problem, the new longitudinal IR image registration algorithm (Genetic Particle Competition, GPC), which is the first automated marker-free longitudinal IR image registration algorithm in the world for breast IR images and may be easily extended to other parts of the human body. The algorithm is based on two novel types of fiducial points, which are the corner points of heat patterns and the other is the branch points of the skeletons of heat patterns, and automated determination of corresponding pairs of fiducial points between two images. Suppose two IR images, namely, the 1st IR image and the nth IR image, are registered as depicted on the top of Fig.1. After finding the initial corresponding points by SIFT and deriving the corner points of heat patterns and the branch points of the skeletons of heat patterns, the GPC mechanism operates to find the corresponding point as follows:

Step 1. Randomly generate a set of candidate points around the initial corresponding point, which form the competitors.

Step 2. For each of the competitors on the deformed nth IR image are calculated the mutual information (MI) between the 1st IR image. Define the competitor with the maximal MI as winner, those ranked the top 50% of MIs as the selected competitors, and replace the remaining losers by new randomly generated competitors until the MI of the winner converges.
With the advent of MRI-guided radiotherapy, radiation dosimetry in the presence of magnetic fields must be addressed in several ways to assure accurate dose delivery and patient safety. To calculate dose accurately in these conditions, the only known method capable of simulating the transport of charged particles in dense matter in the presence of magnetic fields is Monte Carlo. At the present time, general-purpose codes such as PENELOPE and GEANT4 already offer this option and other codes, such as EGSnrc, remain under development. To assure the accuracy of Monte Carlo results, algorithms must be tested in conditions relevant to radiation dosimetry, such as ionization chamber response to radiation dose. To achieve the same rigorous benchmark as does the Fano cavity test, it is necessary to explore the conditions under which it can be performed in the presence of a magnetic field distribution.

This theoretical study is based on Fano's approach and evaluates the possibility to achieve charged particle equilibrium in heterogeneous media having uniform atomic properties. The Boltzmann transport equation, modified to include the Lorentz force, forms the basis of the theory. Two special conditions for the source and magnetic field distributions are evaluated as potential candidates for new Fano cavity tests. The applicability of Fano's theorem in these conditions is shown and the energy deposition is also derived from first principles.

Using the modified transport equation, it is demonstrated that the two proposed conditions on the source and the magnetic field allow Fano's theorem to apply. Moreover, the energy deposition under these conditions is shown to be identical to the one in the absence of a magnetic field, such as in a cavity dose calculation under standard Fano conditions.

This theoretical study demonstrates two possible conditions under which Fano's theorem is applicable in the presence of a magnetic field. While it was previously shown that in general, Fano's theorem cannot hold in the presence of a uniform magnetic field as it does not scale with mass density, this study is a significant improvement towards benchmarking Monte Carlo codes coupling radiation transport with magnetic fields.

**Material and Methods:** Recently our Clinac-2100CD Varian linear accelerator was upgraded to high dose rate Flattening Filter Free (FFF) 6MV X-rays for Stereotactic Radiosurgery. Beam parameters measured from minimum 2x2cm² to 40x40cm² field. As VMAT/IMRT based Stereotactic Radiosurgery comprises of many small segments, Penumbra modeling play a major role in final dose calculation. Both AAA & Acuros-XB algorithms allow users to fine tune the primary source spot size (SSS) so that computed beam profile penumbra can match with the measured beam penumbra for all the field sizes. SSS were varied from 0 to 2mm in steps of 0.5mm in X&Y direction. For each SSS, dose was calculated for open field sizes of 3x3cm², 5x5cm² & 10x10cm² and was analyzed with measured beam parameters. To evaluate beam modeling a water phantom (size=40x40x40cm³) was created and dose was calculated for different fields & for different SSS. The profiles at dmax and 10cms depth were taken for penumbra analysis with respect to measured profile. For all the SSS & field sizes Distance (in millimeters) to agreement (DTA) were performed between computed & measured 80% isodose curves. Similarly for Acuros-XB algorithm the average DTA at Dmax for SSS of 0.5, 1, 1.5, 2.0mm were -0.74±0.73, -0.74±0.73, -0.57±0.67, -0.03±0.64, 0.08±0.63 mm respectively. Similarly for Acuros-XB algorithm the average DTA at Dmax for SSS of 0.5, 1, 1.5, 2.0mm were -0.71±0.59, -0.71±0.59, 0.20±0.28, 0.34±0.31, and 0.62±0.38 mm respectively. The average DTA at D10 for SSS of 0.5, 0.5, 1, 1.5, 2.0mm were -0.52±0.65, -0.52±0.65, -0.15±0.75, -0.09±0.78, 0.11±0.79 mm respectively. Stereotactic treatment plan analysis shows that average PTV mean dose variation with SSS 0.75mm for AAA was found -2.0% compared to 1.0mm default SSS, whereas Acuros-XB SSS 1.2mm variation -1.2% compared to default 1.0mm. Absolute dose measurement results using small volume ion chamber and predicted plan dose variation for VMAT stereotactic plans found very minimal with AAA SSS 0.75mm and Acuros-XB SSS 1.2mm compared to algorithm default SSS.

**Conclusion:** For AAA algorithm the results shows a good agreement between measured dose and calculated dose for spot sizes of 0.5-1mm. On the other hand for Acuros-XB algorithm, a spot size of 0.5-1mm agrees better for the field size up to 5x5cm² & a spot size of 1-1.5mm agrees better for the field size greater than 5x5cm². Algorithms showed good agreement with measurement for range of fields provided primary source spot configuration has been adequately tuned for precise dose calculation and delivery.

**SP025.3 - A Geant4 Helical Tomotherapy model as a tool for 3D dose distribution evaluation**

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Very high technological level is involved in Helical Tomotherapy (HT). The gantry rotation, couch speed, dose rate and accurate MLC leaf positioning are crucial for accurate dose delivery. For a high quality and safe treatment, a machine Quality Assurance (QA) program and patient-specific dose verifications are requested. The most detailed
SP025.4 - Development of 4D actual delivered dose calculation system for dynamic tumor-tracking irradiation with a gimbaled linac
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(1) Purpose
In previous works, we have developed an in-house integrated four-dimensional (4D) Monte Carlo (MC) dose calculation system as a routine verification tool for dynamic tumor-tracking (DTT) irradiation. The purpose of this study was to develop 4D actual delivered dose calculation system for DTT irradiation by gimbals mechanism with Vero4DRT.

(2) Method
First, plans were created for five patients having lung cancers under the normal protocol for DTT. Furthermore, the modified DTT plans were created in consideration of several errors such as intrafractional mechanical, positional predictive, and overall targeting errors during DTT irradiation. These errors were retrospectively computed from orthogonal fluoroscopy images and the system log files stored during DTT irradiation. Subsequently, 4D MC dose calculation was performed with 6-MV photon beam delivered by the Vero4DRT using EGSnrc for both the original and the modified DTT plans, respectively. At that time, phase-space data at each respiratory phase was created from the particle data under the MLC with or without the above errors, respectively. Next, 4D dose distribution was created by summing up the dose distribution under the geometrical combination of the target and the MV beam at each respiratory phase. The dose distribution computed with the above errors was regarded as the delivered dose distribution during DTT irradiation while the dose distribution computed without the above errors was regarded as the planned DTT dose distribution. Finally, isodose curves and DVHs were compared between the planned DTT and the delivered DTT dose distribution.

(3) Result
For all cases, 2D gamma passing rate was 93% using criteria of 2% / 2 mm for each dose distribution on the axial, sagittal, and coronal planes at the isocenter, respectively. CTV coverage, mean dose within the lung, and maximum dose within the spinal cord were comparable between the delivered DTT and the planned DTT dose distribution.

(4) Conclusion
We have developed 4D actual delivered dose calculation system for DTT irradiation using the gimbaled x-ray head. The result has demonstrated that DTT irradiation with Vero4DRT achieves the dose delivery with high accuracy.

SP025.5 - Organ Doses from Hepatic Radioembolization with Y-90, Sm-153, Ho-166 and Lu-177: A GEANT4 Monte Carlo Simulation Study
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Introduction—Y-90 radioembolization are increasingly used for palliative treatment of advanced liver cancer. Since its physical decay is fully via beta emission, imaging following the treatment is rather challenging. Radionuclides with both beta and gamma emissions have been explored as alternative to Y-90 in liver radioembolization, however little information was available in terms of internal radiation dosimetry.

Materials & Methods—Monte Carlo simulation using GEANT4 source code was carried out. The GEANT4 advanced example human_phantom was used. A mathematical female phantom was adopted with organ geometries as specified in MIRD Pamphlet 5. A medium size, spherical hepatic tumor with radius, r = 4.3 cm was modelled within the liver volume. Y-90 sources were isotropically distributed within the tumor with total activity of 1.82 GBq determined using Body Surface Area (BSA) method recommended by SIRTex (Sydney, Australia) for the Y-90 therapy. The dose was calculated in all the organs of the human phantom. The simulation was carried out with the assumption of no lung and extrahepatic shunting, with full localization of Y-90 sources within the tumor volume. The resulting tumor dose was validated by comparing it with the dose calculated using partition model. The simulation study was repeated substituting Y-90 with Sm-153, Ho-166 and Lu-177. GEANT4.9.6.p03 was used.

Results—The 333 cm³ tumor volume corresponded to 18% tumor involvement. The tumor and normal liver tissue doses for the Y-90 simulation were (262.9 ± 0.6) Gy and (2.9 ± 0.1) Gy, respectively. In order to deliver tumor dose equivalent to 1.82 GBq Y-90, approximately 8.32, 5.83, and 4.44 GBq were required for Sm-153, Ho-166 and Lu-177, respectively. Doses to other organs were mainly dependent on the gamma energies (Figure 1). All the organ doses did not exceed 1 Gy.

Discussions—Although the organ doses deriving by Sm-153 and Lu-177 were relatively higher compared to Ho-166 and Y-90, the doses were still far below the maximum tolerance limit commonly used in radiotherapy, i.e. 60, 23 and 17.5 Gy for adrenal glands, kidneys and lungs, respectively. Alternative treatment with Sm-153 or Lu-177 is still feasible as long as the organ tolerance limit were not exceeded.

Conclusion—Ho-166, Lu-177 and Sm-153 offer the advantage of emitting useful gammas for post-procedure imaging. They show potentials as Y-90 substitutes for liver radioembolization, delivering a comparable tumor dose, and doses within the maximum tolerance limit to the surrounding organs.
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Conclusions:
The Acuros XB algorithm performs well for calculating doses for 6 MV FFF beams in and around lung-like inhomogeneities, and shows better agreement with measurements than the AAA algorithm. In bone-like material, it shows good agreement in calculating the dose to medium, but differences above 5% were found in the calculation of dose to water.

Figure 2

SP025.7 - Performance of the ACUROS™ dose calculation algorithm for 6 MV FFF beams in inhomogeneous media
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Purpose:
FFF beams are now commonly used in radiation therapy treatment. Because of the high dose rate that these beams typically offer, they are often used for stereotactic body radiotherapy (SBRT) of the lung. Accurate dose calculations are particularly important in these cases due to the high fractional doses delivered. In this study, the accuracy of Varian's Acuros XB dose calculation algorithm is investigated in inhomogeneous phantoms for both open fields and VMAT treatments.

Methods:
Three series of tests were performed using three different phantoms. ACUROS calculated doses were compared to Monte Carlo (MC) calculations, the anisotropic analytical algorithm (AAA), and film measurements. The phantoms were comprised of water equivalent material, lung equivalent material, and bone equivalent material. In one series of tests, the doses at various depths in slabs of lung and bone material embedded in solid water were evaluated. A second series of tests evaluated the 2D dose distribution in planes containing inhomogeneity boundaries, and a third set of tests used the QUASAR™ phantom (Modus Medical Device Inc.).

Results:
The depth-dose calculations in a slab of lung material embedded in solid water showed good agreement between the Acuros XB, MC, AAA, and measured values. The calculated depth dose values in a slab of bone embedded in solid water calculated by AAA agreed well with the measured values. Acuros calculated depth doses to medium showed excellent agreement with Monte Carlo calculations (dose to medium) and good agreement with film measurement, but differences above 5% were found in the calculation of dose to water with measurements. Monte Carlo calculations were repeated with the Gafchromic film simulated by a thin layer of water and showed excellent agreement with measurements. The 2D dose distributions calculated using the Acuros XB algorithm showed substantially better agreement with measurement than the AAA calculations (Figure 1 a,b,d and e). This was also true for the dose calculations in the lung phantom and for VMAT plans on the QUASAR phantom (Figure 1 c and f).

Conclusions:
The Acuros XB algorithm performs well for calculating doses for 6 MV FFF beams in and around lung-like inhomogeneities, and shows better agreement with measurements than the AAA algorithm. In bone-like material, it shows good agreement in calculating the dose to medium, but differences above 5% were found in the calculation of dose to water.

SP025.8 - Ray Tracing Algorithm for Virtual Source Modelling based on Evaluation of Rounded Leaf End Effect of Multileaf Collimator
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Rounded leaf end effect of multileaf collimator plays a role in penumbra characteristics of dose profile. It strongly influences dose target volume conformity and organ at risk sparing for radiation therapy. Previous studies have shown that parameters in virtual source model could be fitted using dose distribution results obtained from Monte Carlo simulation or dosimetric measurement. However, there is a lack of research in literature reporting on virtual source modeling with the rounded leaf end effect incorporated. In this study, we present an analytical method for virtual source modeling by evaluation of the rounded leaf end effect of multileaf collimator on dose profile. We confine our study to single source modeling, with source energy distribution of Gaussian shaped. Ray Tracing algorithm is introduced and parameter estimation is conducted to revise the source size. Model verification is performed with numerical simulation, which is conducted based on the Monte Carlo codes of EGSnrc/BEAMnrc. It is shown that Ray Tracing algorithm employing the focal spot size of photon source would result in reduced penumbra width, compared with the simulation counterpart. This observation is probably related to the aperture effect of multileaf collimator. In contrast, results of penumbra width and radiation field edge offset using revised source size obtained with parameter estimation agree well with Monte Carlo simulation. In summary, the method we propose could provide insight into virtual source modeling using Ray Tracing algorithm.
SP026 - The Development of a Device for the Fricke Dosimetry for HDR Brachytherapy

Author(s): Camila Salata, Mariano G. David, Carlos E. Dealmeida

HDR-BT is considered an important option for cancer treatment, but the calibration of the Ir-192 is complex. The Fricke dosimetry has been considered an option to determine the absolute absorbed dose to water. It is composed mainly of water and ferrous sulfate, and the ferric ions in the solution will be converted to ferrous ions by the ionizing radiation, proportionally to the absorbed dose into the solution. The optical density of the solution is measured using a spectrophotometer. As this is a liquid dosimeter it is important to have a device where the solution will be irradiated. Some characteristics of the device should be considered: the wall material should be water equivalent and shouldn’t react with the solution; it must be sealed, but easy to vert the solution from the vessel into a cuvette to read it with the spectrophotometer. The main purpose of this study was to develop a device for the irradiation of the Fricke solution, using the HDR-BT Ir-192 sources.

Figure 1: Evolution of the devices created for the Fricke Dosimetry.

The first device created (Figure 1A) consisted of two glass balloons, one inside the other. The solution was disposed in the space between the balloons. The source was positioned in the center, inside a glass tube so it didn’t have any contact with the solution. Some measurements were done, and the disadvantages of this device were: the glass material wasn’t water equivalent; and the solution wasn’t homogeneously irradiated, as the distance from the source wasn’t the same on all the irradiated solution. The device was redesigned to improve the measurements (Figure 1B). The main changes were: the wall material was water equivalent, PMMA; the solution volume irradiated was only a central ring, so the solution was homogeneously irradiated. More measurements were done and it was very difficult to fill the device with the solution, and also difficult to vert the solution to the cuvette. The current device (Figure 1C) is a cylinder ring, where the solution is disposed and have corrected those problems. The source position is now calculated to be at the center of the ring. Now it is easier to fill it with the solution, and to vert the solution to the cuvette. Those improvements of the device are very important to the development of the Fricke dosimetry as an option for the Ir-192 sources calibration.
SP026.2 - A New Methodology for the Determination of the G-value for Fricke Dosimetry
Author(s): Camila Salata1, Leo D.O. Franco2, Mariano G. David3, Carlos E. Dealmeida1
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The Fricke dosimeter is a chemical dosimeter and its base is the ferrous sulfate. It is one of the most widely used chemical dosimeters and has been considered as a possible dosimeter for the determination of the primary standard for the absorbed dose to water of Ir-192 High Dose Rate brachytherapy (HDR-BT) sources. The Fricke dosimeter is mainly composed of water, so its attenuation of radiation is very similar to the water, which turns possible its use as an absolute dosimeter. During the interaction of the radiation with the Fricke solution the ions Fe²⁺ are converted to Fe³⁺, and this conversion is proportional to the absorbed dose at the solution. One of the parameters used to determine the absorbed dose at the Fricke solution is the chemical yield, known as the G-value. The G-value can be defined as the number of molecules of Fe³⁺ produced per joule of energy absorbed in the solution. This parameter has been determined by different authors, for different energies, but those data are old, and the methodology used was based on interpolations. This study proposes a new methodology for the determination of the G-value for Ir-192 HDR-BT sources. On the methodology proposed it was used a PMMA phantom (figure 1A) filled with water with three supports of PMMA for the Fricke solution, one for the ion chamber, and one for the Ir-192 source in the center (figure 1B).

Figure 1: A) PMMA Phantom with the supports for Fricke solution, ion chamber and Ir-192 source. B) The positioning of the supports in detail.

The position of the supports were fixed for each irradiation, and changed clockwise direction, after each irradiation. The source was always fixed in the center of the support. After each irradiation the optical density of the solution was read using a Micronal spectrophotometer. The absorbed dose in the Fricke solution at each position was considered equal to the dose determined by the ion chamber and Ir-192 source. During the interaction of the radiation with the solution the ions Fe²⁺ are converted to Fe³⁺, and this conversion is proportional to the absorbed dose at the solution. The results will be repeated using a new spectrophotometer recently acquired by the LCR, with better resolution and sensibility. This will improve the uncertainties associated with the measurements.

SP026.4 - IAEA Dosimetry Laboratory support to the IAEA/WHO SSDL Network
Author(s): Igor Gomola, Istvan Csete, Ladislav Czap, Joanna Izewska, Ahmed Meghzifene
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The IAEA Dosimetry Laboratory (DOL) is the central laboratory of the IAEA/WHO Network of Secondary Standards Dosimetry Laboratories (SSDLs). In 1976, the IAEA in collaboration with the WHO established this Network to provide a forum in which national SSDLs could regularly perform measurement comparisons and thus strengthen confidence in radiation dosimetry coherence worldwide. This Network, through its 84 SSDL members designated by Member States, provides a framework to establish a direct link between national dosimetry standards to the international measurement system (SI) of standards and the dissemination of SI quantities and units to end users through the proper calibration of field instruments by the SSDLs.

A Quality Management System (QMS) has been established for the DOL following the guidelines of EN ISO/IEC 17025:2005 standard. In 2005, the Joint Committee of the Regional Metrology Organizations (JCRB) and the Bureau International des Poids et Mesures (BIPM)
formally acknowledged that the DOL QMS satisfies the requirements of the Mutual Recognition Arrangement established by the Committee for Weights and Measures (CIPM-MRA) . Since that time, the 23 different calibration capabilities of the DOL are peer reviewed regularly; they are internationally accepted, and published in the frame of the CIPM-MRA.

The activities of the IAEA include an inter-laboratory comparison programme (for air kerma, Kair, and absorbed dose to water, Dw, in Co-60 beam, and Kair for diagnostic X-ray beam qualities) that enables the participating SSDLs to harmonize their calibration practices for measuring instruments used for the determination of different dosimetry quantities in line with the IAEA Codes of Practice TRS-398 and TRS-457. (Figure 2. shows the results for Kair and Dw in Co-60 beam )

In addition, the IAEA offers training opportunities in radiation dosimetry, calibration of dosimetry standards dosimetry audits, and quality management for SSDL staff from Member States. The training of SSDL staff contributes to the improvement of measurement capabilities in radiation dosimetry for radiation therapy, diagnostic radiology and radiation protection applications of ionizing radiation in IAEA Member States.

Examples of our work include:

- The activities of the IAEA include an inter-laboratory comparison programme for air kerma, Kair, and absorbed dose to water, Dw, in Co-60 beam, and Kair for diagnostic X-ray beam qualities that enables the participating SSDLs to harmonize their calibration practices for measuring instruments used for the determination of different dosimetry quantities in line with the IAEA Codes of Practice TRS-398 and TRS-457. (Figure 2. shows the results for Kair and Dw in Co-60 beam )

- In addition, the IAEA offers training opportunities in radiation dosimetry, calibration of dosimetry standards dosimetry audits, and quality management for SSDL staff from Member States. The training of SSDL staff contributes to the improvement of measurement capabilities in radiation dosimetry for radiation therapy, diagnostic radiology and radiation protection applications of ionizing radiation in IAEA Member States.

Figure 1. Results of SSDLs in the ongoing therapy level comparison program using participants’ transfer chambers. (Participant gets further assistance to perform corrective action(s) if its result is out of the acceptance limit.)

**SP026.6 - Monte Carlo corrections for a Fricke-based standard of absorbed dose to water for Ir-192 HDR brachytherapy.**

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**Purpose:** Ir-192 HDR Fricke dosimetry requires a conversion factor dose to Fricke to air-kerma to determine the G-value of a 250 kV x-ray beam, and several correction factors to obtain the dose to water at the reference position. These factors can be determined using Monte Carlo (MC) techniques.

**Methods:** The G-value for an Ir-192 source is determined by interpolation between the G-values of two known beam qualities, Co-60 and 250 kV x-rays. The G-value of the 250 kV x-ray beam is determined by irradiating a bag with Fricke solution of known volume with a 250 kV beam of known air-kerma. A conversion factor dose to Fricke to air-kerma, DF/Kair, is calculated using the EGSnrc user-code cavity combined with a BEAMnrc model of the x-ray source. Knowledge of the Ir-192 G-value makes it possible to measure the dose imparted to a Fricke dosimeter placed at the reference position, immersed in a water phantom. The dose to water at the reference position is derived from the dose to Fricke by applying a conversion to dose to water, DFW, and several corrections to remove the effects of the holder, catheter, and beaker materials (Pwall), and to correct for volume averaging (Kdd). These corrections are determined with the EGSnrc user-code cavity by modeling the microSelectron V2 Ir-192 HDR seed used in our lab and the measuring setup in detail.

**Results:** DF/Kair is the largest factor required, with a value of 1.15 [0.06%]. This large value can be explained mostly by the mass
energy absorption coefficient ratio Fricke to air which is about 1.11 [0.02%] as determined using the EGSnrc user-code g. An Awall calculation with the user-code cavity shows that the rest of this correction factor is due to the contribution from secondary particles to the dose to Fricke (Awall=1.036 [0.002%]). Volume averaging contributes the second largest correction, which is about 1.015, while the wall correction and the Fricke to water conversion factor almost cancel out.

Conclusions: MC simulation can be used to determine the corrections required for HDR Fricke dosimetry. The large value of the Fricke to air-kerma conversion factor can be explained by the difference between the mass energy absorption coefficients for the Fricke solution and air. Remaining differences are caused by the contribution from secondary particles. The factor needed to obtain dose to water at the reference position from the dose to a Fricke dosimeter is significantly smaller and mainly due to volume averaging. Future work will focus on the sensitivity of these corrections to systematic uncertainties in the cross sections used for the MC calculations.

Method

The third party evaluation of absorbed dose to water has been performed between the Tokyo metropolitan hospitals and the Tokyo Metropolitan University (TMU) since 2007. In order to investigate the changes between the JSMP01 and 12, the absorbed dose at calibration depth Dc was evaluated. Absorbed dose measurement was performed separately by the stuff of the facilities and the TMU on the same day. Ionization chamber (TN30013, PTW), electrometer (Inovision 35040), digital quartz barometer (745-16B, Paroscientific), digital thermometer (TL1-A, Thermoprobe) and 1D water phantom (WP1D, IBA) was used for the third party evaluation and own equipment was used for the user evaluation.

Results

Before 2011, mean deviation from Dc evaluated by TMU and its standard deviation (1σ) were from 0.5 % to 0.7 % and from 0.5 % to 0.7 %, respectively. By the investigation in 2013-2014, ND,w and JSMP12 was adopted in 7 of 11 facilities. By analysis using the result of 7 facilities, mean deviation and its standard deviation was reduced to 0.1 % and 0.4 %, respectively. As a result, there is significant difference in mean deviation and variance (p < 0.05) between JSMP01 and 12.

Conclusion

In this report, it was observed that the deviation and variance between user and third party evaluation of Dc was reduced. Therefore it is confirmed that uncertainty of absorbed dose to water evaluation is reduced by adoption of the ND,w calibration and the new dosimetry protocol JSMP12.

SP026.8 - A calibration system of therapy-level dosimeter in Japan organized by ANTM

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In Japan, the therapy-level dosimeter calibration had been carried out in terms of exposure until 2012. Therefore, the conversion factor kD,X was necessary to convert the calibration factor Nx obtained via air measurement to the absorbed dose calibration factor ND,w. In 2011, Japanese National Standard Laboratory (National Metrology Institute of Japan, NMIJ) established the national measurement standard of therapy level absorbed dose to water of Co60 and started to deliver this standard. According to the NMIJ activity, the ANTM (Association for Nuclear Technology in Medicine, the SSDL in Japan) has launched a new dosimeter calibration system in terms of absorbed dose to water from October 2012, too. After that, ND,w determined directly in water is delivered to radiotherapy institutions in substitution Nx. The calibration procedure by ANTM follows Standard Dosimetry 12 published by Japan Society of Medical Physics (JSMP). The concept and formalism of Standard Dosimetry are almost same to IAEA TRS 398. Ionization chambers to be calibrated are fixed at 5cm depth in water phantom. For cylindrical type chambers, appropriate waterproof sleeves are used not only to protect water but also to fix their position in the phantom. The sleeves are made of PMMA with a wall of 1mm in thickness at ionization effective volume of chamber. For flat type chambers that are water proof or have water proof cap are put into water directly.

ANTM is a calibration laboratory certified with the Japan Calibration Service System (JCSS) and can issues certificate with JCSS symbol mark. The JCSS is a standard dissemination system based on Metrological Law. The principles of JCSS are the calibration traceable to national standard and the certification of calibration laboratory. Calibration laboratories certified are proven to have sufficient technical and management competence to carry out calibration. Calibration certificate issued with JCSS symbol mark states both calibration value traceable to the national standard and its uncertainty. Users who use dosimeters calibrated can estimate the uncertainty of their own dose measurements.

During 27 months from October 2012 to December 2014, 5,193 ionization chambers were calibrated in terms of absorbed dose to water. A small differences were seen between calibration factors ND,w and Nx multiplied by kD,X for cylindrical chambers. ND,w are slightly lower than Nx·kD,X for cylindrical type. The main reason is air gap between chamber wall and water-proofing sleeve. However, there is no difference between calibration factors for flat type chambers. The reason is The standard deviation of calibration factors in consecutive two calibration using absorbed dose to water improved
SP027 - Development and Application of Phantoms in Clinical Dosimetry

**SP027.1 - Fabrication of radiotherapy phantoms using 3D printing**

**Authors:** Paul Z.Y. Liu, David R. Mckenzie, Natalka Suchowerska  
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**Aim**

3D printing is becoming more affordable and accessible. The aim of this work is to demonstrate the feasibility of using this technology to create dosimetric phantoms and customized anatomical phantoms that would otherwise be difficult to manufacture. These phantoms were designed and printed to explore the methodology, advantages and disadvantages of 3D printing techniques.

**Method**

The cylindrical dosimetric phantom, created in CAD software (Sketchup), was customized to hold an array of scintillation dosimeters to validate arc and multi-directional treatments. The anatomical phantom was created using patient CT data, which was converted into a 3D model using ImageJ. The open source software Mesh-labs was then used to prepare the model for printing.

The phantoms were printed using fused deposition with the UP 3D printer (3DPP). Both phantoms were printed as hollow objects and filled with two types of material: dental wax and gel bolus. The resulting phantoms were CT scanned to determine their density and uniformity and irradiated with a therapeutic beam to assess their suitability.

**Results**

The 3D printed phantoms are shown in Figure 1. CT scans of the printed and filled phantoms showed a uniform electron density with less than 2% variance. Gel bolus yields a uniform phantom that is close to water in mass density ($\rho_{gel} = 1.07 \text{ g cm}^{-3}$). Dosimetric characterisation of the cylindrical dosimetric phantom filled with gel bolus showed low angular dependence (<0.6%) indicating that the scintillator was located accurately on the axis.

The anatomical phantom provided an accurate surface representation of the CT image. However, the phantom density does not reflect that of the real anatomy. Other 3D printing techniques, such as selective laser sintering and stereolithography, were found to create solid phantoms of a chosen density without the need to be filled.
Figure 1. (A) The cylindrical dosimetric phantom in CAD and (B) the 3D printed phantom. (C) A CT scan of the spinal cord and (D) its printed representation.

Conclusion

The fabrication of radiotherapy phantoms using 3D printing is fast and cost effective. Fused deposition is suitable for creating dosimetric phantoms using wax or bolus to fill a hollow model. Customized patient dosimetry can be achieved with 3D printing of anatomical phantoms, however, more sophisticated printing techniques will be required to achieve the desired mass and electron densities.

SP027.2 - The effect of bismuth shielding during pediatric neck multi-detector computed tomography on thyroid dose and image quality

Author(s): Stephen Inkoom1, Antonios E. Papadakis2, Maria Rais-saki3, Kostas Perisinakis2, Cyril Schandorf4, John J. Fletcher5, John Damilakis2

Method: Four pediatric anthropomorphic phantoms that represent the average individual as newborn, 1-year-old, 5-year-old and 10-year-old child underwent routine neck computed tomography (CT) scans using a 16-slice MDCT system. Scans were performed using a) fixed tube current and b) activated-AEC technique. Each scan was performed a) without bismuth shield, b) using a single- and c) using a double-layered bismuth shield placed on the skin surface above the thyroid gland. Scans were repeated following placement of cotton spacers 1, 2 and 3 cm thick between the skin and the shield, to study the effect of skin-to-shielding distance on image noise. Thyroid dose was measured with thermoluminescent dosimeters. The location of the thyroid gland within the phantom slices was determined using a novel approach which employed 3D printed anatomical phantoms using wax or bolus to fill a hollow model. Customized patient dosimetry can be achieved with 3D printing of anatomical phantoms, however, more sophisticated printing techniques will be required to achieve the desired mass and electron densities.

Results: In fixed tube current shielded technique, thyroid dose reduction for single-layered-shield was 17% for newborn and 35% for 10-year-old, and for double-layered-shield was 25% for newborn and 47% for 10-year-old. The dose reduction for AEC-activated unshielded was 27% for newborn and 46% for 10-year-old. The corresponding reduction in AEC-activated scans for single-layered-shield was 40% for newborn and 60% for 10-year-old, and for double-layered-shield was 40 % for newborn and 66% for 10-year-old. Activation of AEC unshielded compared to fixed tube current unshielded increased the ED by 7% for 1-year-old and decreased ED by up to 27% for 5-year-old. Image noise was found to be up to 71.5, 112.5, 72.2, and 138.2 HU for fixed tube current single-layered, fixed tube current double-layered, AEC-activated single-layered and AEC-activated double-layered-shields, respectively. Elevation of shields by 1, 2 and 3 cm using cotton spacers between shields and phantoms decreased image noise, by 22.0, 9.4 and 5.5 HU respectively for fixed tube current single-layered-shield, while it did not considerably affect thyroid dose. Similar trends were observed for other protocols.

Conclusion: AEC was more effective in thyroid dose reduction compared to in-plane bismuth shields during neck MDCT. The use of fixed tube current with double-layered-shields, and AEC shielded further reduced dose; however, this is associated with higher image noise. Application of cotton spacers had no significant impact on the measured doses, but significantly decreased image noise.

SP027.3 - Use of 3D Printed Materials as Tissue-Equivalent Phantoms

Author(s): Tanya Kairn1, Tim Markwell1, Scott Crowe3

Method: This study used the example of 3D printing with acrylonitrile butadiene styrene (ABS) as a means to investigate the potential usefulness of benchtop rapid prototyping as a technique for producing patient specific phantoms for radiotherapy dosimetry. Phantom samples were evaluated in terms of their geometric accuracy, tissue equivalence and radiation hardness, when irradiated using a range of clinical radiotherapy beams.

Results: Three small cylinders and one model of a human lung (with tumour) were produced via in-house 3D printing with ABS, using 90%, 50%, 30% and 10% ABS infill densities. Physical measurements were used to test the geometric accuracy of the phantoms. Hounsfield unit values in CT scans of the sample phantoms were used to evaluate the tissue equivalence of the phantoms, in terms of densities and linear attenuation coefficients. The attenuation and scattering effects of the phantoms were also evaluated and compared with the effects of commercial tissue- and lung-equivalent plastics, using film measurements, in five different clinical electron beams and three different photon beams. The radiation sensitivity of the samples was assessed by irradiating the samples for several hours a day for 30 days and then remeasuring the densities and physical dimensions of the samples.

The measured dimensions of the small cylindrical phantoms all matched their planned dimensions, within 1mm. The lung phantom was less accurately matched to the lung geometry on which it was based; the use of manual contours to produce an initial design from the CT images led to some simplification of the shape of the lung and some conservative over-estimation of the size of the tumour.

The cylindrical 3D-printed phantoms with ABS infill densities of 30, 50 and 90% were all found to be relatively homogeneous and to exhibit densities and attenuation coefficients within the range of values identified in the commercial tissue-equivalent materials. Film measurement results confirmed that the attenuation and scattering effects of these samples were similar to the effects of established lung- and tissue-equivalent materials. By contrast, the mesh produced by the 3D printing software, when required to produce a phantom with a 10% ABS infill density was so coarse that an anatomically unrealistic structure consisting of solid ABS walls around relatively large (6 mm diameter) air chambers was clearly resolvable in the CT images of the resulting phantom.

The results of this study suggest that phantoms printed with ABS,
using infill densities of 30% or more, are potentially useful as lung- and tissue-equivalent phantoms for patient-specific radio-therapy dosimetry. A 90% ABS infill density was found to result in a material suitable for modelling tumour, muscle or other soft tissue, while ABS infill densities of 30–50% resulted in phantoms with densities low enough to model lung while also avoiding the course mesh structures that occur when lower infill densities (such as 10% ABS) are used. All cylindrical 3D printed phantom samples were found to be unaffected by prolonged radiation and to accurately match their design specifications. However, care should be taken to avoid over-simplifying anatomical structures when printing more complex phantoms.

SP027.4 - Development of water-equivalent materials using the Least Squares Method
Author(s): Leandro Mariano, Paulo R. Costa
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Introduction: The study of water-equivalent materials, which have radiation attenuation and scattering properties similar to the human tissue, is central to the calculation of patient doses in many medical imaging applications. Chemical formulation using thermoplastics as a base and additives for the production of phantoms were developed by the authors for diagnostic imaging energy range (10-150keV).

Methods: The initial composition of the materials was obtained using the Hermann Method. Originally, this method allows the use of three base materials for the manufacture of the water-equivalent materials. In the present work, the Hermann’s methodology was generalized to allow the consideration of a generic number of base and additive materials. The Least Square Method was used as well to obtain the composition of the water-equivalent materials. The methodology was to fit the linear attenuation coefficient of the mixture directly on the linear attenuation coefficient of water.

Results and Discussion: The procedure developed in this work has advantages over the Hermann Method since it takes into account the linear attenuation coefficient over the entire energy range of interest. The Figure 1 shows the comparison of the linear attenuation coefficient for two formulations obtained by these methods using the same base materials.

Figure 1 – Linear attenuation coefficient of two water-equivalent materials using the Hermann and the Least Square Methods (LSM).

Moreover, the transmitted and scattered X-ray spectra of some compositions were experimentally measured and simulated using the PENELOPE code.

Conclusions: The results have shown a good agreement with the water attenuation and it has validated this methodology. The Monte Carlo Method can also be very useful to determine the characteristics of transmission and scattering of x-rays of the materials, without requiring its previous manufacture.

Acknowledgments: The authors thank CNPq for financial support under project 167332/2014-7 and CNPq/FAPESP INCT Rad Metrology in Medicine.

References:
White, D. R Physics in Medicine and Biology. V. 22: p.219-228, 1977

SP027.5 - Development of deformable moving lung phantom to simulate respiratory motion for lung SBRT
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Stereotactic body radiation therapy (SBRT) requires high accuracy in order to protect healthy organs and destroy the tumor. However, tumors located near the diaphragm are constantly moving during treatment. Respiratory-gated radiotherapy has significant potential for the improvement of the irradiation of tumor sites affected by respiratory motion, such as lung and liver tumors. To measure and minimize the effects of respiratory motion, a realistic deformable phantom is required for use as a gold standard. The purpose of this study was to develop and study the characteristics of a deformable moving lung (DML) phantom, such as simulation, tissue equivalent, and rate of deformation. The rate of change of the lung volume, target deformation, and respiratory signals were measured in this study; they were accurately measured using a realistic deformable phantom. The measured volume difference was 30%, which closely corresponds to the average difference in human respiration, and the target movement was -30 mm-+30 mm. The measured signals accurately described human respiratory signals. This DML phantom will be useful for the estimation of deformable image registration and in lung SBRT. This study shows that the developed DML phantom can exactly simulate the patient’s respiratory signal and it acts as a deformable 4D simulation of a patient’s lung with sufficient volume change.

SP027.6 - Characterization of a MOSFET-based system for skin dose evaluation with bolus material
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Purpose/Objective
Post-surgery radiation therapy is one the treatment steps of locally advanced breast cancer. In vivo skin dose evaluation of the chest wall region is important to ensure sufficient dose in structures near surface and it is a valuable tool during radiation treatment to verify the delivered dose to the target. It is also useful to assess the scattered radiation to the contra-lateral breast. In certain cases, to
increase the skin dose, a bolus material with a specific thickness is frequently placed on the chest wall during the last ten treatment fractions.

The purpose of this work was to characterize a MOSFET-based system for in vivo skin measurements in megavoltage radiation (4 MV and 6 MV) and compare calculated and measured dose with and without bolus material.

**Materials/Methods**

Full characterization and calibration of the MOSFET-based system was performed regarding reproducibility, linearity, energy, angular, field size and source to surface distance (SSD) dependences for two the photons energies. All measurements with the exception of the angular dependence were performed in a solid water phantom and a Farmer ionization chamber was used for dose comparison. The angular dependence was performed with a Lucy 3D phantom from 0 to 315 degrees in 45 degree increments.

Surface dose on solid water was also assessed in the presence and absence of 1 cm bolus material and compared with calculated dose in the Treatment Planning System (TPS) (only tested with an orthogonal beam).

**Results**

The detectors presented no energy dependence and a dose linear response for the dose range studied. The measured dose standard deviation varied from 1% to 10% depending on the number of MUs (higher deviation for lower MUs) and the detector. In the therapeutic dose range, the standard deviation for all the detectors is less than 2%. The angular dependence study showed that the deviation is less than 2% over 360º. For SSD response, the system showed linear dependence. Field size dependence was also analyzed and was found to be negligible. Surface dose without bolus is about 50% less than with bolus. The comparison between the TPS calculated and measured dose with and without bolus showed a maximum difference of 5%.

**Conclusion**

Tests performed on the behavior of the measuring system in reference conditions have results consistent with the manufacturer's specifications for the studied energies. The results show that this system is suitable for in vivo skin dose dosimetry in MV range with and without using bolus material in breast external radiotherapy treatments.

**SP027.7 - Calibration procedure optimization through PSDe- signer, a multipurpose simulation platform for plastic scintillation dosimeters**

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**Background**

The literature offers a wide variety of plastic scintillation dosimeter (PSD) and multipoint PSD proof-of-concept that demonstrate how the use of plastic scintillators can lead to accurate, online and in-vivo dosimeters for radiotherapy and brachytherapy. Nevertheless this accuracy is highly dependent on the calibration procedure and the choice of calibration points (CPs). Due to the lack of clear recommendations, researchers often rely on past experiences and generally accepted consideration to calibrate their specific systems. This study presents a numerical technique to find the optimal CPs of any PSD designs. Designs inspired by the commercially available Exradin W1 and the 2- and 3-points-PSD prototypes recently published by Theriault-Proulx et al. are revis-

**Methods**

This study uses PSDesigner, a multi-purpose simulation platform written in Python to generate and evaluate virtual PSDs. With the extensive use of physical data as inputs, this platform can, among others, select optimal CPs. First, virtual PSDs are generated using emissions, attenuation and transmission spectra and response curve of commercially available optical components. Second, calibration procedure involving noisy readings as well as systematic offsets are simulated, generating flawed calibrated PSD. Finally, a stochastic algorithm searches for the best CPs resulting in the most accurate PSD.

**Results**

For the simpler, commercially available Exradin W1-design PSD, Figure 1 shows where optimal CPs ought to be selected. Both the optimal CPs and the ones suggested by Standard Imaging are shown. The latter offers a 0.4% precision on dose measurement; the former improves it down to 0.2%. Figure 1 also shows how intermediate dose to the scintillator, generated in high dose gradient regions, are to be avoided.

The same analysis can be made for a 2-points-PSD inspired system. The optimized CPs, not shown here, result in a 0.6% precision for both measurement points. Work on 3 and more points PSD system is ongoing.

**Conclusions**

The simulation platform developed validates past calibration procedures and shows its useful capabilities for future, more complex PSD design. It goes further, giving the user quantitative insight on how its procedure can be improved and how that will affect dose measurements. The code is versatile and can help researchers optimize complex PSD systems in other ways, notably through the optimal selection of optical components.
**SP028 - HIFU Therapy, Microwave Ablation, Radiofrequency Ablation, Cryotherapy**

**SP028.1 - On Understanding of the Limiting Factors in Radiofrequency Ablation on Target Tissue Necrosis Volume**

**Author(s):** Bing Zhang¹, Michael Moser², Edwin Zhang³, Yigang Luo², Wenjun Zhang⁴

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The aim of this study was to analyze six limiting factors that may be responsible for target tissue necrosis (TTN) generation during the process of radiofrequency ablation (RFA). A comprehensive finite element (FE) model was built to simulate TTN of a liver tissue by using a commercial available RFA system. The model was then served as a test-bed for analysis of factors. Six limiting factors were analyzed using a statistical method. Sixteen RFA experiments were performed, in which the TTN volume was considered as a response variable along with the six control factors. The TTN volumes obtained from the 16 simulations were quite different, ranging from 7.749 to 8433.931 mm³. The applied voltage (V), the frequency (f), the exposure length (L) of the RF electrode, the chilled fluid temperature (T), the large blood vessel (d) in the proximity to target tissue, and the ablation duration (t) account for approximately 78.21%, 9.93%, 2.91%, 0.01%, 4.64%, and 0.08%, respectively, of the effect on the TTN volume. The findings from the present study suggest that the applied voltage (V) and the frequency (f), followed by the large blood vessel (d) in proximity to target tissue, have the highest effect on the TTN volume.

**SP028.2 - Thermal Dose Based Monitoring of Thermal Therapy for Prostate Cancer**

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Thermal dose is a metric for quantifying the amount of thermal damage taking temperature and exposure time into account. An ideal thermal dose model should produce the same dose for a given amount of damage, regardless of the heating protocol used, or the time-temperature profile that caused the damage. The cumulative-equivalent-minutes at 43 Celsius (CEM43) is the most commonly used thermal dose model. It was originally developed for hyperthermia applications (less than 45 Celsius). The validity and accuracy of this mode for higher temperatures, above 50 Celsius is questionable. A new thermal dose model based on the Arrhenius type Vogel-Tammann-Fulcher equation, known as the improved cumulative equivalent minutes at 43 Celsius (iCEM43), has been developed and fit to publish historic thermal data.

The CEM43 and iCEM43 dose models have been retrospectively used to assess the dose delivered to during laser thermal therapy of low-grade prostate cancer, in order to test the consistency of the two methods. This was done by obtaining MRI thermometry images during treatment and gadolinium enhanced MRI images post-treatment to assess vascular shutdown (as an indicator of acute thermal damage), as shown in the figure below. The iCEM43 dose model was found to be more consistent than the CEM43 dose model in predicting post-treatment vascular shutdown.

**SP028.3 - Nanodrug Delivery and Anti-tumor Efficacy for Brain Metastasis of Breast Cancer Enhanced by Short-time Low-dose Ultrasound Hyperthermia**

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Ultrasound hyperthermia can enhance the delivery of chemotherapeutic agents into tumors, while the blood–brain/tumor barrier inhibits the uptake and accumulation of chemotherapeutic nanodrugs in brain tumors. In this study, we investigated the effects of short-time low-dose (STLD) focused ultrasound (FUS) hyperthermia on the delivery and therapeutic efficacy of pegylated liposomal doxorubicin (PLD) for brain metastasis of breast cancer. Murine breast cancer 4T1-luc2 cells expressing firefly luciferase were injected into female BALB/c mice striatum tissues and used as a brain metastasis model. The mice were intravenously injected with PLD with/without STLD transcranial pulsed/continuous wave FUS hyperthermia on day 6 after tumor implantation. The amounts of doxorubicin accumulated in the normal brain tissues and tumor tissues with/without FUS hyperthermia were measured using fluorometry. The tumor growth for the control, hyperthermia, PLD, and PLD+hyperthermia groups was measured using an IVIS spectrum system every other day starting from day 3. Cell apoptosis and tumor characteristics were assessed using immunohistochemistry. The experimental results showed that STLD transcranial FUS hyperthermia was able to significantly enhance the PLD delivery into brain tumors. The tumor growth was effectively inhibited by a single treatment of PLD+hyperthermia compared with both PLD alone and STLD FUS hyperthermia alone. Immunohistochemical examination further demonstrated the therapeutic efficacy of PLD plus STLD FUS hyperthermia for brain metastasis of breast cancer. The results also showed that with the same STLD, pulsed-wave can even produce a better therapeutic result than continuous-wave FUS hyperthermia. This study indicates that the application of STLD FUS hyperthermia after nanodrug injection may be an effective approach to enhance nanodrug delivery and improve the treatment of metastatic cancers.
A critical goal in breast conservation surgery (BCS) is to obtain negative surgical margins to ensure removal of all cancerous tissue. This process usually requires a period of several days to evaluate margin status with conventional pathology, and results in re-excisions for 20-60% of BCS patients due to the lack of a rapid, noninvasive method to evaluate margins in the operating room. Several methods are therefore being investigated for the intraoperative evaluation of margin status. High-frequency (HF) ultrasound (20–80 MHz) was investigated in a 17-patient pilot study for intraoperative margin evaluations during BCS. Through-transmission measurements were acquired from 53 positions on 34 excised specimens at the Huntsman Cancer Institute, Salt Lake City, Utah. Specimens included lymph nodes, surgical margins, tumors, and fibroadenomas. Measurements were acquired with the use of two 50-MHz immersion transducers (Olympus NDT, V358-SU), a HF square-wave pulser/receiver (UTEX, UT340), and a 500-MHz digital oscilloscope (Hewlett-Packard, HP-54522A). Ultrasonic waveforms were averaged in the signal acquisition and downloaded onto a notebook PC using LabVIEW. Parameters acquired from the data included peak density (the number of peaks and valleys in the 20-80 MHz band of the ultrasonic spectra) and attenuation. Peak density is strongly dependent on scattering processes and thus microstructural heterogeneity in the tissue. Statistical analysis of the data for differentiating between malignant and nonmalignant tissue revealed that peak density and attenuation by themselves provided lower accuracy and sensitivity as compared to a multivariate analysis combining the two parameters. Results from the multivariate analysis showed 81.1% accuracy, 76.9% sensitivity, and 85.2% specificity. Table 1 compares the accuracy, sensitivity, and specificity values of HF ultrasound with alternative technologies for intraoperative BCS margin assessments, and shows HF ultrasound is competitive with both small specimen mammography and radio-frequency spectroscopy. Approaches for improving the HF ultrasound method include using additional parameters in the multivariate analysis such as wave speed, calibrating the measurements with phantoms, and conducting larger studies with statistically relevant numbers of patients, specimens, and measurement positions. Such a study at the Huntsman Cancer Institute is currently near completion, and includes 73 patients, 485 specimens, and 1112 measurement positions. Preliminary results are consistent with those from this study.

**Table 1.** Comparison of results from prospective and clinical trials of margin evaluation methods including small-specimen mammography, radio-frequency spectroscopy, and high-frequency ultrasound.

<table>
<thead>
<tr>
<th>Method</th>
<th>Small-specimen mammography</th>
<th>Radio-frequency spectroscopy</th>
<th>High-frequency ultrasound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>102</td>
<td>298</td>
<td>17</td>
</tr>
<tr>
<td>Specimens</td>
<td>102</td>
<td>298</td>
<td>34 (53 positions)</td>
</tr>
<tr>
<td>Accuracy</td>
<td>78.4%</td>
<td>62.1%</td>
<td>81.1%</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>58.5%</td>
<td>74.8%</td>
<td>76.9%</td>
</tr>
<tr>
<td>Specificity</td>
<td>91.8%</td>
<td>46.7%</td>
<td>85.2%</td>
</tr>
</tbody>
</table>


Breast cancer is the second most prevalent cancer among women, affecting one out of eight in their lifetime. The ability to differentiate between malignant and normal tissues during breast cancer surgery would enable the surgeon to remove all of the cancer from the affected region in the breast, thereby reducing the risk of recurrence and the need for subsequent surgeries. Two studies conducted at the Huntsman Cancer Institute (Salt Lake City, Utah) showed that high-frequency (HF) ultrasound (20–80 MHz), and in particular the ultrasound parameters peak density and attenuation, were sensitive to breast tissue pathology. The objective of this study was to determine the effect of tissue microstructure on peak density and attenuation using phantoms that mimic the histology of breast tissue. Phantoms were created from a mixture of distilled water, agarose powder, and 10X TBE stock solution. In order to simulate breast tissue histology and breast density, polyethylene microspheres were embedded into the phantoms in layers, totaling 4 layers per phantom. In one experiment, the volume percent of polyethylene microspheres was kept constant in each phantom while varying microsphere sizes (58–925 μm diameter). In a second experiment, the polyethylene microsphere size (90–106 μm diameter) was kept constant within each phantom while the weight percent concentration of the microspheres varied (0.00g to 0.06g). Pitch-catch measurements were acquired using 50-MHz transducers (Olympus NDT, V358-SU, 0.635-cm diameter active element), a HF pulser-receiver (UTEX, UT340), and a 1-GHz digital oscilloscope (Agilent, DSOX3104A). Glycerol (Genesis Scientific) was used as a coupling agent between the transducers and the phantoms. Spectra were derived from the data, giving peak density (the number of peaks and valleys in the 20–80 MHz range) and attenuation values. The results show that peak density is much more sensitive to the size of the heterogeneity and follows an inverse size (microsphere diameter) relationship, while attenuation is sensitive to the number of heterogeneities present. These results demonstrate that the HF ultrasound parameters, peak density and attenuation, are sensitive to changes in microstructure or heterogeneity observed in malignant breast tissue. Clinical breast cancer studies also showed that, when combined in a multivariate analysis, peak density and attenuation increased the accuracy, specificity, and sensitivity of the measurements for malignant tissue. The high-frequency ultrasound results from the agarose phantoms confirm that peak density and attenuation are complementary parameters for characterizing breast tissue pathology and validate the clinical breast cancer studies conducted at the Huntsman Cancer Institute.
SP028.6 - Rapid Molecular Subtyping of Breast Cancer Using High-Frequency Ultrasound (10-120 MHz) and Principal Component Analysis

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**Introduction:** The molecular subtypes of breast cancer correlate more strongly to prognosis and treatment response than traditional classifications based on genetic and protein expression profiles. The mutations found in aggressive subtypes (basal-like and Her2+) alter the expression levels of proteins that regulate the actin cytoskeleton, thereby altering the biomechanical and ultrasonic properties of the cell. Current methods of testing these changes do not easily transfer to real-time diagnostic methods. The ability to determine the subtype of breast tumors during surgery or biopsy would provide physicians with new diagnostic capabilities to screen suspicious lesions, as well as perform high-precision surgery and personalize treatment for patients.

**Objective:** The hypothesis of this work was to determine the feasibility of using high-frequency ultrasound and principal component analysis (PCA) to characterize and phenotype different molecular subtypes of breast cancer cell lines, and to determine the sensitivity of high-frequency ultrasound to changes in biomechanical properties of the cell.

**Methods:** Computer simulations were performed to determine if changes in the bulk and shear moduli of the cell cytoplasm would measurably alter high-frequency ultrasonic spectra. To verify these models, ultrasonic measurements of seven breast cancer cell lines with different molecular subtypes were obtained over a period of two years by taking pulse-echo measurements of the cell layer with a 50-MHz transducer immersed directly in the growth media of the cell culture plates. The cell reflections within the waveforms were isolated and spectrally analyzed using computer models and PCA. Heat maps were then generated using relative distances between PCA scores of experimental data and model spectra. These heat maps were used to classify the spectra for subtype profiling. A secondary experiment was performed to validate that the cell reflections isolated from spectral data were in fact the waveforms of the cellular monolayer signal, and to determine if chemical modification of the cytoskeleton could be observed with ultrasound. This was done by treating a cell culture with colchicine which is a known inhibitor of cytoplasmic microtubule formation. Measurements of the treated culture were taken incrementally over a period of 90 minutes to record the effect on the cell signal in real time.

**Results:** Computer models showed that changes in biomechanical properties of the cell cytoplasm would significantly alter the cell's ultrasonic properties. Experimental results showed that each cell line produced a unique spectral signature while also demonstrating changes due to seeding density. This showed the sensitivity of high-frequency ultrasound to changes in cell microenvironment as well as the molecular subtype of the cells. The colchicine data also verified changes in the cell signal due to the modification of cytoplasmic microtubules. The heat map generated from PCA was able to classify the measured spectra of each cell line based on their individual biomechanical and morphological properties.

**Conclusions:** The experimental and computational results of this work have demonstrated that high-frequency ultrasound is a feasible method for rapid molecular subtyping of breast cancer. Principal component analysis of the spectral data has additionally demonstrated a prospective approach for the characterization of molecular subtypes.

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SP028.7 - Inverse treatment planning using radiofrequency ablation in cancer therapy

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Radiofrequency ablation (RFA) offers localized and minimally invasive ablation of small-to-medium sized inoperable tumors. In RFA, tissue is ablated due to high temperatures obtained from the current passed through electrodes inserted percutaneously or via open surgery into the target. However RFA can cause incomplete ablation due to several reasons including incorrect needle position. We develop a mathematical framework for pre-operative inverse treatment plans for single and multiple RFA applicators. Borrowing techniques from radiosurgery inverse planning, we design a two stage algorithm where we first identify needle position and orientation, referred to as needle orientation optimization, and then compute the treatment time for optimal thermal dose delivery using thermal dose optimization (TDO). We develop linearly-relaxed TDO models using various thermal damage models including threshold temperature using Pennes Bioheat transfer equation (BHTE) and Arrhenius damage index. We present experimental results on three clinical case studies with 3D patient models.
SP029 - Surgical Navigation: Part 1

SP029.1 - Preliminary evaluation of positron emission based 3D tracking system (PeTrack) in image guided interventions

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In minimally invasive surgeries, a surgeon needs to precisely locate the surgical tools. The recent advancements in image guided surgeries have enabled monitoring the position of the operative tools in the vicinity of internal organs. We are developing a new real-time three-dimensional (3D) tracking technique for medical procedures called PeTrack (Positron Emission Tracking). PeTrack is designed to track the location of a positron emitting fiducial marker(s) using two pairs of position sensitive gamma ray detectors. The marker can be attached to surgical instruments (e.g. a catheter). PeTrack provides the location of the marker in real-time. PeTrack is co-registered with an x-ray C-arm to enable the navigation (Figure 1).

**Figure 1**

The emitted positron from fiducial marker annihilates with an electron, producing two gamma rays in opposite directions. Gamma rays which belong to single annihilation create coincidence line (COIL). The true location of PeTrack marker is defined to have the minimum root mean square distance to all of the COILs collected in a short time interval (e.g. 100 ms). We studied the sensitivity and distortion of PeTrack by Monte-Carlo simulations and experiments. Results show that the sensitivity fluctuates within the detector field of view and revealed a non-uniform distortion. The distortion can be reduced less than 1 mm by correcting for systematic errors. We also performed a navigation experiment by moving a 13.5 μCi marker along a simulated blood vessel and co-registered its positions with an x-ray projection image. Figure 2 shows that PeTrack correctly tracked the locations of the marker.

**Figure 2**

The small dose from the PeTrack marker is offset by the dose reduction when using PeTrack for tracking instead of continuous x-ray fluoroscopy. Therefore, as a wireless tracking technique with sub-millimeter marker and sub-millimeter accuracy, PeTrack has a great potential for 3D navigation during image guided surgery.

SP029.2 - Seymour Shield – An Operative Adjunct Device for Maintaining Visualization during Laparoscopic Surgery

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During Minimally Invasive Surgery or Laparoscopic Surgery, the surgeon is absolutely dependent on the view from the camera. Yet, the rigid-endoscopic camera lens is prone to getting fouled by smoke, fog, blood and/or vaporized organic debris, all of which obstruct vision and thus necessitates removal of scope from abdomen for cleaning. So when lens fouling happens, surgical workflow halts entirely, which jeopardized patient’s safety when visualization is truncated. Hence the scope is removed and the lens is manually cleaned by the nurse with the help of the gauze. Lens is warmed frequently by submerging the tip into a thermos-flask filled with warmed water and it is dried to prevent fogging. Surgeon must then return camera to its previous location and spatially re-ordinate himself in order to resume work. Disruptions in workflow may lead to conversion to open surgery for emergency measures, especially during active bleeding. Currently, conversion rate stands at 10% for most of the laparoscopic surgeries. Time lost contributes to operative duration, which is an independent risk factor for morbidity, as well as cost to the healthcare system. Given that 3.1 million laparoscopic surgeries were performed in USA in 2012 (projected to grow at 5-8%), we estimate a total of 386,000 hours spent cleaning the scope, representing wastage of USD 347 Million in terms of theater time to healthcare system.

At present, laparoscopic sheaths have been devised with fluid irrigation channels that enable lens cleaning without scope removal (EndoScrub 2, Medtronic). However, this still involves loss in visualization and disruption of surgical flow while irrigation is taking place. Recently, a sheath generating air vortex distal to the lens has been developed which disperses smoke produced during electro-cautery dissection (Flosheild, MID Surgical). However it is not effective against blood splatter and thus fails to protect the lens during the most critical moments of the surgery.

Hence, to overcome the above defects, we developed a novel
device, the one-stop solution which addresses all the problems encountered. Our product Seymour Shield is a 12mm/14mm sheath that fits over the conventional 10 mm laparoscopic camera with a distal, constantly-rotating, clear, transparent disc (shield). The rotation serves two purposes; firstly, to remove or prevent buildup of excess fluid and particulate debris on the visualization surface by centrifugal force, and secondly to produce an optical illusion of clarity exploiting physiological persistence of vision and the flicker-fusion threshold of human sight. We are using compressed air\n vacuum which is available readily in Operation Theater as a driver for the whole process. Rotor is designed in such a way that it is propelled by the compressed air and the transparent disk or the shield for the lens is embedded into the rotor. So, as the rotor rotates at high speed, the shield too rotates, thereby shattering all the foreign particles. The compressed air can be used by the doctor whenever required, by just pressing the button in the sheath. Thus Seymour Shield offers easy and instant solution for maintaining clear vision throughout the laparoscopic surgery.

Fig. 1: The upper bound of tumour volume such that there is <95% probability of obtaining a sample with ≥50% core involvement, given needle delivery error of the biopsy system.

Impact:
Optimized planning of within-tumour targets for fusion biopsy could support earlier diagnosis of prostate cancer while it remains localized and curable.


SP029.3 - Optimizing MRI-targeted fusion prostate biopsy: the effect of systematic error and anisotropy on tumour sampling

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Purpose:
Random, systematic and anisotropic biopsy needle delivery errors can arise due to patient and prostate motion, image registration errors, and device-to-image calibration issues. The purpose of this work was to investigate the effect of needle delivery error on tumour sampling probabilities, as a first step toward our over-arching aim of optimizing needle target positions within tumours, accounting for guidance system errors, image registration errors, and irregular tumour shapes.

Methods:
We obtained multiparametric MRI and 3D TRUS images from 49 patients. A radiologist and radiology resident contoured 81 suspicious regions, yielding tumour surfaces that were registered to the TRUS images using an iterative closest point prostate surface-based method. The probability of obtaining a sample of tumour tissue in one attempt was calculated by integrating a 3D Gaussian distribution over each tumour domain, where σ = the needle delivery error. One attempt was calculated by integrating a 3D Gaussian distribution over each tumour domain, where σ = the needle delivery error. The probability of obtaining a sample of tumour tissue in one attempt was calculated by integrating a 3D Gaussian distribution over each tumour domain, where σ = the needle delivery error.

Results:
Our experiments indicated that a biopsy system’s lateral and elevational errors have a much greater effect on sampling probabilities, relative to axial error. We have also determined that systematic errors with magnitude <2 mm have a relatively small incremental effect on sampling probabilities. For a fusion biopsy system with a typical needle delivery error of 3.5 mm, tumours of volume ≤1.9 cm³ may require more than one biopsy attempt to ensure 95% probability of a sample with 50% core involvement, and tumours ≤1.0 cm³ may require more than two attempts (Figure 1).

SP029.4 - Is hemolysis influenced by the dynamic calibration method of CPB roller pumps?

Author(s): Francisco U. Vieira Junior1, Nilson Antunes2, Eduardo T. Costa2
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Introduction: Roller pumps are widely used in cardiopulmonary bypass (CPB) surgeries due to the ease of their operation, maintenance, safety and cost. Several studies have compared the use of roller pumps with centrifugal pumps but few have evaluate the influence of the different roller pump adjusts on hemolysis. The objective of this work was the in vivo analysis of the influence of roller pump adjustment by the dynamic method on hemolysis prevention.

Methodology: We have measured the hemolysis rate of 87 patients submitted to myocardial revascularization, divided in 4 groups, altering the roller pumps adjustment by the dynamic method. We have used an Auxiliary Calibration Device specially developed for this purpose. The adjustments consisted in the monitoring of the pump output pressure (pump at 10 rpm) with the output tube pinched, the pump rollers were adjusted in order to have mean pressures between 75 and 450 mmHg. The adjustment for each group was as follows: Group 1 (n=20) - 75 mmHg; Group 2 (n=24) – 150 mmHg; Group 3 (n=22) – 300 mmHg; and Group 4 (n=21) – 450 mmHg. The hemolysis rates were measured before the start of CPB (T0) and 5 minutes after CPB (T1). The blood plasma free hemoglobin (HLP) was calculated using a spectrophotometer and the data related to a measurement at instant “t” was corrected for the hemodilution according to the equation below using Htbase = 27.5%:

\[ HP(t) = HLP(t) \times Htbase / Ht(t) \]
The hemolysis rates (Tx) were calculated for each patient for the interval T0-T1 using the following equation:

\[ Tx = \frac{(HLp1 - HLp0)}{(T1 - T0)} \]

**Results:** In Table 1 we show the measurement results for each group. Our results have not shown statistical difference for hemolysis rates between groups (p>0.05).

Table 1 – Registered times during CPB with respective measures of free hemoglobin and hemolysis rates. Values are mean ± standard deviation.

<table>
<thead>
<tr>
<th>Group 1 (n = 20)</th>
<th>Group 2 (n = 24)</th>
<th>Group 3 (n = 22)</th>
<th>Group 4 (n = 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (min)</td>
<td>p-value*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1 0 ± 0</td>
<td>0 ± 0</td>
<td>0 ± 0</td>
<td>0 ± 0</td>
</tr>
<tr>
<td>T2 95.0±23.2</td>
<td>104.5±22.1</td>
<td>98.7±22.6</td>
<td>104.6±38.2</td>
</tr>
<tr>
<td>HLP (mg/dl)</td>
<td>p-value*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLP1 9.3 ± 5.0</td>
<td>6.4 ± 2.0</td>
<td>9.6 ± 7.0</td>
<td>9.3 ± 4.0</td>
</tr>
<tr>
<td>HLP2 53.7±18.0</td>
<td>48.1±13.0</td>
<td>52.7±14.6</td>
<td>45.4±11.4</td>
</tr>
<tr>
<td>Hemolysis rates (mg/dl/min)</td>
<td>p-value*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tx 0.5 ± 0.2</td>
<td>0.4 ± 0.1</td>
<td>0.5 ± 0.2</td>
<td>0.4 ± 0.1</td>
</tr>
</tbody>
</table>

* Comparison between groups.

**Conclusion:** Our results have shown that the calibration of the roller pumps for different adjustments have not influenced the hemolysis rates in the analysed groups. Little occlusive calibrations should be avoided due to possible reflux and errors in flow measurements based on the pump rotation.

**SP029.5 - A Fiducial Apparatus for 6DOF Pose Estimation of an External Echo Probe from a Single X-ray Projection: Initial Simulation Studies on Design Requirements**

**Author(s):** Charles R. Hatt1, Amish N. Raval2, Michael A. Speidel3

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X-ray fluoroscopy (XRF) is considered the primary imaging modality for guidance during cardiac interventions. However, visualization of soft tissue is limited. Image registration between transthoracic echocardiography (TTE) and XRF could potentially be used to fuse soft-tissue imaging with device imaging in minimally sedated patients. We propose a method of XRF/TTE image registration in which a fiducial apparatus is rigidly attached to the TTE probe, and the 3D pose of the fiducial is determined based on its appearance in the XRF image. The fiducial consists of a constellation of radio-opaque markers with known geometry. 3D pose estimation accuracy depends on 1) accurate marker localization in the XRF image, 2) geometric properties of the apparatus such as marker diameter, overall apparatus dimensions, marker count, manufacturing tolerances, and 3) pose estimation method. In this work, we performed simulation studies to examine the effect that each variable had on the 3D target registration error (TRE). In the first experiment, we generated simulated XRF images of a spherical marker with varying levels of peak signal-difference-to-noise ratio (pSDNR) and varying marker diameters, and measured the effect on marker localization error (MLE). In the second experiment, using a circular constellation of markers, we tested the effect that MLE, manufacturing tolerance, apparatus dimensions, marker count, and shape constraints during optimization had on TRE. Our results showed that MLE was roughly 0.14, 0.05, 0.02 mm for pSDNRs of 10, 20 and 30 using a 2 mm diameter spherical marker. TRE decreased as the marker count and apparatus diameter increased. Manufacturing error increased TRE, but had minor effects for clinically relevant levels of MLE. Results indicate that, for a “medium” level of pSDNR (~15), the optimal fiducial configuration can achieve a 3DTRE of 0.32 ± 0.22 mm, and can achieve a 3DTRE of less than 1.5 mm for noisier images.

**SP029.6 - Mechanism design a flexible endoscope with USB adaptation to training.**

**Author(s):** Francisco D. Perez Reynoso1, Daniel Lorias Espinoza2, Rigoberto Martínez Méndez2

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The aim of this paper is to present a mechanism to adapt a boroscopic camera to the operation of a flexible endoscope and get the vision of a real device, leveraging technology for portable devices to provide surgeons the visualization so important in the training and application of endoscopy, because without this tool is virtually unenforceable.
SP030 - Lab-on-chip, BioMEMS and Microfluidics

TRACK 08: BIOSENSOR, NANOTECHNOLOGY, BIOMEMS AND BIOPHOTONICS

SP030.1 - Drop-based microfluidics for diagnostic applications
Author(s):
This talk will introduce the use of microfluidics to control very small aqueous drops that can be used as microreactors to perform millions of experiments in very short times and using very small quantities of reagents. These systems have great potential for use in many research and diagnostic applications. Some of these will be described.

SP030.2 - Enhanced multielectrode configurations in miniaturized 3D electrical impedance spectroscopy and tomography - monitoring the overall process of tissue engineering with spatial sensing for future challenges in microfluidics
Author(s):
Over the past two decades, 3D cell culture models have attracted considerable attention to achieve, e.g., in vivo-like structural organization, gene and protein expression, response to stimuli, drug metabolism. A significant challenge in this regard is gaining spatially distributed information when monitoring cell proliferation on a biocompatible scaffold displaying well defined physico-chemical properties. Electrical impedance spectroscopy (EIS) has been shown to be a non-invasive method for biomaterial characterization and monitoring microfluidic cell cultures, gaining an insight on cellular activity and proliferation over time.

We have developed and validated planar and needle-based multielectrode systems which offer the advantage of switching among different two-, three- and four-electrode configurations to focus impedance-based sensing on specific sub-volumes in a 3D cell culture. Information about scaffold architecture supporting cell organization (e.g. porosity, Fig. 1A), medium conductivity, and 3D spatial distribution of cells can be obtained. Furthermore, four-electrode configurations can also be used for electrical impedance tomography (EIT)-based imaging to map the conductivity distribution within a miniaturized 3D cell culture system (Fig. 1B). Finite element simulations were used to optimize electrode number, spacing and orientation with respect to the bioreactor geometry by maximizing the derived sensitivity field distribution for measurements. Validation with phantom experiments, mimicking cell clusters (Fig. 1C), and cell-based experiments was performed aiming to incorporate spatially enhanced 3D sensing into a 8-channel bioreactor array with integrated microfluidics for real-time monitoring of cell proliferation in porous scaffolds (Fig. 1D). The integration of the developed non-invasive sensing methods enable monitoring of tissue development within otherwise inaccessible areas of a 3D tissue construct, overcoming limitations of more traditional optical techniques.
A) Comparison of scaffold porosity between standard method (weight-based) and EIS-based method for different pore densities.

B) Example of EIS-based scaffold porosity mapping.

C) Multiplexing mode 1 results showing impedance (ZL) vs. frequency for different phantoms.

D) Bioreactor setup with inlets, outlets, electrodes, and Lego® motor control.
In 3D environment there is a need for adding the third dimension to EIS sensing for spatial resolution to gain information about distribution of cells in the scaffold (Fig. 1Ba,b,c). Moreover, electrode number, geometry and orientation need to be optimized with respect to the deriving sensitivity field distribution. In order to gain information with a good resolution, we show that several two-, three- and four-electrode measurements can be combined to create complementary sensitivity fields which individually focus on specific volumes inside the 3D cell culture and, taken together, cover the whole measurement chamber volume. This approach was tested for growing hepatoblastoma (HepG2) cells embedded within a 5% w/v gelatin scaffold (Fig. 1Bd).

Electrochemical impedance spectroscopy (EIS) has been proved to be a valuable technique for label-free, real-time and minimal invasive detection of cellular functions in fundamental and applied research. During the last three decades, several two-dimensional (2D) impedance-based systems have been widely used for studying cell adhesion and spreading, proliferation and death. Nowadays, there is an increasing interest towards three-dimensional (3D) cell cultures, which are proposed to create and maintain a more in vivo-like environment. EIS can be applied at different stages when developing a 2D or 3D culture setup, starting from bare scaffold and electrode characterization to monitor cell proliferation and tissue functionality. We present theoretical and experimental comparison of several electrode configurations (or modes) both in 2D (Fig. 1A) and 3D (Fig. 1B) used for following cell growth in real-time. Two different 2D modes were explored measuring between: i) the two combs (working electrode a vs b, WEa vs WEB), interdigitated configuration (Fig. 1Aa,b,c) and ii) WE versus a large counter electrode (CE), conventional “vertical” configuration, and found that the interdigitated configuration provides a higher sensitivity when monitoring HeLa cells adhesion, spreading and growth over 24-h (Fig. 1Ad).
SP030.4 - Development of Microfluidic Paper-Based Electrochemical Immunoassays for the Detection of Prostate Cancer

Author(s): Sean P. Rawlinson, Prosper Kanyong, James McLaughlin, James Davis

Nibec, School Of Engineering, University of Ulster, Newtownabbey/UNITED KINGDOM

Prostate cancer or carcinoma of the prostate is one of the most frequently diagnosed malignancies in the world. Prostate cancer is the second leading cause of cancer death in men worldwide and the fourth most common cancer overall, with more than 1.1 million new cases diagnosed in 2012, and more than 307,000 deaths from the disease. The prevalence of the condition and mortality will clearly vary from one country to another but tends to be higher in developed countries. Prostate cancer incidence is strongly linked to age with the lowest incidence rates being in younger men. In the UK between 2009 and 2011, only 1% of cases were diagnosed in men under 50 and an average of 36% of cases was diagnosed in men aged 75 years and over. In a population with increasing longevity, it is likely that prostate cancer will become even more clinically prevalent in the future. This projected increase is a major concern for the public health sector, especially when there are both problems associated with the detection and the treatment of prostate cancer. Specifically, current practice in prostate cancer and staging leads to inaccurate assessments often resulting in unwanted or even unnecessary treatments that adversely affect the patient’s quality of life with little gain. It will also place a considerable burden on the healthcare provider.

The poster presentation details a new approach to the development of microfluidic paper-based electrochemical devices that will be capable of multiparametric detection. Rather than examining single parameter detection, the strategy adopted here involves the laser machining of cellulose based substrates to create an array of microfluidic channels and detection wells as detailed in Figure 1. Screen printed electrodes are positioned within the wells and can be functionlised with a variety of molecular recognition elements (enzyme or antibody) thereby providing a system which is capable of screening a panel of biomarkers relevant to the diagnosis of prostate cancer. The design, development and bioanalytical characterisation of the prototype sensing systems will be presented and the applicability to point of care diagnosis critically assessed.

Figure 1. Schematic of the microfluidic array.

References


SP030.5 - Investigating chip design for a Raman microfluidic system with clinical radiobiological applications.

Author(s): Samantha J. Harder1, Julian J. Lum2, Andrew Jirasek3, Alexandre G. Brolo4

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Raman spectroscopy (RS) has been demonstrated as valuable for studying biomolecular responses of human cancer cells to clinically relevant doses of ionizing radiation.1 Radioresistance in cancer therapy remains a significant problem and recent studies indicate that RS may provide important biological insight into mechanisms of radioresistance.2 Raman microfluidic (RMF) systems offer several potential advantages over traditional single cell Raman data acquisition techniques. The precise control of suspended particles in microfluidic environments facilitate automation of data collection, reducing the time required and user dependence of data acquisition. RMF systems facilitate efficient sample use which is favourable when dealing with small or rare samples- as is the case with patient biopsies. RMF systems have the potential to make RS more accessible for applications in the clinic and for wide-spread radiobiological studies. The objective of this work is to investigate microfluidic chip design for single cell Raman spectroscopic studies in radiobiology.

Three different prototype RMF systems have been investigated, to determine an optimal chip substrate and design. The first system is formed from polydimethylsiloxane (PDMS) using soft lithography techniques.3 This system varied slightly from traditional PDMS microfluidic systems by employing a MgF2 coverslip to seal the system instead of glass. MgF2 exhibits a relatively weak Raman spectrum in the spectral region of interest, compared to most glasses, making it ideal as a substrate material for chip design. Second, a novel RMF design was realized by forming the base and top surfaces of the chip using MgF2 with Paraflim forming the channel walls. Lastly, a novel design made entirely out of MgF2 was tested. A channel was laser etched into MgF2 using a Ti:Sapphire laser, and the system was sealed using a MgF2 coverslip. Raman spectra from single cells in each RMF system have been collected, using a Renishaw inVia Raman microscope coupled with a 785 nm laser, in order to determine the optimal chip design for radiobiological Raman studies.

The PDMS based RMF chip yielded cell spectra which were contaminated by Raman peaks characteristic of PDMS. These peaks interfere with cellular Raman signals in spectral regions which are important for assessing radiation-induced responses in cells.4 The PDMS chip design is, therefore, unsuitable for radiobiological applications. The novel Paraflim-MgF2 and solid MgF2 chip designs yielded suitable cell spectra for studying radiation-induced biomolecular changes in cells, since in both cases there were minimal contributions from the chip material in the Raman spectra.

Both the novel Paraflim-MgF2 and solid MgF2 chip designs are promising for single cell Raman radiobiological studies. Both systems warrant further investigation as potential designs which may facilitate adaptation of Raman spectroscopy for the clinic and for wide-scale biological research.

Biological investigations during acute and/or long-term hypoxia have become an important key in research that requires extraordinary experimental design. We present a platform of a multifunctional lab-on-a-chip (LOC) system for hypoxic investigation on biological single cells with controlled oxygen content and surroundings. The LOC was combined with the patch clamp technique for electrophysiological investigations, optical tweezers for manipulation of the individual cells in 3D within the closed micro-channel system, absorption spectroscopy to monitor and acquire the spectral response of the cells to different oxygenated states and oxygen sensor to monitor the oxygen level within the chip. All techniques was built on the optically table (Figure 1A). The developed gastight LOC in Plexiglas monitored the oxygen level within the chip. All techniques was an inverted microscope (IX71, Olympus, Japan), on a vibration free optical table (Figure 1A). The developed gastight LOC in Plexiglas with an integrated patch-clamp micropipette (Figure 1B) is aimed to replace the open system in conventional patch clamp technique to achieve control of the gaseous surroundings of the investigated cells. To test the system, a single red blood cell (RBC) from Chicken (Fitzgerald Industries International, USA) was trapped optically, moved in 3D through the micro-channels of the chip towards the integrated micropipette within the gastight chip. The oxygen levels dissolved in the extracellular solution within the micro-channels was monitored by an oxygen sensor (FOXY, AL3000, Ocean Optics, USA) reached values between 0-18% O2 which was verified by studying the oxygenation states of the trapped RBC with UV-Vis absorption spectra (Ocean Optics, HR4000, USA) simultaneously, (Figure 1C). The spectral transfer of the investigated cell from the oxygenated state (18% O2) to the deoxygenated state (0% O2) happened after about 3.7 minutes while a fully developed deoxygenated spectrum was observed after 4.9 minutes. The gas tightness of the hypoxic chamber to the oxygen diffusion was verified by stopping the flow of deoxygenated solution into the channel system while continuously recording UV-Vis spectra, showing an unchanged deoxygenated state during 90 min. Thereafter, a transfer to the oxygenated absorption spectra was achieved after 7.1 minutes when exposing the cell to normoxic buffer solution. The result above showed the long time viability of the investigated cells as well as the control of the hypoxic conditions within the chip. To verify the system for physiological investigations, successful patch clamp investigations (EPC-7, HEKA, Germany) on a trapped RBC were established and the whole-cell access (Ra) and membrane resistances (Rm) were measured to be 5.1 MΩ and 900 MΩ respectively.

Figure 1: A. Schematic figure of LOC system including all technique. B. LOC system integrated with patch clamp technique. C. Absorption spectra of optically trapped chicken RBC with measured oxygen levels and time scale.
SP031 - Pattern Classification

TRACK 09: BIOSIGNAL PROCESSING

SP031.1 - The Recognition of Pinch-to-Zoom Gesture Based on Surface EMG

**Author(s):** Jongin Kim1, Dongrae Cho2, Kwang Jin Lee1, Boreom Lee1  
1Department Of Medical System Engineering, GIST, Gwangju/KOREA, 2Mechatronics, gwangju institute of science and technology, Gwangju/KOREA

I. INTRODUCTION

In recent years, a lot of researchers have tried to construct the system to recognize a hand or finger gesture based on the surface electromyogram (sEMG) since it can be used for the human computer interface.

They have only focused on recognizing simple movements such as an extension or flexion of fingers. However, in our present study, we propose a system to recognize a pinch-to-zoom gesture in real-time for practical applications. Pinch-to-zoom is a gesture to change the distance between the thumb and index fingers in order to control the size of images. For inferring the gesture, sEMG was acquired from the first dorsal interosseous muscle and multiclass classification techniques were used.

II. METHODS

A. Experiment and System settings

We recruited six healthy subjects for our experiment. We asked subjects to maintain the distance between thumb and index finger according to the visual cues (0 cm, 4 cm, 8 cm, and 12 cm).

Our system is divided into a sensor interface and computational unit parts. The sensor interface wirelessly transmits the sEMG to computational unit using Bluetooth. We developed graphic user interface (GUI) based on Matlab. The software reduces the noise, extracts the features and provides a visualization of the distance between the thumb and index finger in real time. (See figure1)

B. Feature extraction and Classification

In order to identify the distinct frequency bands, ANOVA test was conducted between four experimental conditions. Consequently, the powers from 1Hz to 250Hz are statistically significant (p < 0.01). Therefore, the powers from 1Hz to 250Hz were used as features for pinch-to-zoom gesture recognition.

The support vector machine (SVM) was used for recognizing the pinch-to-zoom gesture. Several hyperplanes have to be used for solving an N-class problem (N > 2) because SVM is based on two-partitions. As a result, average classification rate over all subjects was about 91.9%. These results prove that our system can be successfully used for recognizing the pinch-to-zoom gesture in real time.

SP031.2 - Feature extraction trends for biomedical signals

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Signal analytics involves identifying signal behavior, extracting linear and non-linear properties, compression or expansion into higher or lower dimensions, and recognizing patterns. Over the last few decades, signal analytics has taken notable evolutionary leaps in terms of measurement – from being simple techniques for analyzing analog/digital signals in time/frequency/joint time-frequency (TF) domain, to being complex techniques for analysis in a higher dimensional sparse domain. The intention behind this is simple – Feature Extraction; i.e. to identify specific signal markers or properties exhibited in one phenomenon, and uses them to distinguish from properties exhibited in another phenomenon [1-9].

One must realize that real world biomedical signals are non-linear, non-stationary and could comprise of multi-modal components. Evolutionary methods such as Autoregressive modeling, Cepstrum modeling, and Fourier and Wavelet analysis can handle non-stationarity through windowing approaches [7, 9], but with certain limitations such as information loss, lower artifact filtering and low signal-to-noise & distortion-ratio (SNDR). We suggest that modern day feature extraction methods must be as intelligent and trainable as the pattern classifier itself. Ideally instead of windowing, it is recommended to handle real-time signals using a streaming or on-the-fly approach, i.e. extract features as the signal propagates through the source. This could be made possible by employing newer sparse and compressive sensing approaches in combination with TF methods such as non-negative matrix factorization; or even a deep learning network constructed using a cascade of wavelet filters. An intelligent feature extractor could possibly eliminate the need for a feature selection technique (such as mRMR - minimum redundancy maximum representation), as this would happen inherently within the feature extractor. Additionally if the features are visually separable between signal classes, then employing a simple linear classifier could reduce system design constraints thus impacting the hardware design positively. Through this study we are attempting to
determine the best combination of signal processing methods which could generate an intelligent feature extractor capable of: [i] robustness to artifacts, [ii] improving SNDR, [iii] handling non-linearity, [iv] handling non-stationarity, [v] assessing signal component variability, [vi] addressing higher dimensionality of feature space by compact or sparse feature generation, and most importantly [vii] generating a feature set which brings out maximum representation of the signal and helps pattern classification. From a hardware perspective we should also include the following criterion: [i] built-in pre-processing and artifact removal, [ii] low power and memory consumption, [iii] real-time signal processing capability and [iv] computationally cost effective.

**SP031.3 - A Hybrid Model for Diagnosing Sever Aortic Stenosis in Asymptomatic Patients using Phonocardiogram**

**Author(s):** Arash Gharehbaghi¹, Per Ask², Eva Nylander³, Birgitta Janerot-Sjoberg⁴, Inger Ekman³, Maria Lindén¹, Ankica Babic²

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This study presents a screening algorithm for severe aortic stenosis (AS), based on a processing method for phonocardiographic (PCG) signal. The processing method employs a hybrid model, constituted of a hidden Markov model and support vector machine. The method benefits from a preprocessing phase for an enhanced learning. The performance of the method is statistically evaluated using PCG signals recorded from 50 individuals who were referred to the echocardiography lab at Linköping University hospital. All the individuals were diagnosed as having a degree of AS, from mild to severe, according to the echocardiographic measurements. The patient group consists of 26 individuals with severe AS, and the rest of the 24 patients comprise the control group. Performance of the method is statistically evaluated using repeated random sub-sampling. Results showed a 95% confidence interval of (80.5%-82.8%) / (77.8%- 80.8%) for the accuracy/sensitivity, exhibiting an acceptable performance to be used as decision support system in the primary healthcare center.

**SP031.4 - Classification of Load in Hands Based on Upper Limb SEMG**

**Author(s):** Illya Seagal, Evelyn Morin

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The purpose of this study is to correctly classify load lifted during a pail lift task. Surface EMG (SEMG) data were recorded from six locations on the arm and trunk of 15 subjects. Each subject was asked to lift a pail with one hand onto a platform at waist height in front of him/her. The pail contained masses from 0 kg to 20 kg in increments of 5 kg. Each weight was lifted and set down 5 times. The down-lift interval of the task was identified from a recording of an electro-mechanical switch and SEMG data from the triceps brachii and brachioradialis were extracted. The data were filtered for noise reduction using a 12th order high pass Type II Chebyshev filter with a cut-off frequency of 25 Hz, and a low pass 1st order Butterworth filter with a cut-off frequency of 490 Hz. The mean absolute value (MAV) and RMS value were computed and used as a feature set. A hierarchical SVM system shown in Figure 1 was used to classify the load lifted.

Overall the mean inter-subject classification success rate for classifiable trials was 0.490 using a train on 1st subject and test on others scheme, and 0.483 using a train on 1st trial and loads of all subjects and test on all other trials scheme. The combined confusion matrix for the former scheme can be seen below. Using simple features and a hierarchical SVM structure, a reasonable inter-subject classification accuracy was achieved. This outcome may be improved in the future by careful selection of additional features.
An Intelligent Method for Discrimination between Aortic and Pulmonary Stenosis using Phonocardiogram

**Authors:** Arash Gharehbaghi, Amir A. Sepehri, Armen Kocharian, Maria Lindén

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This study presents an artificial intelligent-based method for processing phonocardiographic (PCG) signal of the patients with ejection murmur to assess the underlying pathology initiating the murmur. The method is based on our unique method for finding disease-related frequency bands in conjunction with a sophisticated statistical classifier. Children with aortic stenosis (AS), and pulmonary stenosis (PS) were the two patient groups subjected to the study, taking the healthy ones (no murmur) as the control group. PCG signals were acquired from 45 referrals to the children University hospital, comprised of 15 individuals of each group; all were diagnosed by the expert pediatric cardiologists according to the echocardiographic measurements together with the complementary tests. The accuracy of the method is evaluated to be 90% and 93.3% using the 5-fold and leave-one-out validation method, respectively. The accuracy is slightly degraded to 86.7% and 93.3% when a Gaussian noise with signal to noise ratio of 20 dB is added to the PCG signals, exhibiting an acceptable immunity against the noise. The method offered promising results to be used as a decision support system in the primary healthcare centers or clinics.

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Table 1: Combined confusion matrix for all trials and subjects where the classifier was trained using data from subject 1, and tested on all other subjects. Some trials could not be classified due to poor electro-mechanical switch data.
SP032.1 - NEUROPROSTHETIC SYSTEMS FOR ENHANCEMENT OF NEUROPLASTICITY FOLLOWING STROKE AND SPINAL CORD INJURY

Author(s): Milos Popovic
Toronto Rehabilitation Institute, University Health Network, Toronto/Canada

In this lecture three neuroprosthetic applications will be presented that do not belong to a typical “garden variety” neuroprostheses that one can commonly find discussed in the literature. The first part of the lecture will showcase a neuroprosthetic application, which is aimed at restoring voluntary hand function after severe stroke. In the lecture the results of a Phase II randomized control trial will be presented, which were pivotal for this technology to become a commercially viable product. The second part of the lecture will discuss a neuroprosthetic system for blood pressure regulation for individuals who suffer from orthostatic hypotension following spinal cord injury. In the lecture the results from a Phase I clinical trial will be presented. The third part of the lecture will showcase use of electrical stimulation technology as means to navigate stem cell migration. In the lecture the proof of principle results will be presented. These three projects have been selected to showcase idea generation, product development and clinical trial validation process commonly practiced at the Rehabilitation Engineering Laboratory. The second objective of this lecture is to stress the importance of system level engineering, as a critical tool in the process of creation, development and validation of neuroprosthetic devices.

SP032.2 - Demonstration of Graphene Microelectrodes as a Bioelectronic Interface

Author(s): Michael R. Horn, Arika D. Kemp, Keong H. Yong, Jong-hyun Choi, Sungwoo Nam, Ken Yoshida
1Biomedical Engineering, Indiana University Purdue University Indianapolis, Indianapolis/IN/UNITED STATES OF AMERICA, 2Mechanical Science And Engineering, University of Illinois at Urbana-Champaign, Urbana/IL/UNITED STATES OF AMERICA

In the past 15 years, our lab has developed interfascicular microelectrode arrays (MEAs) for use in the peripheral nerve based upon micropatterned polyimide substrates with metal traces and contacts. These were the thin-film Longitudinal Intra-Fascicular Electrode (tLIFE) and the Transversely Implanted Micro-Electrode array (TIME). Acutely, these electrodes provide a high resolution view of the nerve activity within a nerve fascicle as well as a high resolution means to activate subsets of the nerve bundle. In part, the use of polyimide as the substrate material was to reduce the mechanical property mismatch between the neural tissues and the electrode structure as a means improve the chronic viability of the neural interface. However, chronic implants of tLIFE and TIME structures have shown that despite being several orders of magnitude softer than metal wire electrodes, (~1GPa vs ~150 GPa), the structures became encapsulated in a similar fashion to the metal wire electrodes. It has become clear that the 2 orders of magnitude reduction in modulus was not a sufficiently large enough reduction to show a change in encapsulation of the electrodes in the peripheral nerve, which has a modulus of elasticity of ~100kPa.

We are currently exploring newer softer materials for the substrate, with moduli on the order of 1GPa. However, substrates of softer materials will require traces and contacts that can withstand 10-15% elongation. This pilot study, we explored such a material, graphene.

Analysis of whether a graphene microelectrode array could measure the bioelectrical activity of muscle tissue as a first step towards developing a general purpose ultraflexible neural or muscular bioelectric interface. A graphene MEA (graMEA) was placed on the surface of an ex vivo rat biceps femoris muscle, and the electrical activity resulting from electrical stimulation of the sciatic nerve was recorded. The resulting twitch activity was simultaneously recorded using conventional intramuscular wire electrodes. It was found that the graMEA was capable of measuring stimulus artifact, compound EMG of the twitch and mechanical movement of the muscle, as shown below. Further advancements to the graphene based electrode include increasing the surface area by crumpling, reducing the contact size to increase spatial resolution of small nerve fibers, and using a field-effect transistor (FET) mode to increase signal to noise ratio. The results of this study provide proof of concept that flexible graphene electrodes can transduce bioelectrical activity of bioelectrically active tissues, opening the way towards developing ultra-small, ultra-flexible bioelectric interfaces.
Previous studies and experimental evidences suggest an important role of extracellular electrical cue in the establishment of photoreceptor cell polarity and polarization of intracellular structures, to analyze the special role of an extracellular electrical cue. Using a well-established migration assay, photoreceptors cone-like 661W mouse retina cells were stimulated for 5 h with 5 VDC/cm electric field. Using immunofluorescence techniques we have investigated changes in position of important organelles like Microtubules Organizing Center (MTOC), Golgi Apparatus (GA) and nucleus within those cells after the stimulation. In response to the directional stimulus, the cells have extended membrane protrusions towards the cathode; they got elongated perpendicular to the dcEF and have formed a leading edge towards the direction of cues. Directional migration has occurred towards cathode. MTOC and GA were reoriented in the direction of the leading edge of the cells (cathode), while the nucleus was translocated to the back of the cells, in the rear edge. Nuclear positioning is determined by microtubule and actin networks. The Golgi complex was colocalized with the MTOC in order to facilitate polarized secretion and provide membrane and secreted products directly to the most proximate plasma membrane to the leading edge of migrating cells.

**SP032.5 - Accelerating Neurite Outgrowth Through Electric Field Manipulation**

**Author(s):** Michael T. Purdy¹, Pierre J.J. Wijdenes¹, Wali Zaidi², Naweed Syed³, Colin Dalton³

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Brief electrical stimulation accelerates neuronal regeneration both in individual cells and in living models. In vitro experiments facilitate further understanding of regeneration mechanisms, and stimulation is accomplished through current-injecting micropipettes or commercially available micro electrode arrays. Such stimuli can be approximated as point-sources that emit decaying electric fields with high magnitude field strength near the electrode or micropipette. However, uniform electric fields may be better suited to enhance growth than traditionally used point-source fields. Applied uniform electric fields would allow for long distance stimulation without requiring high voltages that can compromise electrode integrity and cell health. The viability of uniform electric field stimulation was explored in this study through the use of a custom-fabricated planar microelectrode array. Simulation of several electrode configurations resulted in the design of a parallel plate anode-cathode pair. Several electrode pairs were embedded onto a single microelectrode array at various gap widths, to allow for the study of electric field strength on overall growth. With this novel electrode array, individual Lymnaea snail cells were stimulated with a 20 Hz, 1 volt pulse train for one hour. Control cells were plated on identical electrode arrays but were not connected to the stimulus generator. The impact of stimulation on growth was measured 24 hours later, and compared to control groups (Fig. 1). Stimulated cells showed an increase in neurite length compared to controls (Fig. 2). This effect was seen regardless of stimulus magnitude, within the range of 1000 - 2000 mV/mm. Our preliminary study served as a proof of principal for the application of uniform electric fields as a regenerative technique for nerve regrowth. The designed electrode layout improves upon currently available micro electrode arrays, and will allow for further study of regeneration mechanisms. This layout will be more easily transferred to an implantable design for future clinical use.
**SP033.1 - Quantification of breast density using dual-energy mammography, CT and MRI**

**Author(s):** Sabee Molloi, Huanjun Ding  
Radiological Sciences, University of California, Irvine/UNITED STATES OF AMERICA

Breast cancer is the most common cancer and the second leading cause of death from cancer. Mammographic density, which is defined as the ratio of fibroglandular tissue to the total fibroglandular and adipose tissue, is an important risk factor in the development of breast cancer. It has been shown that women with the highest mammographic density (75%–100% fibroglandular volume) have four- to fivefold increased risk of developing breast cancer compared with the lowest density (0%–25% fibroglandular volume). The current standard of care for breast density evaluation involves visual assessment of mammograms. This subjective classification scheme is limited by its considerable intra- and inter-reader variability. Additionally, an important limitation is that an area measurement using mammography ignores the physical 3D character of a real breast. Breasts of different thicknesses can potentially all yield the same measurement of area breast density yet correspond to widely varying volumetric breast density values. Volume-based techniques, which overcome some of the limitations of area-based techniques, include using dual-energy mammography, CT and MRI. Currently, there is no accepted standard for measuring breast density and accuracy of different techniques is not known. Postmortem breast studies were performed to assess the accuracy of breast density measurement for dual-energy mammography, spectral CT, dual-energy cone-beam CT, cone-beam CT and MRI. 40 postmortem breasts were imaged using a dual-energy mammography system. Glandular and adipose equivalent phantoms of uniform thickness were used to calibrate a dual-energy basis decomposition algorithm. Dual-energy decomposition was applied after scatter correction to calculate breast density. Breast density was also estimated using percent volumetric measures described in BI-RADS, standard histogram thresholding and a fuzzy C-mean (FCM) algorithm. The postmortem breasts were also imaged using spectral CT based on CZT photon-counting detectors, dual-energy cone-beam CT and breast MRI. Finally, breasts were chemically decomposed to measure the definitive tissue composition, in terms of water, lipid, and protein. The left-and-right correlations were used to estimate the precision of each technique. The percent fibroglandular volume (%FGV) from chemical analysis was used as the reference standard to assess the accuracy of different techniques to measure breast composition. In the left-and-right comparisons, the standard error estimation (SEE) was calculated to be 9.1%, 9.1%, 9.2% and 4.6% for BI-RADS, standard histogram thresholding and a fuzzy C-mean (FCM) algorithm. The postmortem breasts were also imaged using spectral CT based on CZT photon-counting detectors, dual-energy cone-beam CT and breast MRI. Finally, breasts were chemically decomposed to measure the definitive tissue composition, in terms of water, lipid, and protein. The left-and-right correlations were used to estimate the precision of each technique. The percent fibroglandular volume (%FGV) from chemical analysis was used as the reference standard to assess the accuracy of different techniques to measure breast composition. In the left-and-right comparisons, the standard error estimation (SEE) was calculated to be 9.1%, 9.1%, 9.2% and 4.6% for BI-RADS, standard histogram thresholding, FCM, and dual-energy mammography, respectively. In correlation to %FGV from chemical analysis, SEE was calculated to be 9.9%, 8.6%, 7.2% and 4.7% using quartile volumetric rankings, standard histogram thresholding, FCM, and dual-energy mammography, respectively. The accuracy of breast density measurement for spectral CT, dual-energy cone-beam CT, cone-beam CT and MRI were calculated to be 2.8%, 3.6%, 3.9%, and 6.5%, respectively. In conclusion, the results indicate that dual energy mammography can be used to accurately measure breast density. The variability in breast density estimation using dual energy mammography was substantially lower than quartile volumetric rankings, standard histogram thresholding, FCM and breast MRI. The results also suggested that spectral CT is a very promising technology for breast imaging.
SP033.2 - Study on the Main Nonconformities Found in no Mammography Alagoas State

**Author(s):** Jose R. Almeida Nato¹, Cinhia M.M. Paschoal³, Divanizia D.N. Souza³, Lourdes M. Brasil³, Fernanda C.L. Ferreira³

¹Physics, State University of Health Sciences of Alagoas, Alagoas/BRAZIL, ²Civil Engineering, State University of Vale do Acaraú, Sobral/CE/BRAZIL, ³Physics, Federal University of Sergipe, São Cristóvão/BRAZIL, ⁴University of Brasilia, Brasilia/BRAZIL, ⁵Federal University of South and Southeast of Pará, Marabá/BRAZIL

Mammography is one of the most important radiological techniques in tracking and control of the breast cancer development; capable to accurately identify the absence or presence of diseases, which can assist in the definition of reliable reports in case of viewing any types of anomaly. In this sense, the aim of this work was to conduct a study of the major non-conformities found in mammograms operating in the State of Alagoas, Brazil, warning the risk of negative and false positive diagnosis. In this work, main non-conformities found in the mammography’s equipment of the state are prioritized, such results were classified as compliant and non-compliant according to the guidelines established by the National Agency for Sanitary Vigilance. Following this approach, XLV Diagnostics, a Canadian start-up, is capitalizing on their low cost components to drive down significantly the cost of medical imaging equipment. A higher percentage of non-compliance were A1, B2 and B5, as well, may be recommended that the mammography equipment such institutions should undergo maintenance process and rigorous calibration and frequent quality control tests. Mammograms’ tests A3, A4 and B1 showed satisfactory results, with compliance above 90% within the parameters established by Decree 453 of National Agency for Sanitary Vigilance. Focusing on all mammograms, it becomes necessary to implement a quality control program and will show several of its parametric characteristics.

SP033.3 - Affordable medical x-ray imaging for the developing world: a global vision

**Author(s):** Sorin Marcovici², Vlad Sukhovatkin², Oscar Cisek²

²XLV DIAGNOSTICS INC., Thunder Bay/CANADA, ³XLV DIAGNOSTICS INC, Thunder Bay/ON/CANADA

Imaging technologies, already used routinely for diagnostics, are becoming an essential part of the work flow included in screening, treatment progress monitoring and outcome evaluation. However, various imaging modalities considered standard practice for the medical institutions in the developed world remain today rather inaccessible for the populations at large in the developing countries. One of the limiting factors is the high cost of medical imaging equipment.

To develop and produce low cost, medical imaging systems of good quality requires disruptive innovations and novel approaches to engineering. The sophistication and capabilities of ubiquitous consumer products available today provide a real opportunity to capitalize on their low cost components to drive down significantly the cost of medical imaging equipment.

Following this approach, XLV Diagnostics, a Canadian start-up, is developing a completely new technology, X-ray Light Valve (XLV), for producing very affordable large area, flat panel, x-ray detectors based on which economical medical imaging systems can be built. The first XLV product will be a digital mammography machine for breast cancer screening that will be sold at a fraction of the price asked for presently available machines.

The paper will present the conceptual approach and innovative engineering to create from consumer type components a good quality digital imaging system and will show several of its parametric characteristics.

SP033.4 - Characterization and Analysis of the Physical Parameters in Dental X-Rays Phantom

**Author(s):** Lilian F. Silva¹, Jhonatan M. Santos¹, Cinhia M.M. Paschoal³, Divanizia D.N. Souza³, Lourdes M. Brasil³, Fernanda C.L. Ferreira³

¹Federal University of South and Northeast of Pará, Marabá/BRAZIL, ²Civil Engineering, State University of Vale do Acaraú, Sobral/BRAZIL, ³Physics, Federal University of Sergipe, São Cristóvão/BRAZIL, ⁴University of Brasilia, Brasilia/BRAZIL

All care related to ionizing radiation exposure to patients, the radiographic image quality and gain time is related to quality control equipment and image. Therefore, it is necessary to be realized by using quality control and intercomparison phantom images with the results of previous tests as well as other types of X-ray equipment, or performing the intercomparison of results of quality control testing. The objective of this study was to characterization, and analysis (intercomparison) results periapical radiographs obtained with phantom and evaluate the high and low contrast in dental radiographs service of Maraba, northern Brazil. For the intercomparison of physical parameter of high and low contrast in the periapical radiographic equipment of the Maraba, a phantom developed in Brazil was used precisely in Aracaju, northeastern. It is worth noting that, the phantom used in this work and the interparameter of the equipment of the images showed satisfactory results bringing out the difference from the standard image. However, tests can be used to switch to other equipment in the surrounding towns of the city of Maraba. Thus allowing the cornerstone for the creation of a database with images obtained with the phantom and can be used in training of students and dental professionals.

SP033.5 - In Vitro and In Vivo Studies Glycosylated Gadolinium Nanomagnetic Particles (GD-DTPA-DG) as New Potential Metabolic Contrast Agent in MMRI

**Author(s):** Sara -, Heydarnezhadi, Nader Riyahi-Alam, Soheila Haghgoo, Ensieh Gorji, Hosein Ghenaati, Behrouz Rafiei

Tehran university of Medical Science, tehran/IRAN

Early cancer diagnosis using MRI imaging is of high global interest as a noninvasive and powerful modality in molecular imaging. Therefore demand for new MRI contrast agents, with an enhanced sensitivity and advanced functionalities that improve the targeting to specific tissues or organs, is very high. In this study, D-glucose amine was conjugated to a well-known chelator, diethylenetriamine penta-acetic acid (DTPA), then labeled with Gd to achieve Gd-DTPA-DG, Which is a metabolic contrast agent in mMRI. The contrast agent was synthesized and characterized physicochemical using different techniques including dynamic light scattering (DLS), high resolution transmission electron microscopy (HTEM) and inductively coupled plasma atomic emission spectroscopy (ICP-AES), Efficacy of the targeted contrast agent was assessed by measuring relaxation rate in vitro and tumor MR imaging were performed to determine signal intensity (SI) in vivo (0.1 mmol Gd/kg) in female balb/c mice mod-el. According to the results, the nano metabolic contrast agent penetrate into cells and accumulated in tumor, which cause improve the contrast of tumor tissue in comparison with magnevist. The results showed that the novel nano contrast agent could become useful tool in early detection of cancer.
SP034 - CT: New Techniques

SP034.1 - Design, modeling and performance evaluation of a small animal Micro-CT scanner: A Monte Carlo study
Author(s): Samira Nezhaddeghani, Saeed Sarkar, Mohammad Reza Ay
Department Of Medical Physics And Biomedical Engineering, Tehran University of Medical Sciences, Tehran/IRAN

Introduction: Nowadays, by increasing the interest in the use of small animals in biomedical studies, development of small animals imaging systems such as Micro-CT scanners are promoted. Development of the hybrid systems such as SPECT/CT is the other significant factors in development of this kind of scanners. The diagnostic power will be increased by superposition anatomical and functional images in hybrid systems. Furthermore, obtained attenuation map from Micro-CT can be used for attenuation correction of the SPECT data. The purpose of this study was to design and improves the performance of Micro-CT scanner to develop a small animal SPECT/CT system by using the Monte Carlo simulation. The SPECT module called HiReSPECT already fabricated in our Laboratory.

Materials and Methods: In this study the GATE Monte Carlo package was used for accurate modeling of the system, the tube voltage 30-70 kV with focal spot size 30 µm, anode from Tungsten and aluminum filter with thickness of 0.5 mm. The designed detection system has dimension 5.0 x 18.5 x 4.7 cm³ with 100 microns pixels size and an indirect flat-panel scintillator made from CsI(Tl). In this study, the selected distance from the X-ray tube to object 10-12 cm and distance from object to detection system 8-10 cm was considered. These distances were chosen base on the separation length between two detectors and diameter of gantry of HiReSPECT. In analysis and post process the results of the simulation, spatial resolution, noise, contrast and scatter to primary ratio (SPR) was investigated and an optimal design for the scanner detector was presented. The computerized phantom (MOBY) was implemented in simulated scanner and reconstructed images provided by using MATLAB program.

Results: Tomographic image of the simulated phantom containing nine cylinders with radial 0.5, 1, 2.5 and 5 mm which were considered filled with tissue equivalent material like skull, lung,ribbon and cartilage were represented the designed system is capable to distinguish soft tissue materials and demonstrate 0.5 mm resolution of the skull (Fig 1-B). The achieved spatial resolution for different materials and dimensions varied in the range of 100 to 150 µm with 0.03% of the noise and 0.0015 of SPR.

Conclusion: In this study, a Micro-CT scanner was simulated with GATE Monte Carlo code by considering geometrical limitation of HiReSPECT. Finally all of mentioned parameters were optimized and were obtained good images of it.

Fig. 1 A) Simulated phantom using GATE code; B) Reconstructed

SP034.2 - An imaging method by using electron mode of linear accelerator for soft tissue emphasis
Author(s): Atsushi Muroyama, Hidetoshi Saitoh
Radiological Sciences, Tokyo Metropolitan University, Tokyo/JAPAN

Purpose
Megavoltage portal images are used to verify the proper positioning of the patient in image-guided radiation therapy (IGRT). However, the description of low density material reconstructed by MV image doesn’t reach kilovoltage one because the flattening filter of linear accelerator causes beam hardening and an increase of scattered photon. To solve this problem, we designed a new image acquisition method by using electron mode of linear accelerator. The low contrast image is acquired by this method because the focus of the target becomes large by attaching to the shadow tray of a linear accelerator, and because Mega-voltage X-rays cause Compton scattering much within human body. To approach those problems, in this study, we propose a 2-pass 3D image reconstruction using simple Monte Carlo method. Feld Kamp, Davis and Kress (FDK) method was used for 3D reconstruction, and BEAMnrc based simple Monte Carlo method was developed to estimate scattering photons.

Method
The portal images were taken by using bremsstrahlung x-ray that was generated by the target newly attached under secondary collimators. To estimate scattering photon, 3D reconstruction was performed in two steps. By the first step, the rough structure was reconstructed by FDK method. In this step, graphic processing unit (GPU) was utilized to reduce the processing time. In this study, a NVIDIA GeForce GTX970 (CUDA) was used for parallel processing. By the next step, the simulation for investigating the relation between the generating position of a scattering photon and EPID data was performed by using the first reconstructed data. Although the most reliable method was Monte Carlo simulation, that was time consuming process and was not practical. Therefore, simple Monte Carlo (SMC) using GPU acceleration was proposed. Although some SMC was proposed, we chose the method of holding and reusing in a memory the result of the full Monte Carlo that was calculated beforehand. In this method, BEAMnrc code system was used for estimating position of scattering photon in an object. Since it was necessary to perform our method for every rotation angle of a gantry, the proposed method needed high-speed processing. This method was accelerated by holding beforehand the full Monte Carlo calculation result to the HU range of primary reconstruction data. Aluminum target were selected for proposed method. This method was simulated and measured on 4, 6 and 9 MeV electron beam.

Result and Conclusion
The calculation time of proposed SMC was about 9 seconds per one projection. The processing time consumed to 180 projections was 27 minutes. The result images emphasized soft tissue than the images acquired by high energy X-ray.

SP034.3 - Anatomical noise model for CT head images: preliminary results
Author(s): Rafael A. Miller-Clemente1, Marlen Perez-Diaz2
1Group Of Radiation Medical Physics, Biofísica Médica, Santiago de Cuba/CUBA, 2Study Center On Electronic And Information Technologies, Universidad Central Marta Abreu de las Villas, Santa Clara/ CUBA

The availability of an anatomical predictive noise model provides new knowledge about the physical factors tradeoff and the quantitative effect of multiple factors over the diagnostic image quality. Here,
the anatomical noise was defined as the standard deviation of pixel intensities, contained in a region located at the center of an axial CT pediatric head image. Images were obtained by using an Automatic Exposure Control system. The purpose of this work was to determine the association between the noise on diagnostic images and a noise model based on phantom measurements. The model of anatomical noise obtained has an adequate predictive value, with a correlation coefficient of 0.97 (significance level of 95%) and mean square error of $1.9 \times 10^{-6}$.

SP034.4 - The potential of spectral-CT for material decomposition with gold-nanoparticle and iodine contrast

Author(s): Byungdu Jo
Department Of Radiological Science, College Of Health Science, Yonsei university, Wonju/KOREA

The objective of the this study was to demonstrate feasibility of using gold contrast-agent as a new contrast agent for spectral-computed tomography (CT) system and decompose the iodine and gold materials in the spectral-CT system using K-edge imaging technique. Recently, gold based nanoparticles contrast-agent has been introduced for vulnerable plaque imaging in CT system. The spectral-CT system equipped with Cadmium Zinc Telluride (CZT)-based photon-counting detector has energy-discrimination capabilities and high resolution image acquisition capabilities. We performed a simulation study using the Geant4 Application for Tomographic Emission (GATE) simulation. The CZT detector contained four CZT crystals and total detector length was 51.2 mm with 64-channel array. The results showed that the contrast-to-noise ratios of iodine and gold contrast-agent materials in energy window included K-edge energy of materials (33-49 keV for iodine, 66-81 keV for gold) were increased approximately 1.9 and 1.7 times higher than others. These results also show the possibility of potential of using two contrast-agents at a time to provide the various information of image such as plaque vulnerability assessment.

SP034.5 - Spatial Resolution Studies for a Prototype Proton CT Scanner

Author(s): Tia E. Plautz1, Robert P. Johnson1, Hartmut F.-. Sadrozinski2, Andriy Zaterklyanyan3, Vladimir Bashkirov2, Reinhard W. Schulte2, Robert F. Hurley2, Valentina Giacometti3
1Scipp, University of California, Santa Cruz, Santa Cruz/CA/UNITED STATES OF AMERICA, 2Radiation Research Laboratories, Loma Linda University, Loma Linda/UNITED STATES OF AMERICA, 3Centre For Medical Radiation Physics, University of Wollongong, Wollongong/NSW/AUSTrALIA

We report on the simulation and initial beam test results with the pre-clinical (phase II) head scanner developed for proton computed tomography (pCT) by the pCT collaboration. In the future, proton CT may be employed to improve the accuracy of relative stopping power functions required for image reconstruction. The Phase II proton CT system consists of two silicon telescopes that track individual protons before and after a phantom, and a novel 5-stage scintillation detector that measures a combination of the residual energy and range of the proton. Residual energy is converted to water equivalent path length (WEPL) of the protons in the scanned object. The set of WEPL values and associated paths of protons passing through the object over a 360° angular scan is processed by an iterative parallelizable reconstruction algorithm that runs on GP-GPU hardware. This report will focus on studies of the spatial resolution of the phase II imaging system, while studies of the achievable accuracy of relative stopping power will be reported elsewhere. A custom edge phantom composed of water-equivalent polymer with 4 body-equivalent material inserts was developed. The phantom was first simulated using Geant4 and then built for experimental beam tests with 200 MeV protons at the research beam line at the Loma Linda University Medical Center. A modified version of the oversampling method was used in order to construct edge spread functions and modulation transfer functions for materials of varying relative stopping powers located at several radial displacements from the center of the phantom. A combination of angular cuts with the aim to eliminate large-angle scattered protons, the most likely path (MLP) concept, and a superiorization method in iterative image reconstruction are used to improve the spatial resolution of the image reconstruction. These sophisticated and computing-intensive techniques are being compared to simpler and much faster reconstruction methods including filtered back projection along curved paths and cubic-spline path approximation. Reconstructions of pCT data sets obtained with a realistic anatomical head phantom will further complement the analysis of the MTF.

SP034.6 - Influences of object size and tube potential pairing on the accuracy of iodine quantification using dual energy CT

Author(s): Josh Grimes, Lifeng Yu, Shuai Leng, Cynthia Mccollough
Mayo Clinic, Rochester/MN/UNITED STATES OF AMERICA

Purpose: The objective of this study was to evaluate the accuracy of iodine quantification in phantom images acquired on a dual-source dual-energy CT scanner. The influences of phantom size and different tube potential pairs were investigated.

Methods: Three bottles with iodine concentrations of 3.5, 7 and 10.5 mg/mL were placed inside 8 torso-shaped water phantoms ranging from 15 to 50 cm in lateral width. Dual energy scans of each phantom were acquired on a dual-source CT system (Siemens Somatom Force) using 4 different tube potential pairs (low energy: 70, 80, 90, and 100 kV; high energy: 150 kV + 0.6 mm Sn). CTDIvol was matched for all scans of a given phantom size. Images were reconstructed with 1-mm image thickness at 0.8 mm intervals using a medium smooth body kernel. The dual-energy data were post-processed using commercial software (syngo Via Dual Energy, VA30), which generated virtual non-contrast and iodine overlay images. Iodine concentration (in mg/mL) was displayed for regions of interest drawn over the iodine bottles, and compared with the known concentrations for each phantom size and tube potential pairing.

Results: At 70/150Sn, the measured iodine concentration was within 9% of the known concentration for phantom sizes from 15-45 cm. However, images acquired at 70/150Sn were deemed unacceptable for phantom sizes greater than 35 cm due to ringing artifacts. At 80/150Sn, 90/150Sn and 100/150Sn, iodine concentrations determined for phantom sizes up to 45 cm agreed with known concentrations within 14%, 25% and 19%, respectively. At 100/150Sn, the iodine concentration in the 50 cm phantom was within 27% of the known value. Iodine quantification was most accurate (within 2% for all tube potential pairs) for the highest iodine concentration (10.5 mg/mL) in the 30 cm phantom. As phantom sizes increased or decreased from 30 cm, iodine concentration was increasingly overestimated.

Conclusion: The accuracy of iodine quantification depends strongly on the phantom size. When selecting the tube potential pairing, both image quality (e.g. artifacts) and accuracy of measured iodine concentration should be considered.
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SP034.7 - Characterization of Vulnerable Plaque with Dual-Energy during CT Coronary Angiography: A Phantom Study

Author(s): Ali Ursani1, Sachin Moghe2, Carlton Hoy3, Narinder Paul4

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PURPOSE/AIM:

The aim of this exhibit is to: Demonstrate the utility of Dual Energy image acquisition and post processing to provide high-resolution characterization of mixed arterial plaque in an anthropomorphic coronary artery phantom composed of tissue equivalent materials. Introduce the concept of a Dual Energy index and material decomposition algorithm.

CONTENT ORGANIZATION:

Description of the Dual Energy Coronary Artery Phantom containing arteries with variable degrees of lumen stenosis Specifications for the mass attenuation properties of materials mimicking the spectrum of calcified and non-calcified vulnerable plaque Validation of attenuation properties of phantom based materials compared to biological tissues compared at different energies. Calculation of Dual Energy Index and energy - attenuation plot for iodine and calcium based materials present in the phantom. Use of Dual energy material decomposition software to generate iodine and calcium removed images to improve accuracy of stenosis assessment.

RESULTS SUMMARY:

A tissue equivalent coronary artery phantom is extremely useful in demonstrating significant improvements in accuracy of stenosis measurement and characterization of vulnerable coronary artery plaque with Dual Energy image acquisition and post processing.
Osteoarthritis (OA) is a debilitating chronic joint disease that is becoming a growing concern among the aging population. Due to its complex nature, many questions regarding its initiation and progression remain unanswered. There has been a renewed interest in the bone-associated vasculature, and the role they may play in OA. Thus, having the ability to quantify and characterize the vascular changes (patency, density, and micro-architecture) provide more information into OA’s initiation and progression.

Micro-computed tomography (micro-CT) is widely used for its ability to provide well-characterized bone. However, the visualization of associated vasculature is difficulty due to their (1) size (5-10 μm for capillaries), (2) poor inherent x-ray contrast, and (3) proximity to highly x-ray attenuating bone. We propose the combination of a custom exogenous vascular perfusion contrast agent, dual-energy micro-CT (DECT), and decomposition algorithms to allow for the distinct and separate visualization of the perfused vasculature and bone.

To demonstrate the capabilities of our combination technique, a lanthanide-based vascular perfusion contrast agent and x-ray filter was developed. We perfused the lower half of a rat with our vascular contrast agent through the aorta and embedded the excised left hindlimb in agar. The sample was then scanned on our GE Vision120 phantom with cardiac insert, filled with 99mTc, simulating a SPECT myocardial perfusion acquisition. Images were reconstructed using the standard clinical department protocol, and were analyzed by axial and lateral count profiles and polar distributions. The lateral profile showed that contrast between the lesion region and background in Cardio MD camera is higher (62.2%) than the in the CZT camera (42.5%). The axial profile showed a higher contrast (37.0%) in the CZT camera compared to Cardio MD (31.9%). CZT showed a higher contrast between background and maximum activity point along the line (68.2%) than in the Cardio MD (57.5%). Performing the maximum region relative count and the lesion area analysis, it was verified that contrast between these regions are 31.2% and 25.5% to CZT and Cardio MD, respectively. The results showed the cold myocardium lesion detectability is enhanced in the CZT camera. The polar map in the CZT camera displays a better uniformity between the segments’ counting, which means the lesion identification is clearer than in the Cardio MD camera, where the distribution is diffuse and the lesion is unclear. In conclusion, the physical performance of CZT camera is higher than conventional camera, but further studies are required to evaluate other parameters, such as spatial resolution, sensitivity and contrast-to-noise ratio.

Thus, by applying our combination technique to a well-characterized surgically induced rat hindlimb OA model, we may able to provide further insight into the role of the joint’s vascular supply as OA initiates and progresses.
The x-ray performance of the CMOS APS detector is evaluated based on experimentally measured pre-sampling modulation transfer function (pMTF), normalized noise power spectrum (NNPS) and signal-to-noise ratio (SNR). Image simulation is performed modelling the detector characteristics and the x-ray source (Xcomp5r) to estimate optimal dual energy conditions. Breast phantoms are carefully prepared to simulate the properties of real breast tissue and images are acquired using a tungsten anode x-ray source. Inside the phantom, a 2 mm diameter tube, representing the minimum tumor sizes developing angiogenesis, is placed for the injection of the different contrast media concentrations. The mean glandular dose (MGD) is evaluated and kept as low as possible to achieve sufficient image quality. The influence of scatter radiation on DE images is investigated and artefacts are reduced using a scatter-correction algorithm.

The optimum image combination is found to be at 48 kVp for both low- and high-energy x-ray beams with 0.2 mm tin and 0.3 mm copper filtration, respectively. This combination reduces the irradiation time and consequently minimizes patient motion artefacts and radiation dose. For seven image pairs, the total MGD is 1.4 mGy, which does not exceed the equivalent from a typical mammogram. Good agreement is found between the experimental and simulated results (i.e. 0.5% difference), showing that the image simulation tool is accurate to optimize a larger number of parameters and their combinations for good image quality. It is shown that the scatter-correction algorithm yields an improvement of 24% in determining iodine projected thickness, yielding an overall accuracy of the DE CEDM and CMOS APS combination within about 3% compared to the actual iodine projected thickness.

Results show that the iodine projected thickness can be effectively measured from iodinated images, and other applications, such as the measurement of contrast medium kinetics, are expectable. The performance of CMOS APS x-ray detector is within clinically acceptable accuracy and comparable with state-of-the-art technology reported in literature. This indicates that the proposed technology can be successfully combined with the DE CEDM technique for detection of early breast cancer.

**SP035.3 - Apodized-Aperture Pixel Design of an X-Ray Detector with Enhanced High-Frequency DQE and Reduced Noise Aliasing**

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The detective quantum efficiency (DQE) is a characteristic of an imaging system representing its imaging performance relative to an ideal imaging system. While high DQE values are necessary to maximize image quality using low x-ray exposures, typical DQE values are ~0.7 at low spatial frequencies and ~0.3 or less at high frequencies. We describe a CMOS/selenium-based detector using an apodized-aperture pixel (AAP) design that could achieve a new-uniform DQE over all spatial frequencies for mammographic applications. The method uses very small physical sensor elements on the CMOS sensor to synthesis larger image pixels using a novel filter design. A numerical method of optimizing the filter shape to minimize noise aliasing and maximize the DQE is described. A cascaded-systems analysis shows the limiting high-frequency DQE value can be increased from 0.3 to 0.7. The AAP approach is validated on a CMOS/CSi-based laboratory detector where the limiting DQE is increased from 0.2 to 0.4.

![Figure 1 Developed AAP design of an x-ray detector accompanied by the cascaded system analysis.](image)

![Figure 2 DQE of the conventional versus AAP x-ray detector models.](image)

**SP035.4 - Geant4 Simulations of Scintillation Light Collection and Extraction in PET/CT Detectors**

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**Introduction**

Scintillation detectors are made of scintillation crystals coupled to photodetectors (photodiode, photomultiplier tube, SiPM, etc.). The performance of these detectors (energy and timing resolution, detection threshold, etc.) strongly depends on the collection and extraction of scintillation light from the crystal to the photodetector. To ensure high spatial resolution and high detection efficiency, scintillators must be arranged in compact arrays with unfavorable shapes for photon transport. In typical polished scintillators (n=1.8) with a form factor length/surface > 5, up to 40% of signal is lost to absorption and trapping within the crystal and attenuation through interfaces to the photodetector. In highly pixelated arrays, this loss is compounded with crosstalk effects, squandering valuable signal to adjacent pixels. The purpose of this study is to uncover processes responsible for light losses in scintillator arrays and investigate ways...
of enhancing light transport and extraction from pixelated crystals.

Materials and Methods

The Monte Carlo software Geant4 was used to simulate 511-keV annihilation photon interactions occurring in parallelepiped Lu1.9Y0.1SiO5 (LYSO) scintillators and to track the propagation of the produced scintillation photons. 4×8 crystal arrays made of 12-mm high pixels at a pitch of 1.2 mm were simulated. All crystal surfaces were defined as polished with reflectors (3M-ESR or silver foil) bonded to the lateral faces using an optical adhesive (n=1.5). Each pixel was covered with a diffuse reflector on one end (Lumirror) and read out from the other end by a surface emulating an avalanche photodiode (APD) with quantum efficiency of ~65% @ 420 nm.

Results and Discussion

Simulations revealed four main contributions to crosstalk between scintillators. First, energetic primary electrons generated near pixel lateral surfaces may escape to adjacent crystals, thus losing a fraction of the initial 511-keV energy. Since the maximum free path of 511-keV photoelectrons is limited to ~100 µm, this effect was found to be significant for interactions occurring within ~75 µm from the surface (up to 30% signal loss). Second, the 3M-ESR reflectivity severely drops from 98% down to 20% below 400 nm. Signal loss due to photons transmitted through the reflector was estimated to ~10%. This was found to be avoided with metallic reflectors. Third, the manufacturing technique used to assemble scintillator arrays is responsible for some optical leakage at the edges of pixels, resulting in asymmetric optical crosstalk amounting to 3%. Finally, scintillation photon propagation within the optical coupling layer was also found to spread the signal to adjacent crystals.

Scintillation photons escaping through the readout window have to spread across multiple interfaces (optical coupling, Si3N4) before reaching the photodetector sensitive area. Simulations reveal a strong dependence of the transmitted light fraction on angular distribution and wavelength of photons reaching each surface. Since most photons impinge on interfaces far from normal incidence, improvements in extracting these photons are feasible by adjusting the thickness and refractive index of the multiple interface layers.

Progress in scintillation light transport and extraction can potentially be achieved by optimizing all factors identified in this simulation study.

Several performance characteristics were measured as a function of bias voltage for a set of 10 prototype modules: dark current ($I_D$), relative APD gain, noise threshold (converted into keV for 200 cps without source), gain spread (maximum/minimum photopake position), energy resolution ($\Delta E$) and intrinsic time resolution ($\Delta T$). $I_D$ and APD gain measurements were performed up to breakdown voltage to determine the APD operating range. Other measurements were performed using a LabPET™ multi-channel digital data acquisition system (180 ns peaking time, preamplifier gain=8.4 mV/fC). To estimate the noise level, gain spread and $\Delta E$, a two-minute measurement was acquired with a $^{68}$Ge source (511 keV) in front of the array, followed by a 30-second background measurement without source to subtract the $^{176}$Lu natural radioactivity present in the LYSO. $\Delta T$ measurements were taken in reference to a timing probe consisting of a $^{18}$F-doped liquid scintillation/PMT detector. Results were obtained for bias values from 225 V to a maximum bias where at least 10 channels saturated the electronics.

Results

$I_D$, relative APD gain, and $\Delta T$ curves were obtained as a function of bias for all pixels. At the optimum operating bias determined from $\Delta T$ measurements, the average $I_D$, noise, gain spread, $\Delta E$ and $\Delta T$ results are respectively 18±8 nA, 39±21 keV, 3.2±1, 22±2% and 3.7±0.3 ns (with an energy threshold of 400 keV).

Conclusion

These results confirm the suitable electronic and physical performance of the detector for annihilation radiation detection. Further investigations are in progress to evaluate the imaging performance of the module for PET.

Figure 1. Energy spectra and resolution ($\Delta E$) for a typical LabPETII.5 module. The ER was measured with a $^{68}$Ge source (511 keV). The average $\Delta E$ is 22 ± 1%. The average noise threshold is 31 ± 7 keV.
SP035.6 - An alternate mathematical modeling of image formation, and framework for performance analysis of positioning algorithms in the scintillation camera

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Introduction: Substantive amount of work has been done in modeling the scintillation camera system processes including positioning and image formation. This study presents an alternate mathematical modeling and subsequently framework for performance analysis of different positioning algorithms, followed by experimentation with and comparative study of several of the system parameters.

Methods: Making the assumption that a scintillation occurring in the gamma camera will result in a deterministic number of photons (proportional only to the solid angle at which it sees the detector array), the detector array counts will be found to follow the multinomial distribution with underlying probabilities determined purely through geometrical analysis. The statistical characterizations of mean, variance, and covariance of the counts will therefore be known from statistics. Anger arithmetics being presentable in terms of matrix operations on the counts vector, the mean vector and covariance matrix of the positioning output will therefore be explicitly expressible in terms of statistical characterizations of count values. Maps can moreover be constructed of displacement and blurring intensity corresponding to each point on the detector, characterizing its linearity and resolution performance. This constitutes a framework for performance analysis of different positioning algorithms. In Section I, the model is used to produce comparisons concerning photomultiplier tube (PMT) shape (square-circular-hexagonal), size, non-uniform response, and gain. In Section II, the framework has been used to analyze the performance of two more complex positioning arithmetics, involving nonlinear conditioning and exploitation of row and column sums; to that end, a new matrix formulation of the positioning output is first developed, and statistical characterization of the output are then derived using relations for moments of functions of random vectors. In Section III, the model is extended to include the complete system, including realistic versions of source, collimator and crystal, and maps are constructed for the sample case where the crystal has non-zero thickness.

Results: Figure 1 shows the case where the PMT shape and (equivalent of) size have been studied. Similar figures are created for other parameters.

Discussion: The model is evaluated against Monte Carlo simulation in several scenarios and is found to perfectly match down to any significant digit. This model can be used for in-depth study and analysis of the scintillation camera.

Figure 1: *TOP* Scatter maps showing the positioning output for uniform grid inputs. *BOTTOM* Resolution maps showing the blurring intensity corresponding to each position. In *A* PMT, *B* square PMT, *C* hexagon PMT, and *D* square PMT with source at 3/4 the default value. (A) square replaced by hexagon of equal side-to-side value. (C) hexagon replaced by the inscribing circle, and (D) square moved to 3/4 the default value. Only one quarter of the 8 x 8 detector array and side edges not included are displayed.

SP036 - Treatment Planning - Motion and Robustness

SP036.1 - Robust optimization with independent beams produces robustly matched fields for intensity-modulated proton therapy treatments

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Background

Intensity-modulated proton therapy of the craniospinal axis typically involves matched posterior spinal fields in order to cover the spinal cord. Setup errors separating or bringing the matched fields together can cause respectively under- and overdosage at the field junction. Wedge-shaped matched beam doses, which slowly increase from zero to the prescribed dose, reduce this risk. Beam dose wedges can be achieved by treatment planning using multiple auxiliary planning structures, but such a manual process is often time-consuming. The aim of this work is to give proof-of-concept of how the creation of beam dose wedges can be automated by the use of robust optimization.

Methods

The robust optimization of the RayStation treatment planning system (RaySearch Laboratories, Stockholm, Sweden) was augmented with the ability to let setup uncertainty affect the beams independently. RayStation’s robust optimization uses dose distributions for multiple scenarios and aims to minimize the objective value under the worst case scenario. When the setup uncertainty affects the beams independently, a scenario is constituted of a specific setup error for each individual beam. For example, if two beams are used, then the total dose distribution under a given scenario may be the sum of the beam doses resulting when beam 1 is shifted superiorly and beam 2 is shifting inferiorly relative to their isocenters.

Results

Robust optimization with beams independently affected by setup uncertainty was applied to intensity-modulated proton therapy treatment planning for a craniospinal case using two parallel-opposed lateral cranial fields and two matched posterior spinal fields. The independent beam setup uncertainty was set to ±5 mm along the superoinferior axis. The optimization problem included the planning target volume and the external region without any auxiliary structures. Figure 1 shows line doses of the optimized plan over the spinal field junction. The optimization has resulted in clear beam dose wedges. The nominal total dose is slightly above the prescription of 20 Gy in order to ensure that the total dose resulting when the beams are separated is at the prescription. This provides proof-of-concept that robust optimization is a viable tool for creating robustly matched fields.
Purpose: Previously, we utilized deformable image registration (DIR) to optimize planning target volume (PTV) margins in lung cancer image-guided radiation therapy (IGRT). In this study, we have developed a method using DIR to assess the tolerance of rotational error for different image matching strategies.

Methods and Materials: 132 cone-beam computed tomography (kV CBCT) images of 8 lung cancer patients were used. Images simulating perfect set-up were created by registering each planning CT image with a CBCT image at each fraction with translations and rotations enabled. These images were rotated in all combinations of the x-, y-, and z-directions (pitch, yaw, roll) by 1, 3, 5, and 6 degrees around the centre of the spinal cord. Rotated CT images were translated to match the CBCT data nearby the spinal cord/carina or internal target volume (ITV) to obtain a simulated couch correction. Deformable image registration was used to automatically position the planning ITV on each final CBCT. ITV coverage was quantified as the percentage of the ITV surface that fell within generated PTVs.

Results: Each fraction comprised 26 rotation simulations per rotation magnitude, so a total of 3432 simulated images were analyzed per degree rotation. To achieve perfect setup, mean rotations (± standard deviation) of 1.3 ± 1.0, 1.1 ± 0.9, and 0.6 ± 0.6 degrees about the left-right (LR), anterior-posterior (AP), and superior-inferior (SI) axes were necessary. For our currently employed 6 LR, 6 AP, 10 SI mm PTV margin with cord/carina matching the mean ITV surface coverage was 99.1 ± 3.8, 98.7 ± 4.3, 96.6 ± 6.0, and 94.5 ± 7.9% for 1, 3, 5, and 6 degrees of rotation, respectively. Coverage improvement was seen when matching ITV. Alternatively, Table 1 shows the percentage of fractions where at least 99% of the ITV was within the PTV for different PTV margins and image matching strategies.

Conclusions: We used deformable image registration to evaluate the effect of rotational error in lung IGRT. Our results show that rotational errors of 3 to 5 degrees have significant effect on target coverage in IGRT protocols where couch corrections are employed to match spinal cord/carina or ITV. These results represent a worst case scenario where the patient is misregistered by the given rotation about at least one axis for all fractions. Future analyses will introduce rotations based on their probability of occurring during a treatment course as measured from previously acquired patient data.

SP036.3 - Robustness Assessment of a Novel 4D Optimization Approach for Lung Cancer Radiotherapy

Purpose: Respiratory motion is one of the main challenges in treatment of lung tumours with radiation therapy. A novel approach was to develop IMRT treatment plans, which compensate for respiratory motion and its variations, by combining intensity maps from plans optimized on the “worst case” motion variation scenarios. The objective of this work was to test this worst case planning method on both simulated and patient respiratory motion variations.

Methodology: A 4D optimization approach was implemented using the KonRad inverse planning system. Two approaches to combining the 4D optimized intensity maps were investigated: the first approach takes the average of the two intensity maps and the second approach takes the maximum intensity of the two intensity maps. The robustness of these worst case plans was compared with ITV based plans and with 4D plans optimized for the nominal motion only on three different respiratory motion variation scenarios. Study 1 investigated the robustness to simulated amplitude variations. Study 2 investigated the robustness to respiratory motion variations measured from a healthy volunteer who was asked to breathe irregularly. Study 3 investigated the robustness to motion variations of a NSCLC patient. Plans were deemed robust if they met a set of pre-defined clinical criteria for all motion variation scenarios in a given study.

Results: The average intensity worst case method was robust to motion variations in Study 3 only, except that the target volume was slightly over-dosed for the nominal motion case (64.92 Gy). The average intensity approach was not robust to motion variations in Study 1 and 2, which we attribute to the larger variation which occurred in those studies compared to the patient case. The maximum intensity worst case method, the ITV plans and the nominal 4D plans
were not robust to any of the motion variations that were tested for all three studies.

**SP036.4 - The role of VMAT interplay effects for liver stereotactic body radiation therapy**

**Author(s):** Gillian Eccleston, Greg Pierce

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Stereotactic body radiation therapy (SBRT) is beneficial in the treatment of solid liver cancers as it safely delivers an ablative tumor dose. Volumetric modulated arc therapy (VMAT) is an ideal modality for hypofractionated treatment regimes such as SBRT as it can efficiently deliver a conformal dose. However, treatment accuracy becomes compromised for liver tumors due to their inherent respiratory motion. Clinicians have raised concerns when treating moving targets with VMAT because the tumor motion relative to the dynamically moving MLCs degrades the plan quality; a phenomenon termed interplay. The purpose of this study is to examine if the amount of beam modulation and breathing cycle length elicits interplay effects that influence plan quality for liver SBRT treated with VMAT.

VMAT treatment plans with varying degrees of modulation were constructed using Eclipse treatment planning software, version 11.0 (Varian Medical Systems, Palo Alto, CA). Respiratory motion was modeled using an in house program that shifted the MLC leaves in each plan to simulate the motion of the GTV from the point of view of the radiation beam. IMRT modulation factors (MFs) ranged from 1.5 to 3.5 and respiratory cycle lengths of 3, 5, 10 and 20 seconds were simulated for all plans.

Minor interplay effects were observed and deemed clinically negligible: the 95% dose coverage of the target was not compromised. A slight degradation in the plan quality (size of 95% isodose) was detected and worsened with longer respiratory cycle lengths and low MFs (Fig. 1). This is attributed to the variation in gantry speed that was coupled to the MF. For high MFs (slower gantry speed), more time was available for the tumor motion to average out during each control point and as a result reducing interplay.

We concluded in this limited phantom study that treatment plan quality of liver SBRT is degraded the least by plans with high modulation factors. Plan fidelity was maintained via few partial arcs (to obtain a slow gantry speed) and adequate PTV margins that accounted for respiration.

**Conclusions:** A novel approach to create robust IMRT plans has been tested and found to be robust to most patient respiratory motion variations. Further evaluation over a wide range of tumour sizes, motion amplitudes and variability is required to determine the clinical applicability of the worst case planning method.

**SP036.5 - Interplay of MLC, gantry and respiratory motion during DCAT delivery**

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This study investigated the possible interplay effects arising from the treatment of moving targets using the dynamic conformal arc therapy (DCAT) technique. Interplay effects are known to arise from the treatment of moving anatomy with dynamic wedges and intensity modulated radiotherapy (IMRT) beams. By contrast, volumetric modulated arc therapy (VMAT) treatment beams are currently regarded as largely immune to the effects of motion interplay. This difference potentially arises from the behaviour of multi-leaf collimator (MLC) leaves during IMRT and VMAT delivery, with MLC leaves that moving from one side of each beam to the other during IMRT delivery and MLC leaves frequently change direction throughout VMAT beam delivery. DCAT treatments of lateral targets, including the peripheral lung, often require the treatment isocenter to be displaced medially to avoid collisions between gantry and couch. In these circumstances, the MLC leaf motions in DCAT beams become similar to MLC motions in IMRT beams, moving in one direction from one side of the beam to the other. This situation leads to the concern that DCAT treatments might be more susceptible to motion interplay effects than an assumed similarity to VMAT treatments would suggest.

To investigate this issue, dose from a modulated test beam was measured, with and without phantom motion and with and without a 30° arc rotation, using a diode array placed on a sinusoidally moving platform. Measurements were repeated at five different collimator angles (0, 22.5, 45, 67.5 and 90°), at two different dose rates (300 and 600 MU/min), allowing the relative effects of leaf direction and leaf speed to be evaluated. When in use, the motion platform provided regular, longitudinal (superior-inferior), sinusoidal motion, with a 40 mm peak-to-peak amplitude and a 4 s period.

Results showed that the phantom’s respiratory motion produced blurring of the dose penumbrae and consequent reduction of the area receiving high-doses, as well as dose oscillations throughout the high-dose region, which became more obvious as the MLC motion was aligned with the phantom motion direction. The delivery of the modulated beams as 30° arcs increased the penumbral dose blurring, without reducing the appearance of dose oscillations across the phantom. The dose oscillations arising from interplay...
between phantom and MLC motion were found to increase in magnitude when the dose rate was increased from 300 MU/min to 600 MU/min, effectively halving the time taken to deliver each beam.

These results suggest that DCAT treatment beams may be affected by the interplay of MLC motion and patient respiratory motion, to a similar degree as static gantry IMRT treatment beams, rather than being similar to VMAT beams.

For DCAT beams, like IMRT beams, the negative effects of motion interplay may be minimized by aligning the collimator as close to perpendicular to the dominant direction of respiratory motion as possible, by decreasing the dose rate and thereby increasing the total delivery time of each beam, and by including appropriate margins on treatment targets so that dose blurring at the edges of the beam does not compromise tumour control.

**SP036.6 - Impact of deep inspiration breath hold (DIBH) in lymphoma’s radiation therapy treatment**

**Author(s):** Daniel Venencia, Jorge Torres, Cristina Pfaff, Carola Sanchez, Jonathan Pacheco, Lucas Caussa, Edgardo Garrigó

**Fisica Medica, Instituto de Radioterapia - Fundacion Marie Curie, Cordoba/ARGENTINA**

**Purpose:** Lymphoma treatments usually require radiation therapy of mediastinum and supraclavicular lymph nodes. Planning target volume (PTV) involves several organs at risk (OAR) such as lungs, heart and esophagus. The percentage of irradiated lung depends on the PTV and total lung volume. Deep inspiration breath hold (DIBH) increase the lung volume. The objective of this work was to evaluate the impact of DIBH in the treatment of lymphoma with radiation therapy.

**Methods and Materials:** A virtual treatment simulation was performed acquiring two computed tomography (CT) image series of the patient; the first one during DIBH and the second one with free breathing. Fiducials were placed on the patient’s anterior torso surface for CT image acquisition and then used for IGRT localization. CT images were exported to treatment planning system (TPS) iPlan v4.5.3 (BrainLAB). PTV and OAR were segmented in the DIBH CT series. Treatment plans were generated using sIMRT or IMRT treatment technique with a 6MV photon beam produced by a Novalis TX linear accelerator equipped with ExacTrac IGRT system with gating capability (BrainLAB). Using iPlan RT Adaptive tool, free breathing’s segmentation and plans were generated. Four patients were analyzed (3 sIMRT and one IMRT). All plans were normalized to have the same D95% at the PTVs. Comparison between lung volumes, dose volume histogram for PTV and OAR and monitor unit (MU) were done between DIBH and free breathing plans.

**Results:** DIBH lung volume increased in average 1997.7cc [1458.7, 2785.7]. Lung DVH comparison between DIBH and free breathing exhibits a decrease of 6.2% [5, 8.8] in V6, 5.5% [4.6, 7.7] in V10, 4.8% [3.1, 8.4] in V20 and 1.4% [-0.9, 3.7] in V30. The heart showed a mean dose reduction by 2.4Gy [-0.5, 8.7] and V10 by 8.6% [3.3, 33.0]. The esophagus did not show any significant dose variations. DIBH and free breathing plans did not show any differences in MU.

**Conclusion:** Treatment plans for mediastinal lymphoma planned on DIBH showed a dose reduction in lungs and heart. There is no change in the esophagus dose and MU used. Clinical impact of lung and heart dose reduction must by analyze.

**Table 1:** Comparing the accumulated D10cc of the robust and average methods using a set of simulated breathing patterns.

<table>
<thead>
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<th>Patient</th>
<th>Motion (cm)</th>
<th>Heart D10cc (cGy)</th>
<th>Mean RO benefit (cGy)</th>
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**Conclusions:** The robust optimization method can improve cardiac sparing in left-sided breast cancer IMRT, and it can potentially reduce the number of patients who need breath-hold treatments.
Conclusion

Real-time automatic marker position verification during VMAT using the MIR system is capable of detecting shifts in both static and dynamic targets, permitting reduced PTV margins for SBRT treatment with a high per-fraction dose. Automatic treatment interruption in the case of sudden excessive shifts can increase both treatment quality and treatment safety.
SP037 - Dosimetry in Nuclear Medicine

SP037.1 - Comparative Evaluation of Radiation Dose Rates in Cancer Thyroid Patients Treated with Variable Doses of Radioiodine

Author(s): Ajai Kumar Shukla, Dheeraj K. Tewari
Nuclear Medicine, SGPGIMS, Lucknow/INDIA

Cancer Thyroid patients after near total thyroidectomy are treated at our centre for radioiodine ablation using variable doses of radioiodine ranging from 3700 MBq to 7700 MBq. Initially the regulatory agency had fixed the discharge limits of 400 MBq at a distance of one meter from the patient and it usually involved a minimum isolation of about three days to decline the activity levels in patients to acceptable limits. However recently this discharge limit has now been increased to 1100 MBq and in order to see the effect of this change on the pattern of radiation levels and also on the time of discharge, the present study was undertaken on a total of 27 patients treated with doses of radiiodine I-131 ranging from 3700 MBq to 7400 MBq.

The radiation levels in uSv/hr at one meter in cancer thyroid patients (n=27) were observed to be below 50 uSv/hr on the second day itself which corresponds to about 1100 MBq residual activity. However in patients with metastatic lesions with avid concentration of I-131, the levels could decline below 50 uSv/hr only after three to four days after administration of I-131. The prolonged period taken in decline of the activity was also attributable to the fact that relatively larger amounts of activities upto 5550 MBq and in few patients 7700 MBq were administered. Prior to the change of the discharge limits the levels were used to take in some cases as more than seven days particularly in patients with metastatic lesions and administered with larger activities of the order of 5500 MBq to 7700 MBq. The prolonged isolation causes psychological trauma in some patients and therefore it was observed to be a big relief to the patients to have increased discharge limits which did not cause any significant safety related issues apart from treating more number of patients within the available infrastructure and number of isolation rooms. In addition it also enabled greater flexibility of dosing the patients with advanced disease conditions thereby reducing the overall cost of treatment.

It could be yet another school of thought to consider fractionation of doses of I-131 in those cases which needed more than seven days of isolation to prevent or minimize the risk of patient landing into extreme level of isolational stress.

SP037.2 - Estimation of the influence of other organs of the body in the determination of the gamma fraction energy emitted by iodine 131 deposited within the thyroid gland

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When treating hyperthyroidism using Iodine 131 and to facilitate and accelerate the computation time in the determination of internal dose within the thyroid gland, the shape, composition and volume of the thyroid tissue in this case is the only important factor to take into account.

This study aims to determine the fraction of energy of the gamma emission of the radioactive isotope Iodine 131 in the thyroid gland and the effect of the individual organs constituting the human body with the exception of the thyroid gland by using the geometry and material composition of each organ.

To determine the influence of the entire body, and hence its different constituting organs, on the calculation of the fraction of the gamma energy absorbed by the thyroid gland during the treatment of hyperthyroidism using iodine-131, we have performed simulations using the Monte Carlo Penelope code in the following two situations:

- Simulation of the entire body by a mathematical anthropomorphic phantom with simple geometric shapes and for this we used the example included in the Penelope code (male.geo file).
- The second situation involves simulating the thyroid gland alone.

Comparison of the results obtained by simulating the thyroid gland alone to those obtained by simulating the whole body shows a difference of 3% on average. The error in determining the dose by simulating only the geometry of the thyroid gland without involving the geometry of other organs of the body is estimated to 3%.

SP037.3 - Personalized compartmental biokinetic modelling and internal dosimetry of two novel radiopharmaceuticals

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Purpose The objective of this work is to develop personalized compartmental biokinetic models for two novel radiopharmaceuticals BAY85-8050 [1] and BAY94-9392 [2] to predict their distribution in the human body and associated patient-specific organ doses. We also aim to separately consider activities in organ parenchyma and blood in the modelling and dosimetry.

Methods The models are constructed based on clinical PET/CT images, blood and urine samples of 10 healthy volunteers [1,2]. Following an identifiability analysis of the developed models, model parameters were estimated using the commercial program SAAMII. Organ doses were calculated in accordance to the MIRD/ICRP formalism using specific absorbed fractions for photons and electrons previously simulated in the ICRP male and female reference adult computational phantoms.

Results The developed compartmental biokinetic model structure and the subset of the resulting biokinetic model predictions for BAY94-9392 are presented in Figs. 1 and 2, respectively. The corresponding figures for BAY85-8050 are not displayed here. The results showed a considerable inter-individual variability between the volunteers with effective dose coefficients of 0.016–0.018 mSv/MBq (BAY85-8050) and 0.011–0.018 mSv/MBq (BAY94-9392). We compared the personalized organ doses for two cases: (a) activities in organ parenchyma and in blood are separately modelled; (b) aggregate activities in perfused organs. For most organs the doses in case (a) were higher. Consequently, the average effective dose coefficients increased by 8.3% and 8.9% in case (a) for BAY85-8050 and BAY94-9392, respectively. Additionally, a strong influence of bladder-voiding intervals on the bladder-wall doses was demonstrated.

Conclusion The developed models can be used to estimate distributions and dose levels of two novel radiopharmaceuticals. The con-
siderable inter-individual variability helps to understand the intrinsic uncertainties when reference models are applied to individuals and justifies the advantage of personalized modelling approaches.

Clinical PET/CT centers due to high gamma energy of F18 using in 18F-FDG PET studies. The aim of this study was to evaluate the staff radiation dose in PET/CT department in Masih Daneshvari hospital.

Material and Method: during complete PET/CT imaging steps (from syringe filling to patient departure) the staff radiation dose was investigated with thermoluminescent dosimeter (TLD). The Hp(3) used for doses to the lens of the eyes and Hp(10) for doses to the whole body and Hp(0.07) for doses to the other part. For increasing the measurement accuracy, three chips of TLD used in each point of measurement. Result: the staff radiation dose were measured for work load of 53 adult patients who receive 374.28±100.30 MBq (range 127-540 MBq) 18F-FDG activity. The mean±SD total effective doses per unit of activity received by dispensing staff (n=3), imaging staff (n=5) and injection staff (n=2) were 4×10⁻⁴±5.77×10⁻⁵, 8×10⁻⁴±1×10⁻⁴ and 1×10⁻³±1×10⁻¹ µSv/MBq and received dose in eyes were 1.39×10⁻⁶±5.77×10⁻⁶, 0.87×10⁻⁶±1×10⁻⁴ and 3×10⁻⁴±1×10⁻¹ µSv/MBq as measured with TLD respectively. In this study, the finger radiation dose were higher for injection staff (7×10⁻⁶±1×10⁻¹ µSv/MBq) versus other radiation workers.

Conclusion: staff sensitive organs such as lens of eyes; thyroid and breast were received low dose in our PET/CT and cyclotron Centre. It is observed that the received radiation dose to radiation workers were below the dose limits recommended by the ICRP for all staff working in PET/CT department. This study confirmed that staff’s radiation doses in our PET/CT center were lower than those recommended by the ICRP guideline which can explain using semi-automatic injector, patient video monitoring and strong shielding performed in our center.

SP037.5 - Renewing the radiopharmaceutical accuracy check service for Canadian dose calibrators

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For a ten year period from 1986-1996, a small fraction of the Canadian nuclear medicine community participated in a service offered by the National Research Council (NRC) to check the accuracy of administered doses of radiopharmaceuticals. Similar programs exist in many countries and are of particular importance given the advent of new sources of medical isotope production anticipated to begin with the shutdown of the NRU medical isotope production in 2016. This service depends on the Secondary Standard Ionization Chambers Systems (SSIRCS) at NRC which is composed of a TPA and an NPL ion chamber coupled with an electrometer. These chambers were calibrated using radionuclidic artifacts standardized by primary methods.

These chambers have been in operation for several decades but were not operated for several years from 2001-2008 when the radionuclide metrology program ceased operations at NRC. A new data acquisition program (DAQ) was developed and new methods of determining the response of the ion chamber and electrometer were included to add redundancy and added assurance as to the calibration. Comparisons between the original and new DAQs were performed to provide validation to the chambers’ operation as well as continuity with measurements of radionuclidic artifacts still in the NRC inventory.

The original service involved the participant to measure the desired isotope in a syringe and 5 ml serum vial geometries in their dose calibrator and then send the sample to NRC to be measured in the SSIRCS and to permit an impurity check to be performed. In order to attract participation and simplify the process, the NRC is also offering an alternative service in which an ion chamber is sent to the facility, thus not requiring the shipment of isotopes, at the expense.

SP037.4 - TLD Measurement of Absorbed Dose of Workers in PET/CT Department

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Introduction: Staff radiation protection is the critical concern in
of an impurity check. The NRC conducted a mock service on two commercial dose calibrator models CRC-35R and CRC-ULTRA for Tc99m resulting in serum vial calibration coefficients that were consistent with unity to 1% (1.005 ± 0.006 (k=2)). The reference value delivered with the Tc99m dose from the nuclear pharmacy was determined to be 0.977 ± 0.006 (k=2) of the calibrated activity. While this is well within the recommended guideline of 10% of the required dosage, in most countries, it is significantly different from unity at the 95% confidence interval to warrant the application of a calibration factor, or to monitor this value on a regular basis to detect potential drift due to mechanical of physical changes to the ion chamber.

This work was important to assure the Canadian nuclear medicine community of the existence, validation and improvements of the SSIRCS at NRC and to provide confidence and encouragement in the participation of this proficiency testing service.

SP037.6 - Radiation Dose Assessment of 99mTc-labeled Tetrofosmin in Patients Undergoing Rest-Stress Myocardial Perfusion Scintigraphy

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Purpose: Tetrofosmin labeled with technetium-99m (99mTc) is a myocardial imaging agent. The goal of this research is to evaluate the differences between two methods for assessing radiation dose: internal dosimetry by using a dose calculation program and an analytical model based on patient’s weight.

Materials and Methods: A biodistribution of 99mTc-Tetrofosmin as reported in the literature was used in OLINDA/EXM-1.0e to estimate patient-specific absorbed and effective radiation doses on 91 adults (33 female, 58 male) who were undergoing 99mTc-Tetrofosmin 8 mCi-rest/17 mCi-stress myocardial perfusion imaging. The dosimetry results were compared to the values calculated from scaling by patients’ weight, the effective dose for overweight patients are underestimated, more for female patients than for male patients because ICRP values correspond to an adult male. These underestimations are an important factor to consider if an approach based on differences in patient’s weight is used to adjust the amount of activity to be administered.

Results: The mean effective doses estimated by dosimetry in female patients were 3.46 mSv and 5.91 mSv at rest/stress respectively. In male patients the mean effective dose estimated by dosimetry was 2.87 mGy at rest and 4.86 mGy at stress. For male and female patients of the same weight the dosimetry shows that the women’s effective doses are about 17% higher than for men. The effective doses estimated in patients with a weight of 100 kg by the analytical method differed from those based on dosimetry up to 40% in women and 30% in men at rest and 35% in women and 25% in men at rest.

Conclusions: Even though the standard ICRP dose values are scaled by patients’ weight, the effective dose for overweight patients are underestimated, more for female patients than for male patients because ICRP values correspond to an adult male. These underestimations are an important factor to consider if an approach based on differences in patient’s weight is used to adjust the amount of activity to be administered.

SP037.8 - Biological Excretion and Half - Life of Remnant Radioactive Iodine 131I in Post Treated Hyperthyroidism Patients.

Objective: Following 131I treatment of hyperthyroidism; remnant activity is depleted by physical decay and bio-excretion. ICRP estimated 131I biological half-life as (138d-1960), (120d-1979), (80d-1989). This work assesses semi-empirical bio-excretion models and estimates biological half-life of post treated hyperthyroidism patients.

Patients and Method: 17 hyperthyroidism adult patients were treated with 131I (185-740MBq) depending on hyperthyroidism condition. Thyroid scans were possible by pinhole gamma camera; one and two months post 131I therapy utilizing remnant activity.

Semi-empirical excretion models developed were:

1. fixed amount \( \Gamma a(c/s)=\text{ln}([\text{In}/\text{Io}])*[(1-\text{exp}(-\lambda T))/\text{Io}] \)

2. fixed fraction \( \Gamma f=\text{exp}(-\lambda T)/\text{Io} \)

3. exponential \( \Gamma e=\lambda T \)

Bio-excretion/effective decay = (ln(In)/ln(Io)-Tp/Te, \( \lambda \) and \( T \) are: initial and \( n \)th day activity (c/s), decay coefficient \( \lambda =0.693/T, T=\text{half life} \) respectively, physical, biological and effective.

Results and Discussion: Sample series of thyroid scans are shown in (Fig.1):(A)\( ^{99m}\text{Tc} \) scan pre-treatment;(B)\( ^{131}\text{I} \) scan one month post-treatment, (C)\( ^{99m}\text{Tc} \) scan two month post-treatment, and (D)\( ^{99m}\text{Tc} \) scan six months post-treatment.

A semi logarithmic graph of relative \( \text{In}/\text{Io} \) versus time (d) showed linear relationship of \( ^{131}\text{I} \) remnant activity effective decay and physical decay (Fig.2), slope=0.693/TE=0.103, \( R^2=0.895 \), and slope=1, \( R^2=1 \) respectively. Accordingly, \( T \text{E}=6.73d, T_b=41.0d \). Calculated \( T_b \) average value=40.7±21.4d.
Measured bio-excretion of $^{131}$I contributes 3.5% of effective decay as compared to 96.5% for physical decay. Fixed amount model predicts ~9.3% bio-excretion; not significant with measured values. Fixed fraction and exponential models predict bio-excretion factor $=0.021$ of activity/day ($=0.25$ physical decay factor $=0.083$ of activity/day); significant with measured values.

We conclude that emitted radiation from remnant $^{131}$I will destroy thyroid functioning cells, reducing their ability to produce and excrete hormones, and hence increase biological half-life. Thyroid cells will be subjected to radiation hazards (beta and gamma) for 10 physical half-lives $=80$ days (remnant activity $=0.1\%$ of initial value). Caution is required with pregnant and breast feeding women.

**SP038 - Dosimetry of Non-Standard Fields**

**SP038.1 - Determination of small photon field quality correction factors using EBT3 radiochromic film**

*Author(s):* Ilias Billas, Hugo Bouchard  
Radiation Dosimetry, National Physical Laboratory, London/UNITED KINGDOM

With the upcoming IAEA-AAPM reference dosimetry protocol on small photon fields, quality correction factor data is needed. To determine these factors accurately, Monte Carlo methods are used but reliable experimental methods remain under investigation. Among the different detectors recommended by IAEA-AAPM for such conditions, radiochromic film remains promising with its high resolution and water-equivalence. However, current methods and film models available commercially (EBT3) focused on clinical applications do not meet the accuracy standards of reference dosimetry, contrary to previous models as shown in literature. The goal of this work is to develop a reliable approach for radiochromic film dosimetry, reaching 0.5% statistical uncertainty on relative pixel dose with EBT3 and reducing systematic errors caused by film thickness inhomogeneity.

An original multichannel method is developed based on a simple 2D model of the film response to dose and thickness and statistical analysis of the calibrated film. Gafchromic EBT3 films are irradiated with cobalt-60 beams homogenously, allowing obtaining parameters for scanner homogeneity correction, multichannel analysis and dose response calibration. Software is developed for film characterization and analysis. Dose distribution measurements are compared to reference data and an uncertainty budget is made to quantify the performance of the method in correcting systematic errors in film response. Based on the analysis, conditions to achieve 0.5% uncertainty in relative measurements are determined. Systematic errors are compared to the statistical behaviour of pixel dose.

Comparing single and multichannel methods, it is demonstrated that the proposed method reduces systematic errors significantly. The method allows uncertainties in output factors of 1.2% for single measurements and 0.4% for measurements repeated ten times. Comparisons with known dose distributions show systematic errors up to 10% with single channel analysis, while they are on average diminished by a factor up to three and well below statistical uncertainties with the multichannel method. The figure shows a comparison of the methods in measuring a $10 \times 10$ cm$^2$ cobalt-60 beam profile: a beam profile (left) and a dose map (right).

Results suggest that a controlled experimental procedure and proper analysis yield great potential for small photon field dosimetry using radiochromic film, with uncertainties in quality correction factors comparable to previous film models. It is expected that future experiments with small photon fields will validate the theoretical predictions reported herein.
The upcoming IAEA-AAPM protocol for dosimetry of small photon fields is expected to improve the calibration of such beams, benefitting patient safety and treatment outcome. As a complement to such procedures, a clear presentation of the main effects responsible for large detector correction factors is highly valuable. The physics of small fields is a rather complex subject and has not yet been treated in the literature in a conceptually sound manner. Hence, confusion over the limitations of dosimetry protocols in small fields still exists. The present study aims to provide a comprehensive explanation why dosimetry of megavoltage small photon fields can require significant quality correction factors.

Several concepts are reviewed from a theoretical point of view. The applicability of cavity theory to small fields is described, and a simpler cavity theory is proposed. The concept of charged particle equilibrium (CPE) and its impact on dosimetry is evaluated in detail. The perturbations caused by the presence of a detector are also analysed thoroughly. Four main effects are identified and related to detector characteristics: 1) the density of the cavity material, 2) the atomic properties of the cavity material, 3) the presence of extracameral components and 4) volume averaging effects. The theory is supported by a series of Monte Carlo calculations characterizing detector response to pencil photon beams.

The analysis and results presented here clarify several misconceptions in some of the existing literature on small field dosimetry. Evaluation of the four perturbation effects indicates that significant correction factors arise mainly from the interplay between lack of CPE and cavity density. New Monte Carlo results as well as key publications on the topic strongly support this conclusion. Figure 1 shows simulated detector dose response to a pencil beam under Fano’s conditions, and illustrates the interplay between lack of CPE and cavity density.

This study presents an analysis of the physics of small field dosimetry and allows in-depth clarification of the reasons for significant quality correction factors in megavoltage small photon fields. It is expected to be a valuable complement to the upcoming dosimetry protocol which mainly focuses on the technical aspects of small field dosimetry.

Figure 1. Dose response of a cylindrical cavity, 1 cm diameter, to a 1.25 MeV monoenergetic photon pencil beam, as a function of beam distance from the cavity axis. Calculations are performed using Fano calculations so that the integral of the curve is independent of the cavity density.

### Table 1: Summary of the difference between TG 148 and UK protocols

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<th>Output (cGy/min)</th>
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A new facility to support the adaptation of reference dosimetry in the presence of strong magnetic fields

Author(s): Simon Duane, James Manning, Giuseppe Schettino, Hugo Bouchard

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Novel technology integrating MRI with the delivery of megavoltage photon radiotherapy promises unique advantages for image guidance. At MRI strengths, magnetic fields can have a significant impact on the dosimetry. To calibrate these new machines, detector dose response must be thoroughly investigated and validated data must be available. However, it remains a challenge to isolate the effect of the magnetic field on dosimeter response. While alanine is a promising nearly water-equivalent detector, its potential as a reference dosimeter in the presence of a strong magnetic field has yet to be demonstrated experimentally.

A new experimental facility, unique among standards laboratories, is set up using a dipole magnet with field strengths up to 2 T in a cobalt-60 beam (see figure). The EPR response of nine 2.4 mm alanine pellets in a 2 x 2 x 2 cm³ mini-phantom, irradiated to 20 Gy in 0 T and 2 T fields, is evaluated repeatedly to assure optimal precision. The effect of the magnetic field on absorbed dose to water is determined using a limit approach combining Monte Carlo data and the magnetic field-independence of kerma.

The uniformity of the pellet dose is consistent with expectations given the stack orientation being parallel to the magnetic field and perpendicular to the beam. Doses are averaged for inner pellets, away from the phantom edges. The dose correction in water and its type B uncertainty are estimated from existing Monte Carlo data. The correction kQB,Q0 varies from 0.9897 to 0.9978 over the pellets, with a standard deviation of 0.0030. This gives a mean quality correction factor of 0.9955 with a combined uncertainty of 0.0035 (k=2) at 2 T. This result is consistent with the alanine dose response being only slightly affected by the 2 T magnetic field. It is demonstrated alanine has the potential to serve as a reference detector for the experimental determination of magnetic field quality correction factors.

Combined with alanine/EPR dosimetry, the new experimental facility has the capability of validating Monte Carlo data of detector response in strong magnetic fields. This is expected to impact the robustness of future reference dosimetry protocols adapted for use with MRI-guided radiotherapy machines. Future work includes determining the response of alanine in a wide range of field strengths as well as the characterization of this effect on other detectors.

Figure: Experimental setup: a BEV of the magnet, and the configuration in the cobalt-60 vault.
SP039 - ECG

TRACK 09: BIOSIGNAL PROCESSING

SP039.1 - Improved T-wave Alternans Detection in ECG Signals

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T-wave alternans (TWA) is a pattern in electrocardiogram (ECG) signals characterized by two distinct forms of T-waves appearing in alternation, at a patient’s heart rate in the range of 90 to 120 beats per minute. There exists a relation between the amount of TWA, the heart rate at which it appears, and the risk of sudden cardiac death (SCD). Therefore, it is important to develop better methods to detect TWA in ECG signals.

In this paper, we enhance an existing method for detecting TWA in ECG signals. We reduce the noise in the ECG signals adaptively by using dual-tree complex wavelet transform (DTCWT). Our method for detecting TWA is based on the Matlab code of the champion (Jubair Sieed) in the 2008 TWA challenge. We modified his Matlab code in a number of ways as shown in the full paper. We briefly describe the steps of our proposed method for detecting TWA in ECG signals here:

1) We perform moderate filtering to the input ECG signal x(t), just as the original method.
2) Apply wavelet denoising to every ECG signal adaptively. 
3) We find the R-peaks in the filtered ECG signal.
4) We calculate the T-peaks and their amplitude. 
5) We find the TWA waveform. We use the median instead of the maximum for the T-wave magnitude of each lead.
6) We calculate the T-wave magnitude of the whole ECG signal with multiple leads. 

In our experiments, we select to use the ECG signals provided by the 2008 TWA challenge, which contains one hundred multi-channel ECG records sampled at 500 Hz with 16-bit resolution over a ±32 mV ranges. We perform comparisons among our proposed method and three existing methods, developed by Jubair Sieed, Renata Simoliunine, and Mahdi Zarrini. They have posted their Matlab codes on the 2008 TWA website. We select four metrics for measuring the quality of the detected T-waves: Spearman rank correlation coefficient, Kendall rank correlation coefficient, root-mean-square-error (RMSE), and cross correlation (CC). From Table 1, it can be seen that our proposed method performs the best, compared to the three existing methods.

<table>
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**SP039.2 - Electrical Left Atrial Conduction Delay with Focused Transesophageal Electrocardiography in Cardiac Resynchronization Therapy**

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Cardiac resynchronization therapy (CRT) is an established biventricular pacing therapy in heart failure patients with left bundle branch block and reduced left ventricular ejection fraction, but not all patients improved clinically as CRT responder. Purpose of the study was to evaluate electrical left atrial conduction delay (LACD) with focused transesophageal electrocardiography in CRT responder and CRT non-responder.

**Methods:** Twenty heart failure patients (age 66.6±8.2 years; 2 females, 18 males) with New York Heart Association functional class 3.0±0.3 and 174.2±40.2ms QRS duration were analysed using posterior left atrial transesophageal electrocardiography with hemispherical electrodes. Electrical LACD was measured between onset and offset of transesophageal left atrial signal before implantation of CRT devices.

**Results:** Electrical LACD could be evaluated by bipolar transesophageal left atrial electrocardiography using TO Osypka electrode in all heart failure patients with negative correlation between 54.7±18.1ms LACD and 24.9±6.4% left ventricular ejection fraction (r=-0.65, P=0.002). There were 16 CRT responders with reduction of New York Heart Association functional class from 3.0±0.2 to 2.1±0.2 (r=0.522, P=0.038) during 9.4±10.9 months CRT. There were 4 CRT non-responders with no reduction of New York Heart Association functional class from 3.0±0.4 to 2.8±0.5 (r=0.816, P=0.184) during 13.8±16.3 months CRT. Electrical LACD correlated negative with left ventricular ejection fraction between 75.25±19.17ms LACD and 20.75±6.4% left ventricular ejection fraction (r=-0.831, P=0.169).

**Conclusions:** Focused transesophageal left atrial electrocardiography can be utilized to analyse electrical LACD in heart failure patients. LACD correlated negative with left ventricular ejection fraction in CRT responders. LACD may be a useful parameter to evaluate electrical left atrial desynchronization in heart failure patients.

**SP039.3 - Electrical Interventricular to Interventricular Conduction Delay Ratio with Focused Transesophageal Electrocardiography in Cardiac Resynchronization Therapy**

**Author(s):** Matthias Heinke¹, Gudrun Dannberg², Tobias Heinke³, Bruno Ismer³, Tobias Haber³, Jonas Tumapos³, Helmut Kühnert³

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Cardiac resynchronization therapy (CRT) is an established class I level A biventricular pacing therapy in chronic heart failure patients with left bundle branch block and reduced left ventricular ejection fraction, but not all patients improved clinically. Purpose of the study was to evaluate electrical interatrial conduction delay (IACD) to interventricular conduction delay (IVCD) ratio with focused transesophageal left atrial and left ventricular electrocardiography.

**Methods:** Thirty eight chronic heart failure patients (age 63.4±10.2 years; 3 females, 35 males) with New York Heart Association (NYHA) functional class 3.0±0.2 and 171.7±36.17ms QRS duration were analysed using posterior left atrial and left ventricular transesophageal electrocardiography with hemispherical electrodes before CRT. Electrical IACD was measured between onset of P-wave in the surface ECG and onset of left atrial signal. Electrical IVCD was measured between onset of QRS complex in the surface ECG and onset of left ventricular signal.

**Results:** Electrical IACD and IVCD could be evaluated by transesophageal left atrial and left ventricular electrocardiography in all heart failure patients with correlation to 1.18±0.92 IACD-IVCD-ratio (r=-0.57, P<0.001; r=0.66, P<0.001). There were 32 CRT responder with reduction of NYHA class from 3.0±0.22 to 1.97±0.31 (P<0.001) during 16.5±18.9 month CRT with 75.19±33.49ms IACD, 78.91±24.73ms IVCD, 1.04±0.66 IACD-IVCD-ratio and correlation between IACD and IACD-IVCD-ratio (r=0.84, P<0.001). There were 6 CRT non-responder with no reduction of NYHA class from 3.0±0.3 to 2.9±0.5 during 14.3±13.7 month biventricular pacing, 50.0±28.26ms IVCD (P=0.014), 1.92±1.65 IACD-IVCD-ratio (P=0.029) and correlation between 67.0±24.9ms IACD and IACD-IVCD-ratio (r=0.85, P=0.031).

**Conclusions:** Focused transesophageal left atrial and left ventricular electrocardiography can be utilized to analyse electrical IACD and IVCD in heart failure patients. IACD-IVCD-ratio may be a useful parameter to evaluate electrical left cardiac desynchronization in heart failure patients.

SP039.4 - Analytical geometry based parameters for studying repolarization variability in patients with myocardial infarction

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Myocardial infarction (MI) is one of the leading causes of mortality throughout the world [1]. About 69,000 Canadians and 600,000 people in the United States die as a result of heart attack every year [2]. The myocardium cells of the heart are altered in ventricular repolarization after MI. Thus, studying variability in ventricular repolarization on a beat-by-beat basis has gained significant interest from clinicians and basic scientists. Indeed, the T-wave in the ECG signal refers to the ventricular repolarization and is believed to be a predictor for the risk of ventricular arrhythmias [3]. However, the beat-to-beat repolarization variability in MI patients has not been fully understood. Therefore, the purpose of this research is to study the beat-to-beat repolarization variability and to assess the predictive capabilities of geometry based parameters for studying repolarization variability in MI patients (79 patients) compared to healthy subjects (69 subjects). To study the beat-to-beat repolarization variability, we extracted some geometrical based T-wave parameters [T-wave amplitudes (h), distances between Q-wave onset to T-wave max (Q2Tmax), angles between T-wave max and T-wave end with respect to Q-wave (TmaxQTend)] as shown in Figure 1. The detailed methodology have been described in our recent article [3]. We quantified the standard deviation of the extracted parameters as a marker of repolarization variability, respectively for both MI patients and healthy subjects. Beat-to-beat repolarization variability (in all three extracted parameters) was found to be significantly higher in MI patients compared to healthy subjects. In conclusion, this research shows that the geometrical based parameters for repolarization variability may provide markers for separating MI patients and healthy subjects.

**References:**

1. The top 10 causes of death. 2013, World Health Organization.

SP039.5 - Acute Mental Stress Detection via Ultra-short term HRV Analysis

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Acute mental stress reduces working performances and it is one of the first causes of cognitive dysfunctions, cardiovascular disorders and depression. Stress detection via short-term (5 minutes) Heart Rate Variability (HRV) analysis has been widely investigated in the last years. Recent improvements in wearable sensing devices and mobile computing raised a new research question: is ultra-short (2 minutes) HRV analysis as effective as the short-term
analysis to detect mental stress? This study aimed to answer this research question.

**Methods:** Short and ultra-short HRV analysis were compared in 42 healthy subjects (age 25–38 year) undertaking the widely adopted and highly-effective Stroop Color Word Test (CWTT). HRV was extracted by ECG signals recorded during rest and stress session using a chest wearable monitoring device, the BioHarness M3 (ZephyrTech, NZ). According to previous literature on HRV and mental stress, 18 HRV measures were extracted and analyzed using validated software tools. However, among the 18 HRV measures, only those that changed significantly in the short-term were also investigated in the ultra-short term analysis. Variations in HRV measures in short and ultra-short term were compared using the statistical Wilcoxon significance test, because several measures were not normally distributed.

**Results:** The results of the current study proved that among the 18 HRV measures investigated, 10 HRV measures resulted significantly changed in the short-term analysis during mental stress. Among such 10 HRV measures, only 6 HRV measures presented a consistent behavior in the short and ultra-short registration: Mean RR, Low Frequency power (LF), Sample Entropy (Sampen), Short term and Long term fluctuation slope of Detrended fluctuation analysis (df01, df02) and Mean line length of Recurrence plot analysis (RPlmean). Particularly, Mean RR and df01 significantly increased during stress, while the other significantly decreased. In contrast, the remaining 4 HRV measures, changed significantly in the 5 min analysis but not in the 2 min analysis, although the trends were consistent. In fact, the ratio of LF and High Frequency power (HF) resulted increased during stress, while Correlation dimension (D2), Recurrence rate (REC) and Shannon Entropy (ShanEn) decreased. This can be explained by the fact that in less than 5 minutes the number of RR recorded is too low in order to observe significant changes. This can be verified enrolling more volunteers.

**Conclusion:** The current study showed that among the 18 HRV measures investigated, 10 resulted significantly changed during mental stress. However among those, only 6 changed consistently both in the short and ultra-short HRV analysis, while 4 resulted to be not significant in ultra-short term. This evidence suggested that in the shift from short to ultra-short HRV analysis, not all the features can be equally used and therefore further studies are needed to prove that HRV measures change significantly even during stress in the ultra-short term.

SP039.6 - Classification of Abdominal Fetal Electrocardiogram Recordings using Karhunen-Loève Decomposition

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Maternal abdominal ECG acquisition is a non-invasive technique not usually common in clinical practice but with a growing interest since it could provide enough information to explore the cardiovascular condition of the fetus after the 20th week of gestation. Since the maternal and fetal cardiac activities are combined in the ECG signal, several challenges have to be surmounted to obtain a useful fetal ECG signal from the maternal abdominal ECG like the overlapping observed in time and in frequency of both components and the low signal-to-noise ratio of the signal. In the present study, the maternal and fetal activities were exploited through the decomposition of maternal abdominal ECG recordings using the Karhunen-Loève (KL) transform. Then, several feature sets extracted from the KL decomposition and from the ECG signal were combined in support vector machines classifiers to detect the presence and absence of a maternal and/or a fetal QRS complex from ECG segments of 250 ms duration. Results show that a fetal QRS complex was well detected when there was not overlap with a maternal QRS (sensitivity 88.8%, specificity 97.1%) while detection diminished somewhat when overlapping was present (sensitivity 90.7%, specificity 75.9%). Detecting maternal activity using the KL decomposition was a relatively simple task; the main goal of detecting the fetal activity was effectively achieved when the fetus activity occurred in isolation, but was a more difficult task when accompanied by temporally adjacent maternal activity.

SP039.7 - Dictionary Learning Algorithms For The Application Of Ventricular Arrhythmia Classification.

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**Background:**

The classification of cardiac arrhythmias such as ventricular tachycardia (VT) and ventricular fibrillation (VF) has been an important research topic in the signal processing field due to its lethal effects. Therefore, it is important to classify arrhythmias to deliver the appropriate treatments and prevent sudden cardiac arrests. Researchers presented an automated algorithm that express non-stationary signals by decomposing them into a linear expansion of different known mathematical functions that are well localized in both time and frequency domains. A family of the mathematical functions (atoms) creates a dictionary; the choice of the dictionary plays an important role in an accurate representation. Hence, researchers developed dictionary learning algorithms to create a learned dictionary using a training data to adapt its content to the given signals such that it provides a better approximation from an over complete redundant dictionary. In this work, due to the non-stationary nature of the electrocardiogram (ECG) signals during an arrhythmic event, these existing algorithms were used to classify between VT and VF signals using the dictionary learning algorithm LC-KSVD. Nine hundred and forty four surface ECG signal segments (four seconds each) from the MIT-BIH database were used for the classification derived from twenty three VF signals and ten VT signals.

**Methodology:**

The dictionary learning algorithm that is used in this study is called label consistent K-SVD. In the LC-KSVD algorithm, a discriminative dictionary is learned for sparse coding. It uses a class label of a training data as well as it associates label information with each dictionary item to enforce discriminability in sparse codes during the dictionary learning process (same class signals has similar sparse coding). Furthermore, it uses a label consistency constraint called “discriminative sparse-code error” and combines it with the reconstruction error and the classification error to form an objective function. The optimal solution of the objective function is efficiently obtained using the K-SVD Algorithm. This algorithm learns the dictionary, discriminative coding parameters, and classifier parameters for optimal linear classifier simultaneously.

**Results and Conclusion:**

Based on our analysis using the LC-KSVD algorithm to train an over complete hybrid dictionary consisting of cosine, symlet4, daubechies4 wavelet atoms, we were able to classify the VF and VT signals with an average of accuracy of 70.8% using LDA classifier. The results were validated with four fold cross-validations.
SP040.1 - Working to live: The use of field studies and simulations to make workplaces safer

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Working to live: The use of field studies and simulations to make workplaces safer

Employers want to reduce accidents and overuse injuries amongst their workers but often they don’t possess the required tools and information so they need to turn to research for answers. From a research perspective, first you need to understand the problem and then you can design a solution that will have the greatest impact in reducing or eliminating the problem. This can be accomplished through a combination of field and laboratory studies. To illustrate this I will present results from a series of laboratory and field studies designed to assess and solve occupational problems primarily amongst operators of heavy mobile equipment.

The thought process and studies that went into the design and development of a heavy equipment dynamic armrest will be described. The armrest was designed to translate and rotate in order to mimic natural pendulation of an operator’s arm thus minimizing upper limb and neck muscle activity as they operate joystick controls.

Results from a comprehensive field study which concurrently assessed the biomechanical and physiological requirements of overhead crane cab operation in a steel mill will be discussed as will the companion study which utilized the results of the field study to set up a laboratory based simulation in order to determine if a camera based system could reduce musculoskeletal loading in the trunk, arms and neck for crane cab operators by allowing them to maintain a more neutral posture.

The final set of studies I will discuss describe the results of a series of field to lab to field methodologies developed to intelligently retrofit seats used in steel manufacturing mobile equipment in order to minimize operator exposure to whole-body vibration. When companies retrofit machines, seats are usually selected and implemented without an evaluation process based on actual machine and/or terrain specific vibration inputs to assess seat efficacy. In general, operators test and choose seats from a showroom rather than testing them in operating machines. Our research team utilized a person rated hexapod robot simulator to replicate field-based machine specific vibration to evaluate several commercially available seats to identify the best seat for the workplace application. The selected seat was successfully introduced back into the workplace resulting in reduced vibration exposure and improved worker comfort.

Finally, I will talk briefly about some of the ongoing work with our new driving and hexapod robot heavy equipment simulator facilities which bring together a multidisciplinary team of researchers from engineering, computer science and psychology.

SP040.2 - Pitch movement acceleration measures during the practice of virtual games in adolescents with Down syndrome

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I. INTRODUCTION

Adolescents with Down syndrome (DS) present a range of motor difficulties. Therefore they do not specify a temporal-spatial pattern of muscle contractions, causing major difficulties to perform a task in time.

The Virtual Reality (VR) has been regularly used as a method of physical rehabilitation, which is based on the use of virtual games in order to enable the function of people with several types of disabilities.

The Nintendo® Wii™ console is the most used in the virtual rehabilitation of people with multiple disabilities.

The accelerometry has been used to establish measures of human movement, since it is an inexpensive, effective and feasible method, which has been widely used in scientific researches.

II. OBJECTIVE

Evaluating the characteristics of movement acceleration of upper limbs for adolescents with DS and adolescents with typical development, by playing bowling and golf of Nintendo® Wii™.

III. CASE STUDY AND METHOD

The study evaluated 21 adolescents diagnosed with DS (FDSG and MDSG) and 33 with typical development (FCG and MCG), of both genders (F and M), aged between 10 and 14. The data was gathered by using wireless capacitive triaxial accelerometers.

IV. RESULTS

For the data analysis, four groups were submitted to normality adherence tests, separate by gender.

A. Bowling game

In the significance level of 10%, there was adherence to the normal distribution of the maximum peaks of acceleration obtained by the four groups. The Medium acceleration per group were: FCG 70.51; MCG 70.37; FDSG 37.24; MDSG 45.33.

It was concluded that the groups presented significant statistical differences, with higher peaks of acceleration for MCG and FCG when they are compared with MDSG and FDSG.

B. Golf game

In the significance level of 10%, there was adherence to the normal distribution of the maximum peaks of acceleration, obtained by the three groups (FCG, MCG, FDSG). In the significance level of 10% there was no adherence to the Normal Distribution of the maximum peaks of acceleration for MDSG. The Medium acceleration per group were: FCG 56.80; MCG 74.80; FDSG 30.52; MDSG 45.12.

It was concluded that the groups presented significant statistical differences, with the highest peak of acceleration for the boys group, which had superior average compared to the girls group, observed in both MCG and FCG, as well as in MDSG and in FDSG.

V. CONCLUSIONS

By efficiently using the accelerometry, it was possible to evaluate...
the characteristics of the movement acceleration of the superior limbs of the population diagnosed with DS during the virtual bowling and golf games, using the Nintendo® Wii™ console. It was observed a better performance in every single evaluation for the control group, having lower acceleration in the movement of adolescents with DS. It was concluded that the use of Nintendo® Wii™ associated with the accelerometry technique may be an effective resource to evaluate movement acceleration patterns in population with DS.

**SP040.3 - Movement Training and Assessment with 3D Virtual Reality for Parkinson’s Disease Patient**

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Balance problems such as inability to maintain stability and postural transition are common in patients with Parkinson’s Disease (PD). In clinical, visual cues are used as rehabilitation program in improving postural stability. Ball catching movement is considered a kind of suitable training program for PD patients because of its characteristics of eye-hand-foot coordination. Furthermore, studies have shown that optical flow could provide motion perceptions and improve movement performance of PD patients. The purpose of this study was to develop a 3D virtual reality (VR) training system for providing optical flow information during catching virtual balls under standing and one-step forward movements for subjects with PD. Fifteen PD participants were recruited from local medical center. The effects of optical flow on postural stability were evaluated by standing and one-step forward task using our 3D VR system providing virtual catching ball with and without optical flow. The arm-trunk movement and trunk movement were utilized as the assessment indices of balance and postural control by inertial sensors attached on waist and bilateral of wrists. Our results showed better arm-trunk coordination and higher similarity of arm symmetry with smoother movement pattern, greater trunk sway, and better postural stability index under the standing task with optical flow. Moreover, PD patients also spent substantially less duration prior to gait initiation and achieved greater inclination angle on one-step forward task. The balance training system accompanied with evaluation system demonstrated that arm-trunk control and balance on ball catching performance of PD patients could be improved with optical flow information.

**Keywords:** Parkinson’s disease, virtual reality, balance, optical flow

**SP040.4 - Arm angle detection in egocentric video of upper extremity tasks**

**Author(s):** Jirapat Likitlersuang, José Zariffa Institute Of Biomaterials And Biomedical Engineering (ibbme), University of Toronto, Toronto/ON/CANADA

**Background:** Upper limb function is fundamental to most activities of daily living (ADL), and can be dramatically impaired after neurological injuries, such as spinal cord injury. Currently there is no viable method to assess and monitor hand function once the patient has returned to the community after rehabilitation. Our solution is to track hand use in the community by developing a computer vision (CV)-based wearable sensor using egocentric cameras, in order to capture information about a person’s level of independence and reliance on attendant care. Such a system needs to be able to differentiate object manipulations performed by the user from those performed by a caregiver, as well as the user’s right and left hands. The angle of the arm in the video is important in this classification. Here we describe and compare three methods for detecting arm angles in egocentric view. **Methods:** Following hand detection, Method I uses a Haar-like feature to compare the contents of a rectangle extending from the hand to two parallel rectangles on either side, rotating these through 360 degrees range. Method II is based on Hough line transforms and attempts to determine which of the detected lines passing though the hand correspond to the edges of the sleeve. Method III detects the contour of the sleeve based on a colour histogram obtained through a calibration step. A least squares fit is then applied to the detected sleeve to determine the angle of the arm. The three methods were tested by comparing their output to manually measured angles, in 120 frames of recorded egocentric video consisting of 4 ADLs from 3 different able-bodied subjects. **Results:** Based on absolute error, Method III was shown to have the best performance with a mean absolute error of 23.70 ± 22.89 degrees. This was followed by Method I with the mean absolute error of 34.79 ± 38.48 degrees and Method II with the mean absolute error of 68.76 ± 58.01 degrees (Fig. 1). **Conclusion:** While Method III had the smallest error, it required a calibration step to determine the colour of the sleeve, and this makes this method less practical compared to Method I, which does not require any calibration and still had a comparable error. We have demonstrated that a Haar-like feature method can easily be integrated with hand detection to determine arm angle in an egocentric CV-based wearable sensor for detecting hand usage at home.

**SP040.5 - Development of an image-based calibration technique for use with non-ideal postures in the assessment of kinematics using wearable sensors**

**Author(s):** Jan Andrysek, Monica D. Gomez Institute Of Biomaterials And Biomedical Engineering, University of Toronto, Toronto/ON/CANADA

**Introduction:**

Wearable sensors are emerging low-cost alternatives to expand the current gold-standard camera-based assessment of kinematics, allowing for measurements in real-life conditions and environments. MVN BIOMECH Awinda system is an example of a commercial wearable sensor system used to analyze whole body kinematics. However, to calibrate the device, an ideal upright position known as “Neutral Posture,” or “N-Pose,” must be attained. Hence, these sensors have limitations in the rehab field where muscle weakness, bone deformity, sensory loss, pain or impaired control hinders or makes it impossible to attain N-Pose. Developing a calibration technique that adjusts the model to account for actual orientation and position of body segments, versus the assumed N-Pose, will improve the estimation of kinematics. Therefore, this study aims to produce calibration parameters which will be used to adjust the "N-
Pose”. Here, Kinect sensor is used to extract body segment lengths, knee, hip and ankle angles as the calibration parameters.

**Research Objectives**

**Obj.1** Understand how non-ideal calibration postures affect the accuracy of lower body kinematics estimation.

**Obj.2** Develop an image-based calibration technique using Kinect to acquire calibration parameters.

**Methods**

**Obj.1** A pilot study was conducted to assess the accuracy of knee and ankle angles in the sagittal plane of a participant’s gait. The MVN BIOMECH Awinda system was used to measure patient’s kinematics after calibrating the system with (a) the N-Pose and two non-ideal calibration postures: (b) bent knees and (c) standing on tip-toes.

**Obj.2** The depth sensor Kinect for Windows is used to determine the position of optical markers placed on participant’s body landmarks. With this information, distance between markers is estimated and then used to find joint centers. Next, joint centers are connected to form lines that will represent the body segments, and from these segment lines angles are calculated using the dot product to find the angle between two vectors. In combination with these positions and angles (calibration parameters), sensor data collected from participant’s gait using the MVN BIOMECH’s lower body configuration are used to re-estimate gait kinematics.

**Preliminary Results**

**Obj.1** Results showed that for both cases the difference between angles obtained in (a) and (b) (40.88 degrees) and (a) and (c) (53.88 degrees) is consistent throughout the gait cycle; and the coefficients of multiple correlation [5] represent good level of similarity between (a) and (b) (0.98) and between (a) and (c) (0.93). These results show that the inaccuracy of kinematics after calibrating with non-ideal postures is mainly due to the offset between waveforms. This suggests that the proposed calibration technique for Obj. 2, which is in design stage, can provide a good solution for the calibration problem.

**Clinical Significance**

Improving the calibration process of these wearable systems to account for non-ideal postures makes them suitable for a variety of patient populations. This technique will ultimately provide clinicians and researchers with a valuable tool to analyze the kinematics in real life environments.

**SP041 - Brain Computer/Machine Interfaces**

**SP041.1 - Cross-subject and Cross-gender Emotion Classification from EEG**

**Author(s):** Jia-Yi Zhu, Wei-Long Zheng, Bao-Liang Lu

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Emotion is a general definition for subjective cognition experiences, including psychological and physiological states aroused by one’s feeling, thinking, and behaviors. With the development of artificial intelligence, affective computing based on computer systems is considered to make human-machine interaction more friendly and convenient. Recently, progresses of brain-computer technology encourage researches on EEG-based emotion recognition in the field of neuroengineering. Previous studies have indicated that EEG does change with emotional states in specific patterns. To our best knowledge, however, EEG models used in the existing studies were almost subject-dependent. Thus, there is no definite conclusion on whether these patterns are universal across different subjects.

The main goals of this study are to find a subject-independent EEG model for emotion classification and examine gender differences of EEG patterns as one of the major factors affecting the performance of cross-subject models. In this paper, we use movie clips as stimuli to evoke three emotional states: positive, neutral, and negative. We adopt differential entropy as features, and apply linear dynamic system to do feature smoothing. The average in-subject classification accuracy of SVM is 90.97% with five frequency bands on 15 subjects (7 males and 8 females), while the average cross-subject classification accuracy is 64.82% using data from 14 subjects as training set and data from the rest one subject as testing set. This implies that different persons do share similar patterns for EEG changing with emotions, but there are still some individual differences during emotion processing. We also expand the training set from one subject to 14 subjects and find the average accuracy will then continuously increase with some slight ups and downs. Therefore, we can get an observation: A universally applicable EEG model for emotion recognition can be trained using data collected from enough subjects. Moreover, fuzzy-integral-based combination method is used to combine models across frequency bands and get an average improvement of 8%.

We choose data from the same or different genders to do cross-gender emotion classification, seeing Fig. 1. The better performance of using training and testing samples both from female subjects partly implies that there must be gender differences during emotion processing. Also, for female testing subjects, using single female model, or combining male and female models would both improve the performance of cross-subject emotion classification. Moreover, it can be partially illustrated that the universal EEG pattern is likely to behave more obvious among female subjects.
Emotion plays an important role in human communications and decision making. However, the modeling and mechanism of emotions still remain a challenge problem. Besides logical intelligence, emotional intelligence is proposed to narrow down the emotional gap between humans and computers in artificial intelligence. So far, many approaches to emotion recognition have been proposed based on different modalities. Among these approaches, emotion recognition from EEG allows direct assessment of emotional states of users, which has gained more and more attention recently.

In recent years, great progresses in EEG-based emotion recognition have been achieved and various methods have been studied and evaluated. However, a major limitation of these methods is that only a handful of features and classifiers have been compared in each study. Moreover, most studies evaluate their methods on different, usually small datasets, so the results of these studies cannot be compared directly due to different setups of experiments. It is difficult to judge which types of features and classifiers are most suitable for EEG-based emotion recognition. Although recently Jenke et al. performed a systematical comparison of feature extraction and feature selection methods in their work, there is still a lack of detailed comparisons of classification methods for emotion recognition form EEG.

In this paper, we review different classification methods for emotion recognition from EEG and perform a detailed comparison of these methods on a relatively larger dataset of 45 experiments. Since different classifiers could have different discriminative power for emotion classification, we further propose to combine different classifiers using stacking to improve the performance. Experimental results show that most relevant channels locate on the lateral temporal and prefrontal brain areas and the critical frequency bands are beta and gamma bands. Additionally, the weights of Logistic Regression-I2, SVM-linear and SVM-RBF indicate some relevant features in delta bands except for Random Forest.

To investigate critical brain areas and critical frequency bands for promoting our understanding of emotion processing mechanisms, we perform a contrastive analysis of the weights derived from the classifiers as a way to detect and extract the most relevant features for classification. We find that the relevant features of different classifiers are similar. These results show that most relevant channels locate on the lateral temporal and prefrontal brain areas and the critical frequency bands are beta and gamma bands. Additionally, the weights of Logistic Regression-I2, SVM-linear and SVM-RBF indicate some relevant features in delta bands except for Random Forest.

SP041.2 - Comparison of Classification Methods for EEG-based Emotion Recognition

Author(s): Wei-Long Zheng1, Roberto Santana2, Bao-Liang Lu3

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Emotion plays an important role in human communications and decision making. However, the modeling and mechanism of emotions still remain a challenge problem. Besides logical intelligence, emotional intelligence is proposed to narrow down the emotional gap between humans and computers in artificial intelligence. So far, many approaches to emotion recognition have been proposed based on different modalities. Among these approaches, emotion recognition from EEG allows direct assessment of emotional states of users, which has gained more and more attention recently.

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In this paper, we review different classification methods for emotion recognition from EEG and perform a detailed comparison of these methods on a relatively larger dataset of 45 experiments. Since different classifiers could have different discriminative power for emotion classification, we further propose to combine different classifiers using stacking to improve the performance. Experimental results show that the combination of classifiers using stacking can achieve higher accuracies than single classifiers.

To investigate critical brain areas and critical frequency bands for promoting our understanding of emotion processing mechanisms, we perform a contrastive analysis of the weights derived from the classifiers as a way to detect and extract the most relevant features for classification. We find that the relevant features of different classifiers are similar. These results show that most relevant channels locate on the lateral temporal and prefrontal brain areas and the critical frequency bands are beta and gamma bands. Additionally, the weights of Logistic Regression-I2, SVM-linear and SVM-RBF indicate some relevant features in delta bands except for Random Forest.

SP041.3 - A Brain Computer Interface (BCI) based on intermittent photic-stimulation using multiple coherence to command detection

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Brain Computer Interfaces (BCI) are systems that are capable of translating information from the neuronal activity of a subject into controlling signals for devices. BCI may be either passive or active. This latter uses evoked responses to external, sensory stimulation (e.g. intermittent photic stimulation). Active BCIs exhibit reduced complexity and processing time in comparison with passive interfaces. This occurs due to the fact that the evoked responses occur at a known stimulation, which simplifies the detection algorithm. The present work aims at using a modified algorithm for the multiple magnitude-squared coherence (MMSC) estimation for increasing both sensibility and specificity of the decision system, as well as to reduce the response time. The algorithms for multiple coherence calculation were developed using the sweep operator over the augmented spectral matrix. The algorithms for real time calculation and for obtaining BCI controlling signals with lowest latency. EEG from five subjects has been collected using the following monopolar derivations according to the 10-20 International System: O1, O2, P3, P4, C3, C4, Pz and Cz. The hardware was developed specifically for BCI interfaces based on visual stimulation. Each subject was seated in a comfortable armchair with a monitor containing four distinct LEDs each of which flickering at a distinct frequency (24, 28, 32 and 36 Hz). The multiple coherence detector was used to determine to which LED the subject was looking at and this result was used for a BCI that controlled the cursor movement. The MMSC-values were calculated with segments of L = 0.25 s of EEG signal segments. The proposed system is capable of detecting responses within a time lag that is below 4.54 s with average area under the ROC curve equal to 0.91. For a 24 Hz stimulation frequency, the system had sensitivity and specificity equal to, respectively, 88.3 % and 73.2 %. Fig.1 shows a volunteer controlling the cursor position using the BCI system.

Fig. 1. The weight distribution of LR-I2, SVM-linear, SVM-RBF and Random Forest.

Fig. 1 Average accuracies of cross-gender emotion classification.
The objective of this study was to evaluate a novel paradigm to control brain-machine interfaces (BMI) that has emerged from the need of creating BMI systems that feel natural and intuitive to the user. The first demonstration of such systems started over 40 years ago with a series of studies in which monkeys volitionally modulated single neuron activity through biofeedback. These systems exploit the volitional drive on cortical neurons that allows them to modify their tuning properties through a process of reward-modulated spike-timing-dependent plasticity. Recent studies have employed this alternative strategy to control motor neuroprosthesis and computer cursors, proving that single neuron activity is a promising signal for BMI control because of its greater simplicity to implement and to use.

The objective of this study was to evaluate a novel paradigm to elicit volitional modulation of neural activity in a rat model to control a two-degree-of-freedom BMI. In order to do this, we implanted microelectrodes in the motor cortex and trained the rat to modulate the activity from one selected neuron and maintain the firing target rate for up to 3 seconds. When the rat reached a low-rate target a food pellet was dispensed, while sucrose solution was dispensed with a high-rate target. The rat was free to choose whichever reward it wanted to obtain during the conditioning sessions. Biofeedback was provided in real-time through a LED that varied in brightness. We increased the difficulty of the task by incrementing/decrementing the firing rate thresholds or by increasing the hold time every 5-10 minutes.

In a previous study, we showed that the intrinsic spiking properties of cortical neurons determine the performance in a BMI task. We found that fast-spiking neurons are able to quickly adapt to arbitrary rules, while regular-spiking neurons cannot adapt in short periods of time.

In this study, the rat successfully learnt to control two degrees of freedom with fast-spiking neurons. In total, 7 neurons were used to control the BMI. Some interesting observations include: (1) the rat initially preferred to obtain food pellets (low-rate targets) in the first half of the session and abruptly switched to sucrose solution (high-rate targets) in the second half of the session; (2) the rat successfully suppressed the activity of the neuron and at the same time, was then able to generate bursts of high activity with the same neuron and maintain it for as long as 3 seconds; (3) in the last 3 days of training, the rat no longer showed such marked reward preference during the sessions, but instead learnt to balance the amount of food/sucrose solution rewards obtained in each experiment.

Further work is needed to probe the capabilities and limitations of using operant conditioning of neural activity to develop robust and reliable BMI systems, but we firmly believe this paradigm holds great promise to restore movement after paralysis.

**Objectives**

There is growing interest in the use of brain-computer interfaces (BCI) for rehabilitation of neurological conditions such as stroke. We have developed functional electrical stimulation (FES) therapies and technologies for almost two decades achieving remarkable restoration of upper limb function. In FES therapy, patients attempt specific functional tasks (e.g., lifting a mug from a table) and, simultaneously, the movement is facilitated with electrical pulses applied to the arm/hand. We are now combining our FES systems with a BCI to assist the efficacy of FES therapy when matching the intended and facilitated movements. The objective of this work was to explore the possibility of identifying specific hand grasps, performed with the same limb, using EEG analysis.

**Materials and Methods**

Fifteen participants (mean age was 32 and six were women) with no known neurological conditions performed six hand movements in a ready-go-stop sequence while we recorded EEG signals (C1, C2, C3, C4, Cz, F3, F4, and Fz). Four of the movements are commonly trained during stroke rehabilitation (two-finger pinch, palmar and lumbrical grasps, and hand opening — all finger extension). The movements were repeated at least 30 times with the participants’ self-identified dominant hand, and four of the subjects repeated the experiment with their non-dominant hand.

The time-resolved spectra (256-sample Hamming window, 128 sample overlap, 256-FFT) between 1 Hz and 50 Hz for all EEG recordings were smoothed and correlated with a hyperbolic tangent function to identify decreases in power (typically associated with the preparation and execution of voluntary movement). The spectral components and time ranges with the largest correlation values resulted in movement-specific maps that were used as features to implement a nearest-neighbour classifier.

**Results**

For all participants, at least three dominant hand movements were identified correctly with accuracies between 64%-75%, and 67%-85% when the non-dominant hand was used. We found a difference in accuracy for only one of the movements when the analysis was limited to only ipsilateral or contralateral electrodes. Classification of the different intended movements took place 1.2s (+/- 0.8s) to 0.7s (+/- 0.9s) before dominant hand movement onset and 0.7 s (+/- 0.9 s) to 0.4 s (+/- 0.4s) for non-dominant hand movements.
Conclusions

Our results are comparable to other reports describing the prediction and identification of movements performed with the same limb (92% [1] and 45% [2] with 163 and 128 EEG electrodes, respectively). However, the work presented here uses a maximum of eight EEG electrodes increasing its viability for use in a clinical environment. Our next steps will consist of testing the presented procedure with stroke and spinal cord injury patients. To the best of our knowledge, this is the first report on the analysis of EEG activity to predict specific hand movements targeted in stroke and spinal cord injury rehabilitation performed with the same limb.


SP041.6 - Wireless Distributed Intracortical Neural Interfacing: A New Approach for Brain Machine Interfaces
Author(s): AliReza Zabihian1, Amir Massoud Sodagar2, Mohamad Sawan1
1Electrical Engineering, Polytechnique Montreal, Montreal/CANADA, 2Electrical And Computer Engineering, K.N.Toosi University of Technology, Tehran/IRAN

Brain Machine Interfaces (BMIs), as promising devices for assisting patients with motor disabilities and/or neurological injuries, demand for high-performance recording/simulating capabilities in terms of speed, quality, and quantity, i.e. higher bandwidth, signal-to-noise ratio for neural signal, and interfacing area on cerebral cortex. In this abstract, we present the architecture of a wireless network of implantable microsystems.

There are three major approaches to electrically interface with the brain. They differ in spatial resolution, quality level of signal, and practical area to interface with. Electroencephalography (EEG) is a major approach to record brain activities using multiple surface electrodes on the scalp with poor spatial resolution. Electrocorticography (ECoG) utilizes surface electrodes mounting directly on exposed surface of cerebral cortex. Single-Unit Neural Interfacing is a method to measure single neurons electro-chemical activities (action potentials) using a microelectrode array system. In the last decade, Intracortical Neural Interfacing using wireless implantable microsystems with microelectrode arrays has realized wireless neural prostheses with higher spatial resolution, higher signal quality, and feasibility of freely movement of patient under study. But, in fact, the effective area covered with microelectrode arrays is too limited for most relevant applications.

Here, we propose a novel neural interfacing approach which is as high-performance as intracortical neural interfacing in terms of spatial resolution, quality of signal, and feasibility of freely movement; as well, similar to EEG and ECoG, it covers a significant area of cerebral cortex. The idea is to network several wireless implantable microsystems, which we call it Brain-ASNET: “Brain Area Sensor NETwork” (Fig. 1). To realize the proposed idea, there are many design aspects to be considered, including network architecture and protocol, and sensor node form factor and power consumption. We choose a star network topology, an ad-hoc TDMA MAC protocol, and OOK modulation in 902-928MHz ISM frequency band. The Custom Integrated Circuit (CIC) is designed and laid-out in an IBM 0.13µm CMOS process. The post-layout simulation results show energy efficiency of the designed ad-hoc network protocol and low power dissipation of the CIC. The whole chip, including all functional and peripheral integrated components, consumes 138µW and 412µW, at 1.2V, configured in a synchronized network as a sensor node and the coordinator, respectively.

At the congress, we will present design and implantation aspects of the proposed network, including proposed network architecture and protocol design, the CIC design, and a conclusion will be presented.

Fig. 1. Illustration of the proposed Brain-ASNET approach

SP041.7 - Design and construction of a brain-computer interface for applications in neuro–robotics
Author(s): Alma R. Méndez Gordillo, Marco A. Espinosa Medina, Miguel Villagómez Galindo
Mechanical Engineering, Universidad Michoacana de San Nicolás de Hidalgo, Morelia/MEXICO

A brain computer interface (BCI) is a device that helps people with motor impairments, to communicate externally using the electrical activity of the brain without the assistance of peripheral nerves or muscle activity, promising further improved quality of life of patients. This investigation presents the design and construction of a neural interface in order to study the signals produced by the brain, using a Mindwave mobile prototype device, which measure spectra power of EEG (Electroencephalography, i.e. alpha waves, beta waves, etc.), NeuroSky eSense meters (attention and meditation) and eye blinks in a safety way. As the main objective is to control 3 axis biomedical devices, particularly a robotic arm Model: K-680 Steren, it is important to highlight the contribution of this work in the control, which will be held through Matlab and ArduinoIO programs.
Medical device systems Health Technology Management (HTM) strategies and best practices are now well established in most first world and many developing countries\(^1\). Plans are underway to address identified gaps in HTM, e.g., appropriate equipment selection and lifecycle management. One approach is the 25 years of HTM Seminars provided by WHO-PAHO, IFMBE CED, and ACCE to 70 countries\(^2\).

There is a new emerging challenge in this space as well, that is the requirement for medical device integration into electronic health records to improve quality and safety of care\(^3\).

The Keynote will review this HTM progress, gaps, and new challenges. It will provide a framework to move us forward in collaborative fashion.

\(^1\)Health Technology Management in Less-Developed Countries: An Untold Success Story, Authors: Binseng Wang, Thomas Judd, Ismael Cordero, Antonio Hernandez, Adriana Velazquez, unpublished 2011.

\(^2\)American College of Clinical Engineering (ACCE) International Workshops, see http://accenet.org/International/Pages/Default.aspx

\(^3\)White Paper: New Opportunities for BME/CE Health IT Education, May 2014; Contributors: Elliot Sloane PhD, Joseph P. Welsh JD, and Thomas Judd MS.

SP042.4 - Multi-criteria decision analysis to redesign an Italian Clinical Engineering Service under specific needs and regulation requirements

Author(s): Irene Lasorsa\(^1\), Giulia Abis\(^1\), Barbara Podda\(^2\), Agostino P. Accardo\(^2\)

\(^1\)Department Of Engineering And Architecture, University of Trieste, Trieste/ITALY, \(^2\)Clinical Engineering Service, ASL 5, Oristano/ITALY

The aim of this study is to fulfill the need of re-engineering the Clinical Engineering Service in an Italian ASL (Local Health Authority) located in Sardinia, in accordance with the Italian regulations for healthcare.

SP042.3 - Development of a scoring system to support medical equipment replacement prioritization using the Analytical Hierarchy Process (AHP)

Author(s): Paul Prowse, Kyle Eckhardt, Sarah Kelso

Clinical Engineering, Winnipeg Regional Health Authority, Winnipeg/ CANADA

The Winnipeg Regional Health Authority’s (WRHA) current approach to medical equipment prioritization is based largely on anecdotal evidence and qualitative information provided by the staff who use the equipment. A group of stakeholders representing clinical programs determines how the equipment is ranked for replacement through a peer-to-peer democratic process. However, the voters have little understanding of the true urgency of equipment replacement for the other clinical programs, so votes are won based on the ability of the program to present a compelling argument. The WRHA’s Clinical Engineering Program sought to develop a universal scoring system based on objective criteria to assist in this prioritization process.

A literature review revealed several scoring systems that have been developed utilizing a wide variety of criteria. From these criteria, four were selected for consideration: age, repair cost, reliability, and risk level. These were selected because they are frequently reported as predictors of replacement priority, and also because they could be universally applied to all equipment based on information available in our in-house Computerized Maintenance Management System (CMMS).

Previous studies have applied relative importance weightings to their chosen criteria based on expert opinion. Few have used a systematic approach, however, to determining the respective weightings. In the newly developed system, the pairwise comparison approach of the Analytical Hierarchy Process (AHP) is employed to determine weights that accurately represent each factor’s contribution to a device’s replacement urgency. The AHP was completed by several multidisciplinary groups including clinical engineers, nurses, managers, and administrators. The results from each group and the literature review were averaged to establish the final criteria weightings.

With the weightings established, a score from 0 to 100 was applied to each electro-medical asset with a purchase value greater than $10 000 and recorded in our CMMS. A report of this equipment was distributed to each clinical program to highlight the replacement priority of their equipment as defined by this system. Provided with objective information, decision makers can be better informed about equipment that needs replacement.

Limitations of this system relative to our regional CMMS will be explored alongside the advantages of this process over those developed previously. A summary of the effectiveness of our work in the first year and an outline of our second phase goals will be presented.

Even if methods for processes redesigning in healthcare organizations are available in the literature, there are no recent evidences of their application in Clinical Engineering Services.

Among the multi-criteria techniques, in this work PAPRIKA was used, since it is an easy-to-use and intuitive method for multi-criteria decision making, based on decision-makers’ preferences.

We identified the decision makers’ criteria (Table 1) to be fulfilled and four different preference levels for each criterion (Table 2), as inputs of the method. Moreover four different scenarios were identified and, for each scenario and criterion, the decision makers selected the most suitable level. In order to reduce the number of pairwise comparisons among the preference levels associated to the identified criteria, the online software 1000minds, implementing the PAPRIKA method, was used.

After 460 steps, the software allowed to rank the four possible scenarios. The results show that the Alternative A2 (Outsourced management of some of the activities), weighting 68.8%, represents the best solution for the ASL, followed by the Alternative A1 (current situation), weighting 68.8%, and the Alternatives A3 (Compliant to the Italian Ministerial Program SIGAE 4, CONSIP) and A4 (FULL
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SP042.5 - Developing a system to support equipment repair versus replacement decision making

Author(s): Sarah Kelso, Petr Kresta
Clinical Engineering Program, Winnipeg Regional Health Authority, Winnipeg/Canada

Within the Winnipeg Regional Health Authority there is currently no system in place to guide the process of deciding whether a device suffering a major failure should be repaired or replaced. While the question may not arise frequently, it was determined that a consistent, methodical approach would significantly improve the confidence of decision makers and equipment owners, when Clinical Engineering recommends proceeding with a costly repair, or equipment replacement.

The development of a repair versus replace decision making process encompassed three major pieces of work: define a maintenance approach, establish a process for decision making including factors for consideration, and identify the repair cost threshold at which device replacement should be seriously considered.

Thorough analysis of the repair history data for four sample fleets of equipment indicated a general trend of modest increases in repair costs with age over the study period, but no statistically significant relationship between age and repair cost or repair frequency was identified. Therefore, maintenance/replacement approaches based on the assumption that the equivalent annual costs of maintenance will surpass the projected equivalent annual cost of replacement cannot be directly applied.

A two-phase process for repair versus replacement decision making was developed. The first phase relies on a single repair cost limit, set at 50% of the device acquisition cost, to flag the most costly repairs for further review.

The second phase incorporates factors used for equipment replacement planning, determined through an extensive literature review, to evaluate whether a specific case supports repair or replacement. Ten (10) criteria were selected for this evaluation:

- Past repair cost,
- Age,
- Past reliability,
- Present labour effort,
- Manufacturer support,
- Estimated useful life remaining,
- Projected reliability,
- Condition,
- Past usage, and
- Future usage.

The repair cost threshold value of 50% of acquisition cost has been selected as a starting point. This is near the mid-point of the range suggested in the literature. In our case the limit will be applied to parts and external labour costs only (i.e. not in-house labour costs), and is therefore additionally conservative.

A Clinical Engineering standard operating procedure, evaluation worksheet, and communication template were created to support the process. Next steps will include defining applicability to equipment groups/types and limitations therein, clinical stakeholder (equipment owner) education and consultation, implementation across Winnipeg region, and monitoring and improvement.

RISK contract), both weighting 28.2%.

The application of the PAPRIKA method for redesigning the Clinical Engineering Service in compliance with national and regional requirements for hospital accreditation can be considered successful.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Dimensioning of human resources at CES</td>
</tr>
<tr>
<td>C2</td>
<td>Effects on the organization: work processes</td>
</tr>
<tr>
<td>C3</td>
<td>Supervisory capacity of the administration</td>
</tr>
<tr>
<td>C4</td>
<td>Quality of provided services</td>
</tr>
<tr>
<td>C5</td>
<td>Emergency and urgent problems resolution</td>
</tr>
<tr>
<td>C6</td>
<td>Annual costs the for biomedical technologies management</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>L1</td>
<td>2 engineers, &gt;3 technicians</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>1 engineer, 3 technicians</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>1 engineer, 2 technicians</td>
</tr>
<tr>
<td></td>
<td>L4</td>
<td>1 engineer, 1 technician</td>
</tr>
<tr>
<td>C2</td>
<td>L1</td>
<td>A unique company in charge of all the activities</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>A unique company in charge of MP and VSE</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>Different companies in charge of the activities</td>
</tr>
<tr>
<td></td>
<td>L4</td>
<td>CES in charge of all the activities</td>
</tr>
<tr>
<td>C3, C4</td>
<td>L1</td>
<td>Excellent</td>
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<tr>
<td></td>
<td>L2</td>
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</tr>
<tr>
<td></td>
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<td>Sufficient</td>
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<tr>
<td></td>
<td>L4</td>
<td>Insufficient</td>
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<tr>
<td>C5</td>
<td>L1</td>
<td>Always guaranteed</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>Always guaranteed during working hours</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>Occasionally guaranteed during working hours</td>
</tr>
<tr>
<td></td>
<td>L4</td>
<td>Never guaranteed</td>
</tr>
<tr>
<td>C6</td>
<td>L1</td>
<td>≤2million€</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>&gt;2million€, ≤2,25million€</td>
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<tr>
<td></td>
<td>L3</td>
<td>&gt;2,25million€, ≤2,5million€</td>
</tr>
<tr>
<td></td>
<td>L4</td>
<td>&gt;2,5million€</td>
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SP042.6 - An assessment of Preventive and Performance Maintenance Of Theater Equipment In Public Hospitals Kenya: Case study Five Public Hospitals.

Author(s): Philip A. Anyango
Medical Engineering, Kakamega County General Hospital, Kisumu/KENYA

Medical devices play a key role in health care delivery. They are vital for diagnosis, therapy, monitoring, rehabilitation and care. Effective management of these devices is required to satisfy high quality patient care, clinical and financial governance, including minimising risks of adverse events. Unless medical devices are managed proactively, the same types of adverse incidents happen repeatedly. Good medical device management will greatly assist in reducing their potential for harm.

Cases where life has been lost because of faulty equipment and where patients has been turned away due to non functioning equipment has been captured in both print and electronic media on Kenya. One of the results of the studies done on medical equipment countries cites non functional equipment, as one of the main cause. Lack of maintenance and inadequate funding were found to be the main cause. In the past two decades most countries in Sub Saharan Africa in collaboration with development partners have tried to put in measures to address the challenges including training of technicians, building and equipping workshops. However the challenge still remains. Operation room (theatre) is one of the hospital departments that handle emergency cases and therefore equipment used inside must be in an optimum state all the time.

This paper is about an assessment on preventative and performance assurance maintenance of theatre equipment in five public county referral hospitals in Kenya namely Kisumu, Vihiga, Homa Bay and Kakamega. These hospitals were sampled because of geographical location and high volume of patients handled.

The assessment focused on four major equipment used in operation room namely, anaesthetic machine, vital signs monitor, suction machine and electrosurgical unit. The main objective was to assess why equipment fail. Areas assessed included; Mode of service and maintenance, compliance to manufacturer’s guidelines., Stick on a dated ‘SERVICED’ label noting the next date due,, records of the activities carried, by whom, date and signature, availability of service manual, Training and certification of service engineers and possible challenges.

The findings were analyzed and Preliminary results were as follow

On Compliance with manufacturer’s guidelines it was found out that; Most maintenance is done by in house staff, Very few equipment are under service contract, Manufactures service and timeline instructions are not followed to the letter. Training and certification of engineers- No evidence of certification of service engineers, Records were not well kept. Major challenges identified included; Insufficient funding’ Inadequate staff and adequate skills

Ifrom the results it is evident that the way the equipment is maintained directly affects its performance, lifespan and quality of care to patients and the need for capacity of staff handling the equipment need not be overemphasised.

The paper recommends a comprehensive assessment be carried out in the entire country and should cover entire hospital.

SP042.7 - Mathematical Model for Reliable Maintenance of Medical Equipment

Author(s): Abdelbaset Khalaf
Clinical Engineering, Tshwane University of Technology, Pretoria/SOUTH AFRICA

This paper proposes a mathematical maintenance model that analyses the effect of maintenance on the survival probability of medical equipment based on maintenance history and age of the equipment. The proposed model is simulated in Scilab using real data extracted from maintenance history of Anaesthesia Machine from Draeger. The analysis using survival approach reveals that conducting preventive maintenance (PM) on the selected medical equipment had a positive impact on survival of equipment. The model is then used to analyse the cost of maintenance scenarios and an appropriate scenario is proposed for Anaesthesia machine. A new failure-cost model is developed which may be used to calculate the number of failures of equipment and the annual maintenance cost. The proposed models may be used as a planning tool for selecting maintenance strategies for various medical equipment.
SP043 - Women in BioMedical Engineering

SP043.1 - One thousand years of women in science
Author(s): Monique Frize
Systems And Computer Engineering, Carleton University, Ottawa/ CANADA

Since the beginning of documented history, in every epoch, women have made significant contributions in science and technology. The challenge, since historians have mainly concentrated on men’s work, is to find these women and discover what they have done. A few examples will be presented in this paper, but interested persons can find many books and websites with biographies of women in science and medicine. A few books and websites include women in engineering and technology.

In the 4th century, Hypatia of Alexandria (c.355-415) is said to be the world’s leading mathematician and astronomer of her time. She was a popular lecturer on philosophical topics, attracting many students and large audiences. In the middle ages, women became involved in alchemy, herbal medicine, midwifery, and science in its fullest meaning. For example, Hildegard von Bingen (1098-1179) mentioned heliocentricity nearly 400 years before Copernicus and speculated about universal gravitation 500 years before Newton, composed music, and wrote on medicine and natural history. The renaissance counts many women astronomers that include Sophia Brahe (1556-1643), Maria Cunitz (1610-1664), Maria Winkelmann (1670-1720) and Margaret Cavendish (1623-1673) who published extensively on natural philosophy and early modern science, including over a dozen original works. With revised works, this brings her total number of publications to twenty one. Women were also patrons and correspondents of men like Queen Christina of Sweden and Elizabeth von der Plat. The 18th and 19th centuries count numerous women involved in serious science and mathematics such as Laura Bassi, Maria Gaetana Agnesi, Émile du Châtelet, Christina Roccati, Mary Somerville and many others. Only in Bologna and Padua were women granted doctoral degrees in the 18th and early 19th centuries, before women in general were admitted to University starting from the 1870s.

The presentation is meant to stimulate interest in the discovery of women who came before us and especially to demonstrate the importance of collecting papers and archives on women, their life, and their work. The active participation of women in science activities in all epochs, in spite of important obstacles they faced, is a model for girls and women today, since it is much easier now to follow this path than it has been in all past eras. We should be truly inspired by these stories and dream in our own way about the road we wish to follow.

Sources:
Laura Bassi and Science in 18th Century Europe: The extraordinary life and role of Italy’s pioneering female professor, Monique Frize. Springer, July 2013.

SP043.2 - Creating the Memories and Celebrating the Legacy of Women in Science and Engineering
Author(s): Ruby Heap1, Monique Frize2
1History, University of Ottawa, Ottawa/ON/CANADA, 2Systems And Computer Engineering, Carleton University, Ottawa/CANADA

For centuries, women around the world have actively participated in science and engineering, both formally and informally. Unfortunately, their contributions as innovators and producers of knowledge in these fields remain, to a large extent, unknown or understated. The history of women scientists and engineers is still in its infancy in a large number of countries. One major reason is their invisibility in traditional and established archives, which collected male records and tended to privilege the life and work of men; but another key obstacle has been these women’s inclination to underestimate their own accomplishments, with the result that most did not seek to preserve their papers, and neither did their family, friends, and colleagues. At a time when the call for more women in science and engineering careers resonates strongly within governmental, economic and academic circles, and when there is a strong consensus regarding the benefits of gender equity and increased diversity in these fields, there is a pressing need to provide current and future women scientists with an accurate and inspiring understanding of their past, to learn about the lives and contributions of those who came before them.

This session will discuss an ongoing Canadian initiative which aims to research, recover, and celebrate the lives of women through the creation of an Archives of Women Scientists and Engineers in Canada. Sponsored by the INWES-ERI (International Network of Women Engineers and Scientists-Education and Research Institute), this initiative was launched at a workshop held in September 2014 at the University of Ottawa. Close to 50 participants—engineers, scientists, archivists, librarians, historians, policy makers—discussed the Archives project, along with partners such as the University of Ottawa, IBM Canada, The Canadian Commission for UNESCO, the US Society of Women Engineers (SWE) and a grant from the Social Sciences and Humanities Research Council (SSHRC). An action plan was adopted by the participants and a multidisciplinary Task Force was established to help proceed with its implementation. The main features of the action plan will be discussed in this session: the first steps include building an inventory of existing archives in major local, regional, and national repositories, and in major professional associations and organizations in science and engineering; with the assistance of SWE, we also intend to produce a Best Practices Guide to the discovery, recovery, and preservation of archives (manuscript, printed, audio-visual, digital) on women scientists and engineers.

In this interactive session, participants are invited to exchange with the speakers on approaches, programs and projects that might be developed to document the lives and careers of members of their organisations, document public conferences and exhibitions, books, brochures, oral testimonies, and the preservation of records of scientists and engineers.

SP043.3 - Women In Bio-Medical Engineering In Kenya
Author(s): Salome W. Mwaura
Bio-medical Engineering, MBAGATHI DISTRICT HOSPITAL, NAIROBI/KENYA

Women are often referred to as the weaker sex and in most communities in Kenya, they are regarded as children. It takes a lot of time for male Managers of health facilities to accept them in decision making.

As a primary school going girl, we took my brother to the local district hospital but the Doctors could not fully diagnose his condition due to some equipment in the laboratory and X-ray department
malfunctioning. In my mind, I was wondering what could have been wrong with the equipment and I decided that when I grow up, I must study the course for repair of equipment in hospitals.

After my “O” levels, I got three carrier opportunities in Medical Laboratory, Nursing and Medical Engineering. With my little knowledge about medical engineering, and remembering the incident in hospital earlier, I chose to pursue Medical engineering.

In 1993, I was admitted for a three year Diploma course in medical engineering at Mombasa polytechnic. I joined the civil service in 1997 and I have worked in various hospitals including Kisumu and Nyeri level V and Mbagathi level IV. In 2006, I enrolled for a 2 Year Higher National Diploma course in medical engineering at the Kenya Medical Training College, Nairobi.

In 2006, I was appointed HOD of Bio-medical engineering Department at Mbagathi District hospital heading a team of 8 bio-medics of whom 6 were male. It was an uphill task but today, I can proudly say that my work relation with everybody is very good. I am always involved in decision making as concerns medical engineering in the hospital by the hospital management.

I have attended several trainings. GAME, an American NGO organised one on theatre and ICU equipment in Kisumu, another one by JICA in Nairobi and another in South Africa by SAFHE/CEASA. I have also been to DITEC, USA for an advanced course in X-ray and Imaging.

I am a Member of AMEK which I have served in several capacities, and currently am the Treasurer. I have attended several conferences organised by the International Federation of Hospital Engineering (IFHE). I attend all annual conferences/events organised by AMEK and biennial East African conferences organised by the East African Country associations on rotational basis, the most recent one was in Kigali, Rwanda in December 2014.

**Challenges**

Biomedical engineering in Kenya is male dominated. Hence, fighting for recognition and appreciation by bosses is a major challenge in the field.

When it comes to factory training, most opportunities are given to men in the ratio of one out of ten.

Working with bosses who come from communities that do not recognise women plays a major role in demotivating women in their day to day operations.

**Conclusion**

There is need to support these ladies who are doing everything possible to give quality work in medical engineering and give them a chance as they have the capability.

They also need to be empowered academically in order to shine better in the field.

**SP043.4 - Physics is a waste of your intelligence**

**Author(s):** Shada Wadi-Ramahi

Biomedical Physics, King Faisal Specialist Hospital and Research Center, Riyadh/SAUDI ARABIA

Going to physics was not an easy road. It was unheard of that students who score high in the Jordanian SAT go to science. My parents were outraged. Graduating first in class in 3.5 years, still did not convince them. I was wasting my time and college was a waste of their money.

Fast forward to 2003, I graduate with a PhD in Medical physics from the US. Time to go home. I land a position in the country’s leading cancer center, joining a team of 7 physicists. It was not easy to be the only one with a higher degree in physics, most of the problems though did not come from fellow physicists, but from the chairman who could not handle having a “doctor” female staff. In official communications I was always referred to as “Ms.” instead of “Dr.”. The excuse was “you are like my daughter”. Later the attitude escalated. In one of my earlier meetings with linac vendors in 2004, I challenged the representative of a company on one of his claims. The chairman annoyed that I spoke up, yelled “Hey girl stop this!” It took a good year before attitudes changed to formal behavior …. At least on paper.

The policies of the institution prevented discrimination, and later I became the head of medical physics. However, harassment came in many forms; it was encouraging male physicists (my subordinates) to side step me and report to the chairman directly, it was over-riding the staff work schedule often after I distribute it (something that never happened to the chief technician … a male), it was ridiculing my expertise even after I obtained ABR certification. It was stopping warning letters addressed to staff members who yelled at their supervisor (me). Harassment took many forms and shapes. Did I think about leaving? Yes, I wanted to go “back” to the US.

I loved my profession and I was determined not to let a male-dominated culture sway me off track. I am in my country contributing greatly to the treatment of cancer patients, and if I am not part of the force of change then I am a quitter. I endured.

Eleven years later in 2014, when I announced I am leaving to a position in another highly competitive institution in the region, my chairman gave me a counter offer and tried hard to convince me to stay. The offer was generous, and the emotions were real. It was a moment of vindication, my dedication to work and perseverance paid off. Alas, it was time to move on.

Women in science world-wide are a minority, in the Middle East they are a rarity. Women in science in the Middle East who assumes higher positions in par to their male colleagues are a species of their own.

I am proud of my achievements … I am proud to call myself a medical physicist … I am proud to call myself an Arab, but above all I am proud to be a woman.

**SP043.5 - Medical physics – or how a change in career path becomes a passion**

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I was trained as a physicist in a country under transition after half a century of communism. I enjoyed being a student at the University of Timisoara (Romania) where I studied physics for six years under the guidance of some highly respected professors. After graduation, I was lucky enough to get a teaching position in my hometown at the University of Oradea, where, for the first time, I stood on the other side of the desk. While it was a great teaching experience, I felt that I needed something more for a fulfilled scientific life.

That was the moment of a life-changing decision: moving to Australia. In Adelaide, South Australia, I have been able to continue my scientific education in a specialised branch of physics that I fell in love with. I had the good fortune to be offered a scholarship to attain my PhD in Medical Physics. I got to work with an extraordinary group of people at the Royal Adelaide Hospital where I continued my career for nearly a decade. The people, the facilities and the working conditions all put together offered an optimal learning environment and a
SP044 - Bio-Impedance and Imaging (Other)

TRACK 01: IMAGING

SP044.1 - Personal Time-Varying Magnetic Fields Evaluation During Activities in MRI Sites

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A person moving in and around the MRI site may experience strong time-varying magnetic fields. The physical consequence of the time variation of the magnetic flux density is the induction of currents in body parts. In this paper the time-varying gradient exposure associated with the magnetic flux densities is evaluated and measured. The acquired data, obtained from a personal magnetic dosimeter, represent the magnetic flux density function, B = B(t), related to the operator movement inside the MRI site. Such data have been processed to evaluate the corresponding dB/dt curves, that were estimated by calculating the time derivative. All the measurements were conducted on a 3.0 T MRI site, dedicated to research procedures, in two different conditions: at first during routine patient positioning, and secondly, simulating an emergency. In both the measurement conditions, two dosimeters, with different acquisition times, were simultaneously used. They were positioned the first time on the operator’s torso and the second one on his head. The analysis conducted, simulating both normal and emergency conditions, demonstrated that the dB/dt peak values strictly depended on human motion through strong static magnetic fields, and, sometimes, exceeded the recommended limit. This consequence highlighted the necessity of drawing up, as in case of ionizing radiation, behavioural rules to be followed by workers and patients. Therefore it will be necessary to assess risk conditions in a proper manner.

SP044.2 - ECG Imaging of Ventricular Extrasystoles

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Objectives: Frequent ventricular extrasystoles can lead to ventricular tachycardia and ventricular fibrillation and are therefore life threatening. They can be treated with RF ablation, provided the focus of the extrasystole is precisely known. Invasive ablation procedures can be accelerated significantly if the focus of the extrasystole is known beforehand from non-invasive measurements. This project aims at the localization of ventricular extrasystoles from Body Surface Potential Maps (BSPM).

Methods: 9 patients with frequent extrasystoles were selected. BSPM datasets and MRI images were acquired. The MRI data contained an enddiastolic dataset of the heart and a thorax scan. Heart, lungs, liver, spleen, stomach, kidneys and aorta were segmented. Tetrahedral meshes of typically 3000 nodes in the heart and 350000 nodes in the thorax were created for FEM calculations. A thorough localization and registration procedure for the electrodes was implemented. During the invasive procedure stimuli were given at various positions and the BSPM were measured. Finally the foci of the extrasystoles were ablated. Various algorithms of reconstruction of electrophysiological sources in the heart from BSPMs have been implemented and tested, e.g. Tikhonov (with and without bounds), activation times, model based optimization and Maximum-a-Posteriori (MAP) estimates. Thorough validation was carried out.

great source of inspiration. Radiobiology became my new passion, a field that I am continuously learning and which never ceases to amaze me.

In life circumstances and priorities change, so after ten years of learning, working and teaching in Adelaide, it was time to give something back to the country where I was raised and educated. I am now back on home soil where I have helped the Physics Department of the Science Faculty within the University of Oradea set up a Medical Physics training programme at both undergraduate and postgraduate levels. It is a wonderful feeling to pass on your own experience and teach students that have the same thirst for knowledge that I had at the beginning of my academic career. Medical Physics is a developing field in Romania and we need enthusiastic and well-trained specialists to raise this branch of science to European standards. The love and passion for this field should start from studenthood, and as the first woman medical physicist has once said “We must have perseverance and above all confidence in ourselves. We must believe that we are gifted for something” (Marie Curie).
by comparing the reconstructed foci with the ones found during the invasive ablation procedure.

Figure 1: Three examples of reconstructed transmembrane voltages together with the true location of the extrasystole (pink bullet). **Method:** Tikhonov 2nd order. Blue bar indicates the time of reconstruction in the ECG (extracted from the BSPM).

**Results:** Figure 1 shows three examples. A median error of 20mm was achieved. This is somewhat disappointing but agrees with other publications with thorough validation of ECG imaging. The various reconstruction methods tested in this project deliver good results in one patient and worse results in another – no algorithm is the clear winner for all patients. The model based optimization performs slightly better as compared to the other methods.

Discussion: Despite the fact, that all the reconstruction algorithms mentioned above show very good results in computer simulations, the strict clinical validation uncovers some deficiencies. The results support the hypothesis, that the model assumptions that underlay all reconstruction algorithms are not yet perfect.

**SP044.3 - Experimental Study on Amplitude Frequency of Acoustic Signal Excited by Coupling Magneto-Acoustic Field**

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Object To study the relationship between exciting source characteristic and magneto-acoustic signal, also explore the frequency corresponding relationship between exciting signal and acoustic signal applied on the experimental sample. Methods A practical system has been established to detect magneto-acoustic signal. While single period sine pulse current with different amplitude and frequency were loaded in the sample of straight copper wire, acoustic signal was detected synchronously. Amplitude and frequency of exciting current and acoustic signal were analyzed by using time-frequency method, which was adopted by short time Fourier transform STFT and shifted smoothing rectangle window. Then, comparative study was conducted basing on the processed data. Result Giving the current same frequency as well as different amplitude, linear relationship is obtained between the output amplitude of acoustic signal and current amplitude. However, giving the current same amplitude as well as different frequency, the corresponding frequency spectrum of acoustic signal show different variation law, and thus, there is great difference among the system functions. Conclusion Detecting system is highly sensitive to frequency. In order to acquire more information in the magneto-acoustic signal, both of detecting circuit SNR and acoustic transducer bandwidth should be promoted.

**SP044.4 - In vivo electric conductivity values of cervical cancer patients reconstructed with a 3T MR system for improved SAR determination**

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**Introduction:** Reliable tissue electrical conductivity ($\sigma$) values are required to determine the RF energy absorption for Hyperthermia Treatment Planning (HTP) or for Magnetic Resonance Imaging (MRI) for safety purposes. Currently used $\sigma$-values are mostly based on ex vivo measurements, and tumor $\sigma$ is mostly unknown. Our aim is to acquire in vivo pelvic tissue conductivity for muscle, bladder and cervical tumor using 3T MRI.

**Methods:** Conductivity values were reconstructed using Electric Properties Tomography (EPT) which is based on the measurable B1+ field. Earlier we have validated this method for the pelvic region using phantom experiments and in vivo simulations. In this study, MR measurements of 12 cervical (squamous cell) carcinoma patients and one uterine adenocarcinoma patient were used to reconstruct $\sigma$-values in tumor, muscle and bladder. For a reliable $\sigma$-reconstruction the composition of a particular tissue should be relatively homogenous and sufficiently large (>3cm). Thus the $\sigma$ of 9 tumors and 7 bladder fillings could be reconstructed. Results were compared to literature data.

**Results:** The reconstructed $\sigma$-values of muscle tissue were up to 35% elevated compared to literature values (Figure 1a). Moreover, the reconstructed $\sigma$-values of the bladder were up to 10 times higher than values currently used in human models for HTP (Figure 1b). Finally, for 75% of the squamous cell carcinomas the $\sigma$-values were 5-12% higher than the $\sigma$ of muscle tissue found in this study. The reconstructed $\sigma$ of the adenocarcinoma was 22% higher compared to muscle tissue.

**Discussion & Conclusions:** This study demonstrated the feasibility to measure the $\sigma$ of healthy tissue and tumors in vivo. The measured conductivities were higher than reported in literature, which could probably be explained by the higher blood and water content during in vivo conditions. A decrease of $\sigma$ after death has been reported for bladder corresponds to bladder wall tissue, the volume percent of which is lower than that of urine. However, this study shows that urine $\sigma$ is much higher and shows a large inter-subject variation. Future studies will determine to which extent the reliability of HTP improves when using these patient-specific $\sigma$-values. These results are further interesting for applications such as MR safety and RF coil design for MR systems.
Liquid lenses, which are basically a soft capsule of oil or water, have recently been demonstrated capable of adaptive tunable focus. Its curvature changes can be activated by various means, mechanical, thermal, electrochemical or electrical. In mechanical or pneumatically activated liquid lenses, change of liquid pressure or membrane stress can induce the curvature changes and thus the variable focus. Such variable focus liquid lenses have a compact and lightweight design with integrated actuator, simpler than hard lenses\(^1\). However, it does not have as good shape stability as hard lenses. The liquid capsule may sag under gravity if its size is larger than 1 cm. In addition, the liquid lens may deform in response to vibration, causing image distortion. In contrary, human crystalline lenses, which are made of gel, generally can function robustly despite orientation change and last for a long life time (>40 years).

Inspired by the human crystalline lens, we make use of solid-state silicone gel (Dow Corning Dielectric Gel Kit 3-4170) to build a tunable focus lens, which is electrically activated by an annular dielectric elastomer actuator. The annular dielectric elastomer actuator acts like ciliary muscles that control the eye’s lens accommodation. Initially when the actuator is idle, the gel lens is flattened under the membrane pre-tension. Upon activation by the annular actuator that elongates, the gel lens bulges. Our experiment showed that this gel lens can vary focus on the objects between 2.5 cm and 30 cm when activated under voltages in range of 0-3 kV at very small dc current of <20 μA. As such, the gel lens consumes low electric power of <60 mW to work robustly more than 10,000 cycles. Furthermore, miniaturization of the dielectric elastomer actuators in terms of membrane thickness could help reduce the driving voltage requirement. This gel lens showed good potential to be commercially adopted due to its enhanced shape stability.

**SP044.6 - Ultra-low-field MRI for improving spatial accuracy of bioelectric source imaging**

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In magnetoencephalography (MEG), one measures the extremely weak magnetic fields generated by electrical brain activity using an array of highly sensitive, typically superconducting magnetic-field sensors around the head. As a functional brain imaging modality, MEG surpasses functional magnetic resonance imaging (fMRI) in terms of temporal resolution and has a spatial accuracy superior to electroencephalography (EEG). However, the spatial accuracy is limited by coregistration, the procedure of aligning a structural image of the head with the MEG coordinate system. Typically, this is done manually by digitizing anatomical landmarks on the head in the MEG session and separately localizing corresponding points in a structural head MRI.
Besides errors in identifying and digitizing the anatomical landmarks in both modalities, manual coregistration contains errors produced by a number of factors, such as the head-position measurement in MEG, distortions in high-field MRI, skin movements, and small differences between supine and seated positions regarding the geometry of the soft brain and cerebrospinal fluid.

The spatial coregistration accuracy is important not only for the alignment of electrical sources with the anatomy, but also for the reconstruction of the spatial origin of the signals, which depends on the geometry of the head and the changes in electrical conductivity across different tissues. As models for source localization become more detailed, their sensitivity to inaccuracies in geometry and conductivity values increases. The volume currents being particularly important in EEG, an accurate model of the conductivity structure is required especially for full benefit of the complementary information of simultaneous EEG and MEG. A hybrid MEG-MRI system provides natural approaches to addressing these issues.

At Aalto University, Finland, we have built a hybrid MEG-MRI system based on an array of sensors based on Superconducting Quantum Interference Devices (SQUIDs). The MRI is implemented at ultra-low field (ULF), around 50 µT, and measured inside a magnetically shielded room. The SQUID sensors tailored for ULF MRI can also be used for MEG. Together with the common sensor array, high-precision ULF-MRI electronics, and a stable coil structure, our novel algorithms can transform the largely manual coregistration problem to a fully automatic calibration, thereby eliminating human error and achieving sub-millimeter accuracy.

We describe the current state of our system and present obtained images. We further discuss the unique possibilities, shown recently, of ULF MRI in current-density imaging (CDI), potentially allowing also the imaging of electrical conductivity using the same hybrid device. We describe our methods, computations, and experimental setups for implementing the methods in our hybrid MEG-MRI device, along with preliminary results. If successful, conductivity imaging combined with sub-millimeter automatic coregistration will provide significant improvements to MEG and EEG source localization.

At Aalto University, Finland, we have built a hybrid MEG-MRI system of simultaneous EEG and MEG. A hybrid MEG-MRI system provides natural approaches to addressing these issues. We describe our methods, computations, and experimental setups for implementing the methods in our hybrid MEG-MRI device, along with preliminary results. If successful, conductivity imaging combined with sub-millimeter automatic coregistration will provide significant improvements to MEG and EEG source localization.

SP045 - Molecular Imaging PET/SPECT: Part 1

SP045.1 - Quantitative accuracy of SPECT imaging with a dedicated cardiac camera: Physical phantom experiments

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Introduction

Recently, there has been increased interest in dedicated cardiac SPECT scanners with multi-pinhole designs and improved detector technology due to their improved count sensitivity and resolution over traditional parallel-hole cameras. However, the pinhole-colli- mator design introduces position-dependent attenuation, sensitivity and resolution variations. Differences in attenuation patterns and energy-spectrum responses compared to conventional SPECT scanners can also inhibit accurate measurement of activity distributions. Simple correction methods for these effects are easily implemented however their level of accuracy is unclear. In this study, we assess the quantitative accuracy and reproducibility of absolute activity measurements made using easily implemented correction techniques applied to controlled physical phantom experiments.

Materials and Methods

Activity in the cardiac compartment of an Anthropomorphic Torso phantom (Data Spectrum Corporation) was measured through multiple 99mTc-SPECT acquisitions (n=10). The ratio of activity concentrations in organ compartments resembled a clinical 99mTc-sestamibi scan and was kept consistent across all experiments (6:1 heart to background, 1:1 heart to liver, 6:4 heart to lung ratio). To assess the effect of activity spill-in and increase scatter into the myocardium compartment, experiments were repeated with- and without activity in the soft-tissue torso compartment. The true net activity in each compartment was measured with a dose calibrator (CRC-25R, Capintec Inc). A ten minute SPECT image was acquired using a dedicated multi-pinhole cardiac camera with cadmium-zinc-telluride (CZT) detectors (Discovery NM530c, GE Healthcare), followed by a CT scan for attenuation correction (AC). Data were reconstructed with no corrections (NC), AC and AC with dual energy window (DEW) scatter correction (ACSC), using reconstruction with resolution recovery.

Results

T-tests comparing hot- and cold torso datasets (Table 1) showed no significant mean difference for all three reconstruction methods (NC, AC, ACSC: hot vs cold torso) (p>0.08). AC and ACSC significantly reduced the mean error over NC (p<0.001). The mean AC and ACSC errors were significantly different for the hot torso (p=0.04) but not for the cold torso (p=0.09), highlighting the effectiveness of DEW-SC in reducing errors introduced by photon scatter. While DEW-SC seemed to increase measurement uncertainty compared to AC in both cases, the increase was not significant (p=0.2). Both AC and ACSC significantly increased uncertainty over NC for the cold torso phantom (p<0.03), but not for the hot-torso case (p>0.1).

Conclusions

CT-AC and an easily implemented DEW scatter correction significantly improve quantitative measurement of 99mTc-SPECT myocardial activity with a dedicated cardiac camera producing an error of <= 2.2 +/- 6.5%.
SP045.2 - The Impact of time of flight algorithm and PSF modeling on standard uptake value in clinical PET/CT imaging

**Introduction:** Time Of Flight (TOF) and Point Spread Function (PSF) modeling are the most advanced reconstruction algorithms in PET/CT which dramatically improve the image quality. The aim of this study was to evaluate the impact of TOF and PSF modeling on Standard Uptake Value which is commonly used by physicians for staging of metastasis and monitoring response to therapy.

**Materials and Methods:** In this study, a whole-body 18F-FDG PET/CT scan performed on 9 patients (BMI=25.4±1.21, 5.02±0.07 MBq per kg) using GE Discovery 690 PET/CT. The scanner was capable to reconstruct images with TOF, and also PSF modeling which is commercially named SharpIR algorithm. All PET data were reconstructed with HD+SharpIR (use for clinical report in this center), TOF, and TOF+SharpIR algorithms. 40 Focal points (short axis diameter of 1.1±0.38 cm) were identified, and a semi-quantitative analysis was done by using SUVmean for normal lung tissue, SUVmax, and SUV50 for metastases. Furthermore, impact of lesion size, and location on SUV variation were assessed. We also evaluated noise in the images without and with attenuation correction using the volume of interest (VOI)-based analysis on 17 myocardial segments.

**Results:** Our semi-quantitative analysis verify using TOF, and/or SharpIR algorithms significantly enhance SUVmax (15.95±3.38% for TOF, 33.01±3.1% for TOF+SharpIR), and SUV50 (16.37±3.43% for TOF, 34.4±3.23% for TOF+SharpIR) in compare with the image reconstructed using HD+SharpIR. The statistical analysis showed that for smaller lesions, TOF, and TOF+SharpIR lead to more robust changes in SUVmax, and SUV50 (P-value<0.05). Figures 1 shows weak correlation between lesion location and SUV enhancement for both TOF, and TOF+SharpIR algorithms (R²=0.11, R²=0.03 respectively, P-value<0.5). Despite lesions, SUVlung wasn’t affected by reconstruction algorithms. Image noise for TOF+SharpIR algorithm was similar to HD+SharpIR, but noise for images reconstructed with TOF algorithm were superior (p-value<0.001).

**Conclusion:** This study showed that SUVs of metastases are highly affected by reconstruction applied method. Based on our results, it can be concluded that it’s vital to consider effects of TOF, and SharpIR algorithms on accuracy of SUV.

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**SP045.3 - Can Pacemaker and ICD degrade CT-Based Attenuation Corrected cardiac SPECT images?**

**Introduction:** Quantitative processing of myocardial perfusion is a questionable issue in the SPECT imaging due to the some artifacts such as attenuation. Although it has been demonstrated that CT-based attenuation correction (CTAC) technique can significantly improve the diagnostic accuracy of SPECT imaging, the presence of cardiac Pacemaker and ICD leads in CT imaging will impact the reconstructed myocardial perfusion SPECT image during the CTAC procedure. In this study we investigated and quantified the degradation magnitude of the metallic artifacts due to pacemaker and ICD leads on the CT-based attenuation corrected SPECT images using phantom studies.

**Materials and Methods:** A cardiac phantom with capability of including pacemaker and ICD leads was scanned in SPECT/CT scanner. Attenuation correction of the SPECT data was performed using the artefactual (metal artifact) CT images (Figure 1). Quantitative evaluation was performed between the actual activity and the measured activity concentration in the myocardial perfusion SPECT images without and with attenuation correction using the volume of interest (VOI)-based analysis on 17 myocardial segments.

**Results:** Quantitative analysis shows an overestimation of about 9% and 15% and an underestimation of about 6% and 11% in CT-based attenuation corrected SPECT images with pacemaker and ICD leads, respectively.

**Conclusion:** Since photoelectric interactions are more significant at CT energies and are dependent on atomic number, the metallic composition of pacemaker and ICD leads, especially ICD lead, can induce considerable artifacts on CT images. Despite the influence of cardiac lead-induced artefacts on inaccurate quantification of some segments of the myocardial perfusion SPECT images when using the CT-based attenuation correction process, however it does not induce erroneous clinical interpretation of the SPECT images corrected for attenuation using artifactual CT images. It can be concluded that implementation of down sampling and smoothing on the artifactual CT images for generation of attenuation map reduce the impact of metallic artifact during the CTAC of SPECT data.
SP045.4 - Impact of Point spread function modeling on tumor quantification in clinical PET/CT imaging

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Introduction: Quantitative assessment of PET images is increasingly used in cancer staging and therapy monitoring. In PET, partial-volume effects and point-spread function cause inaccurate estimation of lesion size and uptake. By regarding PSF-modeling during reconstruction procedure, the spatial resolution of PET images improves and as consequence the partial volume effect reduces. The aim of the present study was to evaluate the impact of PSF reconstruction (HD+SharpIR) compared with conventional OSEM reconstruction (HD) in non TOF PET imaging on quantitative accuracy of the lesions with respect to the lesion contrast.

Materials and Methods: In this study 17 patients (BMI:25.1±0.84) with 100 lesions were scanned using Discovery 690 PET/CT scanner. The patients were scanned 60 minutes after intravenous injection of 370 MBq of FDG (5.25±0.11MBq/kg). Emission data were acquired at 2 min/bed. All images were reconstructed using HD and HD+SharpIR algorithms with 3 iterations, 18 subsets, and 6.4 mm FWHM of post-smoothing filter. Image quality was evaluated by calculating COV (coefficient of variance) for a 3 cm spherical region in liver. The quantitative analysis was performed by measuring relative changes of standardized uptake values (SUV) and lesion size based on lesions location, and contrast with and without PSF-modeling. Contrast was defined as max activity concentration at lesion to mean activity concentration in background.

Results: Average of liver COV for HD and HD+SharpIR were 9.14±0.36 and 7.38%±0.33 respectively. PSF modeling increased SUVmax by 12% compared with HD algorithm. The regression analysis showed that relative differences for SUVmax significantly increased with increasing lesion contrast (figure1, R²=0.41,p<0.001) and lesion distance from the central axis (R²=0.24, p<0.001). For lesions with contrast less than 3, SharpIR algorithm reduced the size of lesion to 4.36%, and for high-contrast lesions (contrast higher than 3) the size decreased up to 17.81%.

Conclusion: Image quality was improved by using of SharpIR algorithm. SharpIR performance was better in lesions with smaller size, further distance from the central axis and higher contrast. So the effectiveness of the algorithm is more in high contrast lesions.

SP045.5 - Incidental Thyroid Cancer Identified on 18FDG-PET/CT for Ovarian Cancer Evaluation-Case Study.

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Objective: This study presents the clinical significance of focal increased 18FDG uptake in the thyroid as incidentally identified on PET/CT for ovarian cancer evaluation. Ovarian cancer is known to metastasize to the thyroid resulting in clinical hypothyroidism.

Clinical History and Results: A 54 year-old female with papillary adenocarcinoma of the ovary, underwent 18FDG-PET/CT post-surgery evaluation. 18FDG PET/CT was performed 1hr post IV 18FDG of 370MBq, (Fig. 1). A focal hyper metabolic lymph node lesion was visible in the left lower posterior deep cervical region with volume=12.4cm³, SUVmax=12.6. Thyroid was enlarged, focal nodular with irregular hyper metabolic 18FDG uptake in both lobes. The left and right lobes’ nodule volume=(2.05; 2.4)cm³, and SUVmax=(9.58; 9.88) respectfully. The rest of the body showed normal and physiological 18FDG metabolism. Thyroid Function Test was advised.

Results of TSH=7.9 IU/L, Tg=18.9 ng/ml, suggesting diagnosis of lymphocytic thyroiditis or differentiated thyroid cancer. The histopathology of US-guided FNAB samples showed: papillary carcinoma and Hashimoto thyroiditis; classical type. Tumor location: in both lobes with largest diameter: 3.5 cm. Lymph vessel invasion: present.

The patient underwent total thyroidectomy followed by 131I ablation dose of 3700 MBq. Post therapy 18WBS and neck by pinhole showed three focal areas (3x2; 2x2; 2x1.8 cm²) of residual tissue in both sides of neck, (Fig.2).

Conclusions: Incidentally found hyper metabolism of 18FDG PET/CT in thyroid was due to papillary carcinoma, most probably metastases from ovarian cancer. Elevated serum levels of TSH hypothyroid and Tg were significant with incidental finding of focal increased uptake.

We recommend that for patients with ovarian cancer; metastatic disease to thyroid should be considered, especially when PET/CT scan showed focal hyper metabolic lesion in the thyroid or elevated TSH. Further work is needed aiming at assigning a threshold level of SUVmax in thyroid to differentiate benign from malignancy.

SP045.6 - Zinc material filter for scatter correction in Tc-99m myocardial SPECT Imaging: Heart thorax phantom study

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Objective: SPECT is one of the techniques which provide the high diagnostic accuracy for the assessment of myocardial perfusion. However, the limitation in the diagnostic accuracy in the presence of Compton scattered photons in the image data. And the procedure is more
Thus, this work focuses on the investigations into the effect of Zinc (0.1mm and 0.198mm) material filter on image quality. The anthropomorphic torso phantom was used to perform the experiments. Data acquisition was obtained with the dual head gamma camera (Infinia GE Hawkeye II), equipped with low energy high resolution (LEHR) collimators. The gantry performed a 90° rotation, thus covering 180° (dual-head) with thirty six projections using step and shoot acquisition and with total 2400 kcount. Matrix size 128 x 128 was used with window widths of the energy 20% by using a Tc99m source at 140 keV. The data was reconstructed by a filtered back projection method of Butterworth filter of order 10 and cut off frequency 0.4 cycles/cm was applied. The value of Chang’s attenuation correction method was applied by selecting 0.164/cm linear attenuation coefficient. Image quality was analyzed by measuring contrast of lateral, anterior and septal defect using system software Xeleris 2.0. Images tomogram in Short Axis (SA), Vertical Long Axis (VLA) and Horizontal Long Axis (HLA) were also analyzed visually using MATLAB software with and without material filter. Results show that the contrast of the defect-to-healthy myocardium for lateral defect decreased with implantation of material filter compared to without filter, but for anterior defect the results were vice versa. For the septal defect there were slight decrease and increase for Zn 0.1mm and Zn 0.198mm compared to without filter, respectively. For the signal to noise ratio, with usage of Zn 0.1mm, the results show progression for lateral, anterior and septal defect compared to without the filter but is shown decrease for Zn 0.198mm. There was an insignificant decrease for left-ventricle-(LV) to-healthy myocardium contrast with implementation of material filter compared to without a filter. Qualitative analysis shown enhancement image quality for image obtained from Zn filter compared to without a material filter. So the application of the material filter in SPECT imaging has the potential to enhance the quality of the images, so it can increase the accuracy in the interpretation.

Conclusions:

- For lateral defect there were slight decrease and increase for Zn 0.1mm and Zn 0.198mm compared to without filter, respectively. For the signal to noise ratio, with usage of Zn 0.1mm, the results show progression for lateral, anterior and septal defect compared to without the filter but is shown decrease for Zn 0.198mm. There was an insignificant decrease for left-ventricle-(LV) to-healthy myocardium contrast with implementation of material filter compared to without a filter.
- Qualitative analysis shown enhancement image quality for image obtained from Zn filter compared to without a material filter.
- The application of the material filter in SPECT imaging has the potential to enhance the quality of the images, so it can increase the accuracy in the interpretation.

**SP046 - Assessment of Radiotherapy Response**

**TRACK 04: RADIATION ONCOLOGY**

**SP046.1 - Early prediction of lung cancer recurrence after stereotactic radiotherapy using texture analysis of automatic graph cuts segmentations**

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**Purpose:** Stereotactic ablative radiotherapy (SABR) is becoming a standard treatment option for patients with early-stage lung cancer, and can achieve local control rates comparable to surgery. However, following SABR benign radiation induced lung injury (RILI) appears as radiographic changes on computed tomography (CT) imaging. These changes can be tumour-mimicking, making it difficult to distinguish recurrence from benign RILI. Current approaches do not reliably detect recurrence within a year post-SABR. Our previous work has shown the ability of CT texture features calculated within manually delineated regions of interest to predict recurrence post-SABR. The purpose of this study was to evaluate the accuracy CT texture features extracted within automatically derived regions of interest for prediction of eventual tumour recurrence.

**Methods:** We analyzed 22 patients with 24 lesions (11 recurrence, 13 RILI). Two regions of common post-SABR changes were manually delineated: consolidative and ground-glass opacities (GGOs) shown in red and green respectively in Figure 1. The consolidative regions were also automatically delineated using a OneCut graph cuts algorithm with the only operator input being the single line segment measuring tumour diameter, normally taken during the clinical workflow. Surrogate GGO regions were approximated by automatic expansion of the consolidative regions. Within the GGO regions, second-order texture features from grey-level co-occurrence matrices were calculated. Classification was performed using a linear Bayes normal classifier and evaluated using cross-validation (CV).

**Results:** Leave-one-out CV on images taken 2–5 months post-SABR showed robustness of the entropy texture measure, with classification error of 26% and area under the receiver operating characteristic curve (AUC) of 0.77 using the automatic segmentation: the results using a fully manual segmentation were 19% and 0.80 respectively. Using our fully automated approach, AUCs for this feature increased to 0.82 and 0.93 at 8–14 months and 14–20 months post SABR, respectively, suggesting even better performance nearer to the date of clinical diagnosis of recurrence.

**Conclusions:** Texture features calculated within GGO delineated from a fully automated algorithm using only an input diameter measurement have shown the potential to predict recurrence in individual patients within 6 months of SABR, eliminating the need for any manual delineations. Based on our ongoing validation on a larger sample, we aim to develop a computer-aided diagnosis system which can be integrated into a physician’s workstation to improve their assessment of response post-SABR. This could allow for earlier salvage for patients with recurrence, and result in fewer investigations of benign RILI.

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Parametric response map (PRM) analysis is a voxel-based image analysis method for predicting treatment response which shows promise as a means for guiding locally adaptive radiotherapy (RT) (e.g. sub-volume boosts). However to date, PRM predictive utility has been primarily verified with respect to global outcomes such as overall survival (OS). Here we investigated whether voxel-wise treatment response information can be inferred from a PRM analysis that has been correlated with OS.

PRMs were generated from rigidly registered MRI-derived apparent diffusion coefficient (ADC) maps (1 and 3 months post-RT) for n = 14 patients treated for high-grade glioblastoma. PRMs indicated whether each tumour voxel had undergone a significant increase, decrease, or no significant change in ADC. The fraction of the tumour volume (fractional volume) classified by the PRM as significantly increasing in ADC (FVinc) was the only PRM measure found to be significantly correlated with OS (p = 0.63, p = 0.02, Spearman rank test). FVinc values were then used to classify responding patients (R; OS > 18 months) in a receiver-operating characteristic analysis which produced an area under the curve of 0.92 (Fig. 1).

To investigate voxel-wise treatment response, the fraction of voxels in each PRM class that remained within the tumor boundary at 6 months post-RT was computed for each patient (Fig. 2). Despite the positive correlation with OS, significantly increasing ADC voxels (red) were found to be more likely to remain within the 6-month tumour volume compared to significantly decreasing voxels (blue) within the patient group.

In summary, the PRM showed potential for predicting both global and voxel-wise treatment response, however, the relationship between the two could not be directly inferred suggesting that rigorous validation for each target demographic is needed if the PRM is to be used to guide locally adaptive RT.

Using Magnetic Resonance Imaging Radiomics to Personalize Brain Metastases Treatment

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Purpose: For patients with brain metastases, early and accurate treatment selection is critical to maximizing quality of life and potentially extension to life. Prediction of response to stereotactic radiosurgery (SRS) informs personalized treatment selection. The classification of brain metastases as “homogeneous”, “heterogeneous”, and “ring-enhancing” has been shown to be predictive of overall survival (OS) after SRS [1], but is subject to inter-observer variability. Our objective was to improve OS prediction by developing and testing a radiomics software platform for quantitative assessment of brain metastases appearance.

Methods: Thirty-one brain metastasis patients (44 lesions) underwent routine gadolinium-enhanced T1 weighted magnetic resonance (MR) imaging prior to SRS. Each lesion was manually contoured and classified as “homogeneous”, “heterogeneous”, or “ring-enhancing” [1]. Image intensities were normalized using the brain ventricles as a statistical reference. Image features including the first-order image statistics, size and shape-based features, and gray-level co-occurrence (GLCM) textures averaged over 13 three-dimensional offsets were measured. Image features between the three contrast-enhancement groups were measured using the Kruskal-Wallis test followed by the Mann-Whitney U test. Correlations between image features and OS were evaluated using the Spearman correlation.

Results: The median time to compute 335 image features was 0.6 minutes/patient (range: 0.3 – 4.6) using a non-parallel and unoptimized MATLAB implementation. The three contrast-enhancement patterns showed significantly different first-order statistics (P < 0.0025) (Figure 1). Size and shape-based features and GLCM-based textures were not significantly different amongst the contrast-enhancement groups. Using the largest lesion in each patient as the index lesion, first-order energy showed a significant correlation with OS (rho = -0.61, P < 0.001). Range, 90th percentile, 99th percentile, surface area, normalized radial length entropy, correlation, and cluster prominence showed marginal correlations with OS (P < 0.05).
Figure 1. A heat map showing image features (columns) for each lesion (rows). Red and green indicate higher and lower standardized scores, respectively. (*), (†), and (‡) represent significant differences between homogeneous vs. heterogeneous lesions, homogeneous vs. ring-enhancing lesions, and heterogeneous vs. ring-enhancing lesions, respectively. A Bonferroni-corrected $P < 0.0025$ was considered significant.

Conclusion: First-order image statistics calculated by our radiomics platform correlated with expert qualitative classification of contrast-enhancement patterns, and first-order energy correlated with OS. Future work includes optimizing the calculation of GLCM-based textures and determining a combination of image features that can accurately predict OS for individual patients.

Reference

The purpose of this study is to explore whether Raman spectroscopy is able to assess the response of lung tumors and healthy lung tissue in mice following radiation therapy. 4T1 mouse breast cancer cells were injected intramuscularly to metastasize to the lungs at day 14. These, 4T1 cancer cells were injected subcutaneously into the flanks of 18 Balb/C female mice. Five additional mice were used as “normal lung” controls. After 14 days, cohorts of mice bearing tumors received 6, 12 or 18 Gy to the left lung with 6MV photons. Five mice were treated as “unirradiated tumor” controls. After 24-48 hours, lungs were excised and the specimens were sectioned for Raman measurements and pathologic evaluation using a cryostat-microtome. A total of 775 Raman spectra were collected; 107 from unirradiated normal lung tissues, 126 from unirradiated tumors, and 318 from tumors irradiated with 6, 12 or 18 Gy. Raman spectra were also collected from normal lung tissues of mice with unirradiated tumors (29) as well as irradiated (6, 12 or 18 Gy) tumors (195). Principal component analysis (PCA) and discriminant function analysis (DFA) were performed to analyze and interpret the results. Normal lung tissues and tumors were identified 100% of the time relative to pathologic scoring. Raman spectral data showed prominent results between unirradiated tumor and tumors receiving 12 or 18 Gy. Thus, in a model consisting of unirradiated and irradiated tumors (12 or 18 Gy) classification accuracies were 97.6%, 79.6%, and 80.5%, respectively, relative to pathologic assessment (see Fig.). Overall, 85.4% distinguishability was observed for unirradiated and irradiated (6, 12 or 18 Gy) normal lung tissues. Preliminary results demonstrate the promise for Raman spectroscopy in the prediction of normal vs. lung tumors as well as in the assessment of response of tumor and normal lung tissues following radiation therapy.

**Results**

32 patients were recruited, 27 completing all scans. On average, the GTV-T and GTV-N were reduced, at week 7 to 55±19% and 63±18% of their volume at week 0. Larger reductions were observed for all studied PET image features: on average, the GTVPET-T and GTVPET-N were reduced, at week 7 to 17±8% and 7±3% of their volume at week 0, and the SUVpeak was reduced by 33±4% and 41±8% for tumoral and nodal disease, respectively. On average, the maximum rate of change occurred early in the treatment for all image metrics considered in this study.

**Conclusions**

In a homogenous LA-NSCLC population, we have shown, using serial 4DCT and 4DPET images acquired during chemo-radiotherapy, that tumor anatomy and physiology change at different rate, and that the maximal rate of change in image features occurs early into treatment. These results may help determine the optimal time for adaptation of therapy. Correlation of image features and their respective rates of change with clinical outcomes is ongoing.
SP046.6 - Evaluation and Visualization of Radiogenomic Modeling Frameworks for the Prediction of Normal Tissue Toxicities

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We explore techniques for the evaluation and visualization of radiogenomic data-driven models in an effort to investigate the integration of genetic variations (single nucleotide polymorphisms [SNPs] and copy number variations [CNVs]) with dosimetric and clinical variables in modeling radiation-induced rectal bleeding (RB).

One hundred and twelve (N=112) patients who underwent curative hypofractionated radiotherapy (66 Gy in 22 fractions) between 2002-2010 were retrospectively genotyped for SNPs and CNVs in six genes: XRCC1, XRCC3, VEGFa, TGFβ1, ERCC2 and SOD2. A logistic regression modeling approach was used to assess the risk of severe RB (Grade≥3) using dosimetric, clinical and biological variables. Statistical resampling based on cross-validation was used to evaluate model predictive power and generalizability to unseen data. Principle component analysis (PCA) and vector biplots were used to visualize the quality of model fit.

Biological variable XRCC1 CNV showed good overall fit to RB outcome data (p<0.001). When added to the logistic regression modeling, XRCC1 CNV improved classification performance over standard dosimetric models by 33.5%. No clinical variables were found to adequately fit the data.

As a proof-of-concept, we demonstrated that the combination of genetic and dosimetric variables could provide significant improvement in NTCP prediction using data-driven approaches. Moreover, we have shown that visualization techniques could aid in interpreting multivariate model predictions.
**SP047.2 - Validation of a Commercial GPU-Based Monte Carlo Dose Calculation Algorithm for use with an Elekta MRI-Linear Accelerator**

**Author(s):** Moti R. Paudel¹, Anthony Kim², Syed Ahmad³, Arman Sarfehnia⁴, Stephanie Lim-Reinders⁵, Sami Hissoiny⁶, Michel Moreau⁵, Arjun Sahgal¹, Brian Keller⁶

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**Purpose:** A treatment planning algorithm from the commercial vendor Elekta® has been developed to be used with a future MRI-linear accelerator (MRI-LINAC). This is a GPU-based Monte Carlo dose calculation algorithm (GPUMCD) that is capable of modelling the magnetic field ($B$-field) associated with the MRI-LINAC. The purpose of this work is two-fold: 1) to validate the algorithm without the presence of the $B$-field as this algorithm can also be used to model a standard linac, and 2) to validate this algorithm, with the $B$-field activated, against an independent Monte Carlo algorithm (Geant4), as will be the case with the MRI-LINAC.

**Methods:** The research version of the Monaco TPS version 5.09.05 was used. This version contains the GPUMCD algorithm in addition to the XVMC algorithm that is in current clinical use. For the initial validation of the TPS for a standard linac, a beam model was created for an Elekta Agility linac for 6 MV. A heterogeneous phantom, simulating either bone-in-tissue, lung, tumour-in-lung, or steel-in-tissue, was designed and built to compare radiochromic film...
measurements with the ability of the TPS system to model the dose. We compared film measurements with the Monaco GPUMCD and XVMC algorithms and with the Pinnacle collapsed cone algorithm (CCC). In terms of B-field validation, an independent MC algorithm, Geant4 version 4.10, is being used to compare against Monaco.

**Results:** For the standard validation (no B-field), film measurements were done in the heterogeneous phantom for field sizes ranging from 1x1 to 10x10 cm², where a tumour in a lung was simulated, and these were compared with Monaco (1x1x1 mm³ dose grid resolution and 0.5% statistical uncertainty) and with Pinnacle. Our preliminary results indicate that Monaco GPUMCD algorithm shows good agreement with measurements for the comparisons done thus far. The largest differences were seen for the 1x1cm² field size, where the measured dose, in the lung region, was higher by 3.5% (compared to GPUMCD), 10% (compared to XVMC) and 14% (compared to CCC). Doses were relative to the depth of dose maximum and uncertainties will be discussed. There was negligible difference between the Monaco GPUMCD and XVMC algorithms for the other field sizes. The results for the B-field modeling are currently being generated and will be presented.

**Conclusions:** The Monaco GPUMCD algorithm showed good agreement with measurements. The agreement for this algorithm appears better at the small field sizes compared to Monaco XVMC and Pinnacle CCC algorithms.

### SP047.4 - 4D Monte Carlo simulation for verification of delivered dose to deforming anatomy

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**Objective:** To develop a dose calculation method using 4D Monte Carlo (MC) simulations that accurately reconstructs and verifies the dose delivered to a moving anatomy during radiotherapy treatments. The method is to be used for accurate dose calculations of dynamic radiation therapy treatment plans such as VMAT (Volumetric Modulated Arc Therapy) and IMRT (Intensity Modulated Radiation Therapy).

**Methods:** Quasar respiratory motion programmable phantom was used for measurements with an Elekta Agility linac. A square beam of size 4x4 cm² was chosen to cover the tumor (1.5 cm radius) inside the lung insert of the phantom and the source to axis distance (SAD) was 100 cm. The beam was delivered to the phantom in static (no motion) and moving (1.8 cm respiratory amplitude) states. Doses were measured using calibrated EBT3 film and RADPOS 4D dosimetry system.

Treatment planning was performed with XiO Treatment Planning System (TPS). Dose calculated by XiO was compared against results from measurements and MC calculations.

The EGSnrc user code BEAMnrc was used for simulating photon beams from the Elekta Agility linac. The DOXYZnrc and def-DOSXYZnrc user codes were used, respectively, for static and deforming anatomy dose calculations on the phantom file created from 4D CT-scans of the Quasar phantom, using the same beam configurations as in measurements. Dose calculation voxels were 0.25x0.25x0.6 cm³. Varian’s Velocity software was used to perform the deformable image registration of the tumor in different respiratory phases to the tumor in the static anatomy. Deformation vectors were then extracted and input to the defDOXYZnrc code to model the phantom motion during the dose calculation.

<table>
<thead>
<tr>
<th>Backscatter factors*</th>
<th>Aluminum</th>
<th>Bone</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGSnrc</td>
<td>1.076</td>
<td>1.029</td>
</tr>
<tr>
<td>Monaco</td>
<td>1.080</td>
<td>1.055</td>
</tr>
<tr>
<td>eMC</td>
<td>0.975</td>
<td>0.988</td>
</tr>
<tr>
<td>Measured</td>
<td>1.095</td>
<td>1.042</td>
</tr>
</tbody>
</table>

*Calculated and measured backscatter factors at 1 mm from the heterogeneity of interest.
Results: Table 1 shows the calculated and measured tumor doses and their uncertainties.

<table>
<thead>
<tr>
<th>Phantom</th>
<th>TPS</th>
<th>MC</th>
<th>Measured</th>
<th>%Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>MC/ TPS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Film</td>
<td>RADPOS</td>
</tr>
<tr>
<td>Static</td>
<td>120.7 ± 1</td>
<td>121.1 ± 0.6</td>
<td>118.9 ± 2.4</td>
<td>116.9 ± 2.4</td>
</tr>
<tr>
<td>Dynamic</td>
<td>-</td>
<td>110.9 ± 0.7</td>
<td>108.5 ± 2.2</td>
<td>112.7 ± 2.3</td>
</tr>
</tbody>
</table>

Conclusions: Our work demonstrates that 4D Monte Carlo calculations using the defDOSXYZncr code is an accurate method to calculate dose delivered in a moving anatomy.

This work was supported by OCAIRO grant.

SP047.5 - Clinical implementation of an EPID-based in vivo dose verification system for SBRT-VMAT delivery; catching errors

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Introduction: Most linear accelerators (linacs) used for radiotherapy are equipped with a mega-voltage electronic portal imaging device (EPID). Literature has determined the EPID to be a reliable dosimetric device. The portal dosimetry research group at CancerCare Manitoba has developed a set of physics-based tools which utilize measured EPID data acquired during treatment in order to reconstruct the 3D in vivo dose delivered to the patient. Our model can also predict the in vivo dose similar to a treatment planning system (TPS). Due to the hypofractionated regimen of stereotactic body radiation therapy (SBRT) treatments, a verification of the inter-fractional dose could provide additional safety for the patient because any error in delivery, when compared to conventional treatments, would have a greater radiobiological impact on the patient. In this study, the results of a one year clinical implementation test of our dose verification system will be presented for lung and spine SBRT-VMAT treatments.

Methods: Our in vivo model employs an inverse dose reconstruction method which combines a back-projected measured EPID focal fluence and a predicted linac-head extra-focal fluence. The primary in vivo patient dose is calculated by taking the total incident fluence on the patient, converting it to TERRA, and performing a collapsed cone convolution with Monte Carlo derived point-based dose deposition kernels. In vivo patient scatter dose is calculated through convolutions of the incident fluence with a library of Monte Carlo derived patient scatter kernels. Heterogeneities are accounted for through radiological scaling of the dose deposition and scatter kernels via electron densities from CT data.

Overall, 43 lung and 13 spine patients were treated over roughly a one year period using a Varian 2300ix model linac operated in 6MV SRS-mode. Continuous EPID images were acquired every 1.25-2.50 seconds. Fractions sizes were between 1 and 8 while doses were in the range of 6 to 24 Gy. All per-fraction data were compared to the Eclipse TPS dose calculation. Mean percentage dose differences and 3%/3mm gamma analyses were performed to compare the low dose voxel (LDV) regions (containing 20% of prescribed dose) and the high dose voxel (HDV) regions (containing 80% of prescribed dose).

Results: Three of the lung patients had significant errors in all fractions: mean HDV percentage differences and gamma pass rates were 10-20% and 50% respectively. A review of these three and seven other patient treatment histories (with less significant differences) revealed errors due to anatomical changes, patient setup, planning, as well as disruptions in EPID image acquisition. An average gamma pass rate of 90.6±8.3% and mean percentage dose difference of 4.8±1.9% were determined in the HDV region for the ‘other’ 40 lung patients. Due to the greater complexity and heterogeneity of the spine treatments slightly less agreeable results were determined.

Conclusion: A robust, EPID-based in vivo dose verification system has been employed clinically to test its feasibility in capturing inter-fractional SBRT-VMAT delivery errors. Significant errors were found which should encourage a full clinical implementation.

SP047.6 - pGPUMCD, a GPU-based Monte Carlo proton transport code

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Purpose: The most accurate dose calculations in proton therapy result from Monte Carlo algorithms. However their clinical implementation remains problematic due to long computation times. To accelerate these simulations, a GPU-based Monte Carlo transport code was developed. pGPUMCD is an adaptation for protons of GPUMCD, a validated GPU-based Monte Carlo code for photons and electrons. Implementation strategies and validation results are presented in this work.

Methods: In pGPUMCD, protons are transported in a voxelized geometry by a class II condensed history approach with a continuous slowing down approximation. Energy straggling is considered as well as multiple scattering. Ionizations are modelled and secondary electrons are not transported. Moreover, elastic and non-elastic nuclear interactions in water are considered based on an empirical model. pGPUMCD was benchmarked against Geant4. Simulations consisted in a mono-energetic, mono-directional circular proton beam of radius 1 cm impinging normally homogeneous or heterogeneous phantoms. Relative statistical uncertainties were derived from a history by history scheme and were below 1% in 1 mm³ cubic voxels containing 50% of the maximal dose. A Geforce GTX Titan was used in pGPUMCD while Geant4 simulations were done on a
Xenon-based CPU cluster. The evaluation of GPU/CPU acceleration was carried out without computation of statistical uncertainties and with a single 3.3 GHz Intel Core i3-3220 CPU.

**Results**: Considering only electromagnetic processes, proton transport with pGPUMCD yielded results within 6% of Geant4 values, with the largest errors in the Bragg peak for a speed-up factor of at least 300 compared to a single-core CPU execution. The transportation of one million protons of 230 MeV took 50 seconds with pGPUMCD and eight hours with Geant4. A complete dose validation is under evaluation with Bragg peaks, dose profiles and gamma studies for several materials and different energies.

**Conclusion**: GPUMCD now allows proton transport with pGPUMCD. Preliminary results suggest good agreement with Geant4 and significant savings in terms of computation times. Nuclear reactions in water were implemented in pGPUMCD and the validation is under investigation as well as the improvement of efficiency and computation time.

**SP048 - Dosimetry of Protons and Heavy Ions**

**SP048.1 - An Attempt to Predict the Proton Relative Biological Effectiveness using Radical Recombination**

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Most proton treatment facilities have adopted a relative biological effectiveness (RBE) of 1.1 for proton therapy. However, most of the in vitro and in vivo studies indicate that the RBE of the spread-out Bragg peak (SOBP) protons increases with depth. The increase in RBE of proton beams on the SOBP is a well-known phenomenon that is difficult to quantify accurately in vivo studies. The reason for this explains that the RBE increases as linear energy transfer (LET) increases within the SOBP. The fact that intra-track radical recombination can indicate to produce fully competent lesions in room. The purpose of this study was to analyze an impact on radical recombination for the RBE in the SOBP proton beams. First, a depth-dose curve for the 210 MeV proton beam measured using a gel dosimeter and an ionization chamber. Second, the spatial distribution of the physical dose was calculated by Monte Carlo code system PHITS; the role of nuclear interaction was taken into account and the geometry of the apparatus was faithfully reproduced. The simulation results were compared with measured the depth-dose distribution and very good agreement was found, and the spatial distribution of an LET-weighted dose with threshold LET value (4.9 keV/μm) was calculated by the same code. Then, the relative distribution of the radical-recombination was calculated from the physical dose and LET-weighted dose. The relative distribution of the radical-recombination was calculated at each depth as the quotient of relative dose obtained using physical and LET-weighted dose. The agreement between the relative distributions of radical-recombination and RBE was good at the SOBP.

**SP048.2 - A correction method for absorbed dose estimation using TEP-TLS/SR1 in therapeutic carbon beam**

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**Introduction**: TEP-TLS/SR1, a slab type tissue-equivalent thermoluminescence dosimeter, has the advantage of acquiring 3D dose distribution in a single irradiation. This property is favorable to be a QA tool for radiotherapy. One of the difficulties by means of TLDs in heavy ion dosimetry is the LET dependence of thermoluminescent (TL) efficiency. It has been reported that LET dependence of TEP-TLS/SR1 can be observed in not only the TL efficiency but also glow curve. The high temperature ratio (HTR) estimated using glow curve is a function of LET. Therefore it is possible to correct TL efficiency without information of LET for therapeutic carbon beam dosimetry. **Purpose**: The relation between HTR and TL efficiency is clarified and the feasibility of TEP-TLS/SR1 for carbon beam dosimetry is evaluated. **Methods**: An in house TL readout system was used to obtain the glow curve with high accuracy and low uncertainty. Each TLD chip was calibrated individually by absorbed dose to water in 60Co γ-rays. The TLD chips were irradiated by a 290 MeV carbon beam to clarify the relationships of HTR vs. LET (HTR-LET) and TL efficiency vs. LET (εLET). HTRLET and εLET at 60Co γ-ray were normalized to 1. The normalized TL efficiency (εLET, Y) as a function of HTR (HTRLET, Y) was obtained from two relation-
ships HTRLET and εLET. The feasibility of HTR correction for the TEP-TLSD/SR1 was evaluated using a carbon beam. Results: The HTR increased with LET, and TL efficiency showed exponential decrease with increasing LET. Dose difference at SOBP region reduced from 20-30% to 10-20% after HTR correction. Conclusion: A correction method for determination of absorbed dose in therapeutic carbon beam using TEP-TLSD/SR1 was developed.

The normalized TL efficiency as a function of HTR.

SP048.3 - Biologically-weighted dosimetric quantities based on a multiscale approach
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Particle therapy with protons and ions has gained increasing interest and its use has grown worldwide. Due to the different biological dose response of these types of radiation compared to high-energy photon beams, the current approach of treatment prescription is based on the product of the absorbed dose to water and a biological weighting factor. This method, however, is insufficient for quantifying the biological outcome of radiation, hence the need to define new dosimetric quantities that allow a separation of physics and biological processes.

“Biologically-weighted quantities in radiotherapy” (BioQuaRT) [1], a joint research project funded within the European Metrology Research Programme, uses a multiscale approach to lay the foundation for such new dosimetric quantities. This approach involves simulation and experimental techniques to determine the physical properties of ionising particle tracks on different length scales from a few nanometres (diameter of DNA) to micrometres (size of cell nucleus), which are then correlated with biological effects of radiation.

The present work focuses on the simulation aspect of the project – the development of a comprehensive multiscale simulation tool [2] that incorporates radiation interaction cross sections with DNA and production rates of radical species. This simulation tool is used to relate track structure characteristics at the nano- and micrometre level to biological consequences of radiation interaction, such as DNA strand breaks. This work has led to the development of existing Monte Carlo simulation codes dedicated to radiobiology, in particular PTRA [3] and Geant4-DNA [4], which is used as a base for the simulation tool. The incorporation of interaction cross sections of DNA-substitute materials (rather than the conventional use of water) as well as fragmentation cross sections used to derive DNA strand break probabilities are among the improvements.

This multiscale approach has the potential to underpin the definition of new biologically-weighted dosimetric quantities relating track structure to relative biological effectiveness in proton and ion beam therapy.

References:

Acknowledgements: The EMRP is jointly funded by the participating countries within EURAMET and the European Union.

SP048.4 - Studies of Helium and Carbon Ion Fragmentation processes in Water and in PMMA, using versatile Semiconductor Detectors
Author(s): Giulia Arico1, Jan Jakubek2, S Pospisil2, Naruhiro Matsu-fuji3, Oliver Jäkel4, Maria Martisikova2
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Background/Purpose:
Heavy ion radiotherapy enables a more conformed dose distribution to the target than conventional radiotherapy. Moreover, helium and carbon ions have additional advantages when compared to protons, such as a narrower penumbra. However, ions heavier than protons may undergo nuclear fragmentation processes within the patient. The consequence is a spectrum of lighter fragments which affect the delivered biological dose distribution. Currently there is a lack of knowledge regarding ion nuclear fragmentation processes. Our research aims to provide some of the relevant data. The information gained in this study might be used to benchmark Monte Carlo codes and to improve the accuracy of the treatment planning systems.

Materials and Methods:
We use a single particle registration technique to compare the fragments arising from ion beams crossing water and polymethyl methacrylate (PMMA), for different target thicknesses. Solid PMMA is often used in dosimetric measurements to replace water phantoms. The used Timepix detectors [Llopart et al. NIM A 581, 2007], developed by the Medipix collaboration, have a sensitive area of 1.4 cm² (256x256 pixels, 55x55 um pitch) and 300 um or 500 um
Results:

With the presented experimental setup, we analyse: 1) the percentage of primary ions which undergo fragmentation processes; 2) the number and kind of fragments arising from single primary ions; 3) the relative number of created fragments, for each fragment species; 4) the lateral particle distributions. Comparing the results obtained in water and PMMA targets with same water equivalent thickness, good agreement is achieved in thin targets, while greater differences are obtained above 100 mm-w-\text{eq} thickness. Monte Carlo simulations are also performed, for comparison.

Conclusions:

Timepix detectors are small and highly flexible devices, which enable to study fragmentation processes very close to the target. The presented comparison of ion fragmentation processes occurring in water and PMMA phantoms shows some limits in the equivalence of these two materials. The differences become higher with increasing the target thickness and should be carefully taken into account when PMMA is used in place of water for dosimetric purposes.

Acknowledgments:

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**SP048.5 - Monte Carlo study of secondary neutron dose for multipurpose nozzle in proton therapy**

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Two full rotating gantry with different nozzles (Multipurpose nozzle and Scanning Dedicated nozzle) with conventional cyclotron system is installed and under commissioning for various proton treatment options at Samsung Medical Center in Korea. Currently, an issue in proton therapy is to evaluate the influence of the secondary neutrons produced by nuclear interactions with the modules of nozzle and proton beam. In our proton facility, the multipurpose nozzle was composed of many modules such as scatterer, ridge filter, multi-leaf collimator (MLC), compensator, and aperture. Therefore, the purpose of this study is to investigate neutron dose in multipurpose nozzle for proton beam with Monte Carlo simulation.

A Monte Carlo studies with the Geant4 toolkit were performed based on multipurpose nozzle’s geometry (MLC, compensator, aperture, ridge filter, scatterer and etc) given by Sumitomo Heavy Industry and secondary neutron dose was simulated with 230 MeV proton beams and 5 cm SOBP using a 10 x 10 cm\textsuperscript{2} brass aperture in a 40 x 30 x 30 cm\textsuperscript{3} water phantom. At first, we calculated the neutron energy spectrum at water phantom surface. Next, we calculated neutron dose at isocenter, 20, 40, 60, 80, 100 cm distance from isocenter and compared with other research groups.

We used the phase space option of Geant4 toolkit to reduce the simulation time for repeated calculations and calculated neutron energy spectrum binned in 30 keV intervals on water phantom surface for wobbling beam at multipurpose nozzle. The portion of neutrons in the total neutron energy spectrum with energies less than 1 MeV and greater than 165 MeV were 53.5% and 43.8%, respectively.

Next, we calculated neutron dose at isocenter, 20, 40, 60, 80, 100 cm from isocenter and 2 different depths (surface and mid-SOBP) for the proton beam with and without water phantom. At a distance of 20 cm from isocenter, the neutron dose rapidly decreased because of the relatively small magnitude of the dose after lateral profile of the proton beam. In the water phantom, low energy neutrons were captured by an absorbing material (water) and high energy neutrons lost energy by inelastic collisions.

Neutron dose to water phantom for multipurpose nozzle under proton treatment conditions was simulated. The results of this showed comparable results with measured or simulated neutron dose of other proton therapy center. In future studies, we plan to investigate experimental measurement of neutron dose and validation of simulation data for treatment beam with additional neutron dose reduction method.

**SP048.6 - Investigation of the uncertainties involved in the low energy proton interaction in different MC-codes for proton therapy application**

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Background: High precision external radiation therapy can be delivered by protons with a strongly increasing energy deposition that creates a narrow peak of dose, called the Bragg peak at the end of the particle’s range and with sharp lateral dose fall-off, allowing to tailor the dose distribution to the target volume. The Monte Carlo (MC) method is an accurate and rigorous tool to simulate radiation transport and score energy deposition in heterogeneous media such as the human body. MC techniques have been implemented clinically for dose calculations in radiotherapy. The electromagnetic processes are well validated in different MC-codes, however there are discrepancies in nuclear models for low energy protons and therefore production of secondary particles such as neutrons. Neutrons contribute to out of field dose and in the long term may cause secondary cancers especially in children and young adults.

**Aim:** To Implement more accurate physics models and cross section for low energy proton interactions to be able to study secondary cancer induction related to primary protons in a clinical set up.

**Method:** Depth dose measurements were performed in the Svedberg Laboratory (TSL) proton therapy center at Uppsala University, Sweden, for a Gaussian shaped, mono-energetic beam with a energy of 178.25 ± 0.2 MeV using Scanditronix p-Si diode. The TSL beam setup was modelled and simulated with MC-codes Geant4.10.00 and MCNP6. Calculations were performed with the standard available models and cross section libraries of each code as well as importing new sets of cross sections for proton transport below 200 MeV from the TENDL-2012 library. The primary (proton) and secondary particle fluence (proton, neutron and gamma), proton depth dose and neutron equivalent dose were scored. The secondary particle fluence was filtered by several physics processes to find the process that causes the largest difference.
Results and discussion: The depth dose from protons is in agreement for both codes and measurements. However, there is a significant difference between both versions of Geant4 and MCNP6 in production of secondary particles despite of the use of same cross section library. The default version of Geant4 underestimates the production of secondary neutrons and overestimates the production of gammas compared with the modified version. The main difference between the default and modified version of Geant4 is due to proton inelastic process. The difference between the codes needs further investigation. The calculated neutron fluence must be verified with measurements.

Conclusion: The accuracy of models and cross sections implemented in different MC codes affects the accuracy of the dose calculation for proton beams and estimation of secondary dose calculation.

SP049 - Nanotechnology in Radiation Therapy and Imaging: Part 1

TRACK 06: NEW TECHNOLOGIES IN CANCER RESEARCH AND TREATMENT

SP049.1 - A plasma electrochemistry reactor enabling the rapid, efficient, automatic and on-site synthesis of radioactive gold nanoparticles for brachytherapy treatments

Author(s): Mathieu Bouchard, Stéphane Turgeon, Marc-André Fortin
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Gold nanoparticles (Au NPs) are increasingly considered for use as radioactive sources (198Au) for prostate brachytherapy procedures [1], [2]. The range of the 198Au β-particle (0.96 MeV, ~ 11 mm in soft tissue, ~ 1100 cell diameters) is sufficiently long to provide cross-fire effects of a radiation dose delivered to cells within the prostate gland, and short enough to minimize the dose to healthy peripheral tissues. The integration of 198Au NPs into brachytherapy procedures requires the development of more efficient, safer, and more compact Au NP synthesis methods. Indeed, because of their relatively short half-life (2.7 days), 198Au NPs should ideally be synthesized on site (directly in hospitals) and upon request. However, the current NP colloidal synthesis methods invariably rely on the expertise of skilled chemists. The preparation of NPs with current techniques comes with several manipulation steps (ligand exchange, solvent exchange, purification procedures), which represent critical radioprotection challenges. Therefore, novel bench-top technologies must be developed to facilitate the automated production of 198Au NPs. Here we report on the development of a plasma reactor used to synthesize Au NPs based on plasma-liquid electrochemistry (Fig. 1a) [3]. In this reactor, an argon plasma is generated at the surface of an aqueous solution containing gold salts (AuCl4-) and surfactant molecules. This method yields a continuous production of stable Au NP suspensions directly in water. Within only 45 minutes, a 50 mL solution containing 1 mM of AuCl4- can be reduced into NPs with a reduction yield of 99.3 ± 0.7 %. Thus-synthesized Au NPs are readily capped with dextran, a biocompatible molecule widely used in vascular injection media. The diameter of Au NPs can be tuned by varying the initial concentration of dextran in the solution. Finally, an integrated UV-visible spectrometer is used to monitor the Au NPs growth kinetics and their final size (Fig. 1b: plasmon peak: 531 ± 3 nm for 5 nm diameter NPs, 570 ± 4 nm for 120 nm diameter NPs), which is necessary for quality control. Overall, plasma electrochemistry could enable the efficient, on-site and upon request production of 198Au NPs for a next generation of brachytherapy procedures.

References:


SP049.2 - Dose Enhancement in Radiotherapy by Novel Application of Gadolinium Based MRIContrast Agent Nanomagnetic Particles in Gel Dosimetry

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The primary goal of radiotherapy is increasing dose in tumor cells and sparing normal tissues. One of the novel ways to achieve this goal is enhancing tumor dose by high atomic number (z) materials. Using high-z radiosensitizers in tumor cells could increase the effect of radiotherapy treatments through increasing photoelectric cross section and number of auger electrons. Advancements in nanotechnology made it possible to use nanoparticles in cancer imaging and treatments. Although many studies have been done on radiosensitization by different materials, most of them have focused on the dose response in the presence of gold nanoparticles. Of our knowledge there is not any experimental study on the radiosensitizing by gadolinium oxide (Gd2O3) nanomagnetic particles in brachytherapy and megavoltage beam radiotherapy. In this study we evaluate dose enhancement properties of gadolinium nanoparticle which is an MRI contrast agent in complex form. Because of increasing relaxation time and high atomic number (z=64), Gd2O3 can be used in image-guided radiotherapy. In recent studies there was a great interest on MRI guided radiotherapy, so it could be efficient to use an MRI contrast agent simultaneously as radiosensitizer in radiotherapy. Herein, dose enhancement in the presence of gadolinium oxide nanoparticles with 0.1mM concentration in a gel filled phantom was investigated. The results show maximum dose enhancement about 15%±0.01 up to 22%±0.02 in brachytherapy by Iridium-192, however this value is about 3.8%±0.002 in external beam radiotherapy with 6 MV photons. Our study approved radiosensitization property of this value is about 3.8%±0.002 in external beam radiotherapy with 15%±0.01 up to 22%±0.02 in brachytherapy by Iridium-192, however nanomagnetic particles with 0.1mM concentration in a gel filled phantom was irradiated by four X-ray beams with different spectra. For both types of beams, the incident number of particles was 108. Five nm width water slabs were positioned at a variety of depths behind the GNP in order to obtain the dose distribution of secondary electrons.

Results
In both proton and X-ray simulations it was confirmed that the dose enhancement effect occurred in both the depth and lateral directions. The effective area in the X-ray beam was shown to be much larger than that in the proton beam. However, the dose enhancement by protons was more intense near the GNP compared to that by X-rays. The results suggest that if GNPs are absorbed into cells or cell nuclei in high concentration, proton beams benefit by higher radiosensitizing effects than X-rays.

Conclusion
The dose enhancement effects of a GNP exposed to proton and X-ray beams was investigated in order to show the difference of dose distributions. A larger effective area was formed by X-rays while a higher enhancement in the vicinity of the GNP was observed in the proton irradiation. The results in this study suggest that the appropriate GNP concentration should be chosen depending on the type of radiation in order to obtain the maximum radiosensitizing effect.

SP049.3 - Monte Carlo simulation of the radiosensitizing effect by gold nanoparticles: comparison between proton and X-ray irradiation

Author(s): Jihun Kwon, Kenneth Sutherland, Takayuki Hashimoto, Hiroyuki Date
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Purpose
Radiosensitizer gold nanoparticles (GNPs) have recently drawn attention. GNPs target tumor cells by functionalizing proteins. When GNPs are irradiated, electrons are ejected, causing a dose enhancement effect. Although this effect is usually discussed in the context of X-rays, we have investigated the effectiveness under proton beam irradiation and shown that the dose enhancement occurs in both depth and lateral directions around the GNPs. In this study we compare the characteristics of dose enhancement between protons and photons.

Methods
The dose distribution around a 20 nm diameter GNP was calculated with the Geant4 Monte Carlo simulation toolkit for a 0.7 MeV proton beam and 6 MV X-rays. For the proton simulation, a GNP was exposed unidirectionally at 0.5 μm depth in a water box (10 μm × 1 μm × 1 μm) so that the Bragg Peak was formed at the approximate location of the GNP. In the X-ray simulation, two steps were used: (i) 6 MV photons were shot into a water cube (30 cm on a side) and the energy spectra was tallied by 1 nm diameter water spheres at 4 depths, (ii) a GNP inside a water box (10 μm × 1 μm × 1 μm) was irradiated by four X-ray beams with different spectra. For both types of beams, the incident number of particles was 108. Five nm width water slabs were positioned at a variety of depths behind the GNP in order to obtain the dose distribution of secondary electrons. In both proton and X-ray simulations it was confirmed that the dose enhancement effect occurred in both the depth and lateral directions. The effective area in the X-ray beam was shown to be much larger than that in the proton beam. However, the dose enhancement by protons was more intense near the GNP compared to that by X-rays. The results suggest that if GNPs are absorbed into cells or cell nuclei in high concentration, proton beams benefit by higher radiosensitizing effects than X-rays.

Conclusion
The dose enhancement effects of a GNP exposed to proton and X-ray beams was investigated in order to show the difference of dose distributions. A larger effective area was formed by X-rays while a higher enhancement in the vicinity of the GNP was observed in the proton irradiation. The results in this study suggest that the appropriate GNP concentration should be chosen depending on the type of radiation in order to obtain the maximum radiosensitizing effect.

SP049.4 - Colloidal quantum dots: radiation resistant nano-scintillators for radiation-based applications

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Purpose: CdSe quantum dots (QDs) optical properties have been investigated for many years. Their tunable luminescence emission peak, sweeping the visible range, has fed interest in these nanocrystals. Emission wavelengths are directly determined by the size of the QDs, which is well controlled during the nanocrystals synthesis. The choice of the scintillation light color provides flexibility for different applications and allows a predictable match to the best sensitivity range of photodetectors. In this work, we compare a novel CdSe colloidal quantum dots (cQDs) system with multiple layers to an existing CdSe/ZnS commercial sample. This study presents a radio-resistant scintillating quantum-dots formulation for multiple applications in different medical physics fields like dosimetry, imaging as well as other possible applications in nanotheranostics.

Methods: CdSe/CdS/Cd0.5Zn0.5S/ZnS multi-shell cQDs were grown through the successive ionic layer adsorption and reaction (SILAR) synthesis. The nanocrystals, in powder form, were incorporated to a fiber optic-based detector: the cQDs were placed at one extremity of a non-scintillating plastic collecting fiber, with the other extremity free to be coupled to a photodetector. A similar detector
was prepared with commercial CdSe/ZnS (Ocean NanoTech) QDs. Luminescence signal of the QDs was collected with a CCD camera (Apogee U2000C) to measure the integrated signal. Two devices were used to irradiate the QDs: an Xstrahl 200 orthovoltage unit for kV energies (120, 180 and 220 kVp) and a Varian Clinax iX for 6 and 23 MV.

Results: For all beam energies, scintillation intensity decreases as a function of dose cumulated. Damage caused by radiation creates trap states that enhance the proportion of charge carriers experiencing non-radiative recombination, hence decreasing their contribution to the scintillation light. This trend was already reported in the literature but here cQDs demonstrated a better resistance to radiation. For a 220 kVp beam energy, the multi-shell cQDs signal drop of 1.6% per kGy (38% decreases with 23.5 kGy of accumulated dose) compared to a 5% signal loss per kGy measured for the commercial monolayer QDs sample. Literature predicts larger signal drop at MV photon energies, between 500-700%/kGy for monolayer QDs. The commercial CdSe/ZnS QDs shows a similar behavior with a significant drop of 30%/kGy for a 6 MV beam energy, an effect not observed for our cQDs.

Conclusion: Loss of scintillation light production from initial measurement of our cQDs was found to be small and negligible for standard irradiation found in radiation therapy and medical imaging. Therefore, our multi-shell cQDs showed much better resistance to radiation than other commonly used CdSe/ZnS QDs. One could take advantage of this durability in making cQDs part of applications requiring a scintillating material, keeping in mind their particular property of size-tunable emission wavelength.

SP049.5 - Use of gold nanoparticles and pH-LIP (pH Low Insertion Peptide) to increase radiation effectiveness in cancer cells. 

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Gold nanoparticles have been shown to increase the effectiveness of radiation on cancer. Increased radiation effectiveness would allow for smaller radiation doses to be used on patients, reducing side effects; alternatively, more cancer killing can be achieved using the radiation doses currently in use.

Gold nanoparticles increase radiation effectiveness because they have a higher absorption rate than human tissue at photon energies around 100 keV, and because they release Auger electrons upon irradiation. The effect of these Auger electrons is very localized, which means that proper placement of the gold nanoparticles is crucial in optimizing the effect. In our recent experimental work, we used the cancer-targeting molecule pH Low Insertion Peptide (pH-LIP) to target the gold nanoparticles to tumors. pH-LIP has been shown to target tumors using the property that tumors are more acidic than normal human tissue.

Our experimental results show that the use of pH-LIP with gold nanoparticles causes a statistically significant increase in gold uptake by cancer cells, and that the gold nanoparticles locate mostly to the cell membrane. In a clonogenic experiment, cells exposed to gold and pH-LIP survived less well than control cells as well as cells exposed to gold nanoparticles alone, by a statistically significant amount.

These results suggest that the use of pH-LIP significantly improves the impact of gold nanoparticles on improving the effectiveness of radiation. In vivo studies are in preparation. Previous work by members of our research collaboration has shown that pH-LIP is capable of significantly increasing the amount of gold that locates to a tumor in a mouse model. Thus, it appears likely that pH-LIP will also increase the impact of gold nanoparticles on radiation effectiveness in mice.

SP049.6 - The use of nanoparticles to improve hadrontherapy

Author(s): Marta Bolsa-Ferruz, Erika Porcel, Noriko Usami, Katsumi Kobayashi, Olivier Tillement, Hynd Remita, Ryochi Hirayama, Yoshiya Furusawa, Vladimir Ivosev, Daniela Salado, Lenka Stefancikova, Sandrine Lacombé

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Radiotherapy, one of the main treatments in cancer, can be improved by the use of heavy atoms, as radiation enhancers. Many investigations are conducted in this area. The challenge is to increase the radiation damage on tumor whilst preserving healthy tissue by improving targeting. Recent developments in nanotechnology brought new perspectives by using nanoparticles, which can be specifically functionalized. We have shown recently that platinum nanoparticles enhance even more than platinum complexes the DNA damage induced as well by fast carbon ions [1], as by gamma rays [2]. This effect is not due to the nature of the incoming radiation but explained by the auto-amplification of electron cascades into the nanoparticles. This result finds strong interest for developing medical protocols such as hadrontherapy and nanomedicine.

Similar results were found with gadolinium based nanoparticles (GBN) which give the possibility to associate RMN imaging to radiotherapy. Furthermore, a decrease of mammalian cell survival was also observed when GBN are associated to ions radiation [3].

This last result allows us to measure how the use of heavy nanoparticles could improve treatments by enhancing efficiency and targeting of radiations into the tumor. The treatment could be simultaneously followed by MRI.


SP050 - Time-Frequency Analysis

SP050.1 - Frontiers of Neuroengineering
Neuroengineering field is seeing an explosive growth thanks to the major brain initiatives worldwide, and the belief that technologies that can push the scientific and clinical frontiers in brain sciences as well as diagnosis and treatment of the nervous system diseases and disorders. Technology is playing a key role from discoveries at cellular to whole brain level. Examples include nano and microprobes are used for recording from neurons, nerves and from many brain regions, and various imaging modalities using high resolution optical neuronal imaging to whole brain functional imaging. Neurotechnology is also playing a key role in diagnostic and therapeutic domains. Among the exciting frontiers are neural interfaces to restore function (limbs and visceral organs), treating brain disorders, neuropsychetics, and brain machine interfaces. This talk will overview the emerging technologies and key applications and successes driving the field of Neuroengineering as well as lay out several problems and challenges.

SP050.2 - Neural responses to hearing own names comparing with repeated/non-repeated unfamiliar stimuli

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Neural responses to self-related stimuli have been investigated to reveal the function of self-recognition. Subject’s own name (SON) is the word which closely related to self-recognition process. The present study focused on this own name stimulus and examined neuronal responses to hearing SON by measuring and analyzing electroencephalography (EEG), comparing with hearing unknown names.

Our experimental sequence consisted of calling SON and unfamiliar names (UN) those have no relationship with each participant. By this experimental sequence, we performed EEG measurements and analyzed the collected EEG data by wavelet transform. Then we obtained event-related (de-)synchronization (ERD/ERS) in each condition from wavelet coefficients.

In SON, we found significant beta ERD, while sUN showed beta ERS at the same latency. The mean value of beta power in rUN was midway between those of SON and sUN. This linearity of beta power changes seemed to be related with familiarity levels. SON was the most familiar stimulus among the stimuli, and stimuli of sUN were completely not because they were presented only once. The familiarity of rUN could be increased by repetition during an experiment, though it was not familiar one before the measurement. Considering these results, we suggest that beta power changes related with the familiarity levels.

The spectral analysis using Fourier Transform (FT) formalism shown to be very useful in a wide range of MRS applications. However, this technique can be tricky in some cases where peak superposition occurs, a common situation during in vivo data quantification process. This work describes an unsupervised deconvolution algorithm using Krylov Basis Diagonalization Method (KBDM) with multiple signal truncation and clustering. The KBDM is a fitting algorithm based on Lorentzian model functions and its mathematical approach is described at [1-4].

We exploited the fact that varying the number of points of the signal (M) used to construct the matrices aforementioned leads to different representations of noise components to minimize its effect in the estimation of each signal component. We applied the method multiple times with different values of M, clustering its results with a density-based algorithm and averaging the values of each cluster.

Our results show that using the proposed processing strategy, KBDM-estimated values are highly consistent with simulated values for different sets of spectra and noise level. The effects of the noise in the spectral quantification was not found to be critical, at least for simulated data with signal-to-noise ratio equivalent to that typically found in clinical MRS at 1.5T. In summary, KBDM is a promising tool that can provide complimentary information to the well-established Fourier techniques, especially when overlapping peaks are present. Further studies are in progress in order to validate the proposed method for in vivo data processing.


SP050.3 - MRS data deconvolution through KBDM with multiple signal truncation and clustering: circumventing noise effects

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The spectral analysis using Fourier Transform (FT) formalism shown to be very useful in a wide range of MRS applications. However, this technique can be tricky in some cases where peak superposition occurs, a common situation during in vivo data quantification process. This work describes an unsupervised deconvolution algorithm using Krylov Basis Diagonalization Method (KBDM) with multiple signal truncation and clustering. The KBDM is a fitting algorithm based on Lorentzian model functions and its mathematical approach is described at [1-4].

Basically, the output of the KBDM is a tuple (T2, frequency, amplitude and phase of each signal component) of M points obtained from a generalized eigenvalue equation of MxM matrices built using M points of the MRS signal. If only K Lorentzian components are present in the signal, the remaining M-K components will vanish for noiseless signal. When noise is present, it will be represented using Lorentzian components, which will lead to spurious components.

We exploited the fact that varying the number of points of the signal (M) used to construct the matrices aforementioned leads to different representations of noise components to minimize its effect in the estimation of each signal component. We applied the method multiple times with different values of M, clustering its results with a density-based algorithm and averaging the values of each cluster. The figure below shows the original noisy signal (top), the estimated signal using our method (middle) and the residual (bottom).

Our results show that using the proposed processing strategy, KBDM-estimated values are highly consistent with simulated values for different sets of spectra and noise level. The effects of the noise in the spectral quantification was not found to be critical, at least for simulated data with signal-to-noise ratio equivalent to that typically found in clinical MRS at 1.5T. In summary, KBDM is a promising tool that can provide complimentary information to the well-established Fourier techniques, especially when overlapping peaks are present. Further studies are in progress in order to validate the proposed method for in vivo data processing.

In vivo data processing.
Introduction: Rostral fluid shift during sleep can increase neck circumference (NC) and narrow the upper airway cross-sectional area (UA-XSA). Such narrowing in UA-XSA may increase turbulence of airflow passing through the upper airway; thus, induce snoring. The objective of this study was to investigate whether acoustic features of snoring change with the increases in NIV, NC and decreases in UA-XSA (100-4000Hz: r = 0.72, P = 0.019; 150-450 Hz: r = 0.73, P = 0.016) and UA-XSA (100-4000Hz: r = -0.71, P = 0.022; 150-450 Hz: r = -0.79, P = 0.006) were achieved in non-REM stage 2 of sleep.

Conclusion: Our findings suggest that an increase in NC and narrowing in the UA-XSA could increase snoring sounds’ power in various frequency ranges.

Method: Twelve men (age: 46±13 years, BMI: 26±3, AHI: 39±25) attended the sleep laboratory for a daytime sleep study. Subjects slept in supine position only, and their sleep was assessed by a regular polysomnography. NC and UA-XSA were measured before and after sleep using a measuring tape and acoustic pharyngometry, respectively. During sleep, snoring sounds were recorded with a microphone attached to the neck. Snoring segments were annotated manually by an expert. Snoring features such as duration and occurrence of snoring, average power for seven frequency sub-bands were extracted in various sleep stages as well as the entire sleep duration. Correlations between snoring features and changes in NC and UA-XSA were assessed by Pearson or Spearman’s correlations.

Results: Increases in NC after sleep were found to be associated with an increase in average power of the snoring sounds in the frequency range of 100–4000 Hz (r = 0.76, P=0.011) and of 150–450 Hz (r = 0.73, P=0.017). Furthermore, reductions in UA-XSA increased snoring sounds’ average power in the frequency range of 100–4000Hz (r = -0.70, P=0.025) and 150–450Hz (r = -0.64, P=0.044). Similar strong correlations between snoring sounds’ average power and changes in NC (100-4000Hz: r = 0.72, P = 0.019; 150-450 Hz: r = 0.73, P = 0.016) and UA-XSA (100–4000Hz: r = -0.71, P = 0.022; 150–450 Hz: r = -0.79, P = 0.006) were achieved in non-REM stage 2 of sleep.

Conclusion: Our findings suggest that an increase in NC and narrowing in the UA-XSA could increase snoring sounds’ power in various frequency ranges.
SP051 - Rehabilitation Robotics

SP051.1 - Biomechanical Simulation of Upper Extremities Exoskeleton to Aid Stroke Patients
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Recently many efforts are carried out that can help people with restricted arm movement or rehabilitate injuries and disabilities. In this case exoskeleton is the most extensively used equipment to get rid of this restriction. Exoskeleton helps to boost strength and endurance as well as reduce the efforts required to perform various activities in day-to-day life.

In order to manipulate characteristic of the exoskeleton, we carried out two virtual experiments. Initially using Denavit–Hartenberg parameters, we patronized our model with number of degree of freedom. ADAMS and AnyBody simulations were carried out. We computed results of effects over human body with and without exoskeleton.

While studying exoskeleton effect on human arm, we studied several joints, muscles and bones reactions in different load conditions. We studied two different load conditions while concentrating on performance of the exoskeleton. The very first condition was constant load where as the second one is the variable load acting on the arm. In both the case we considered gravity force to get more precise result. Below shown graphs are some of the results which we have explained later.

SP051.2 - Testing a mobile robot toy for children with disabilities
Author(s): Adriana M. Rios Rincon, Daniel A. Quiroga Torres, Javier Castellanos, Maria F. Gomez Medina, Antonio Miguel Cruz, William P. Rodriguez
School Of Medicine And Health Sciences, Universidad del Rosario, Bogotá/COLOMBIA

Robots showed a potential to enhance engagement in free play of children with severe motor impairment, however, they are too expensive to be used in low-income settings. The objective of this study is to perform technical assessment of a prototype of a low cost car-like robot that can be operated by head movements for children with motor impairment. We designed a robot that and tested its technical features. We found that the robot power efficiency is low (47%), current peak for both motors were 474.4 mA (right) and 416 mA (left) both of them were below 2 Amp which is the maximum current limit threshold tolerated by the L293B component, as the robots get far away from the control the response time slightly increased.

The reaching distance of the remote control was 20.7 meters which is enough for using in therapeutic activities. Regarding the functional features, the robot moved forward in a straight line 86.6% of the tested trials (26/30) and was able to turn 90 degrees left or right 93.3% of the trials (28/30). The robotic prototype met basic technical and functional requirements. Power efficiency, safety and apparel features should be improved for being used by children with using for children with motor impairments.

SP051.3 - Pilot study of a soft metal hydride actuator for a wearable rehabilitation system
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A prototype actuator for a wearable rehabilitation system was proposed in this study.

A wearable rehabilitation system has a potential to play an important role in remote rehabilitation to free patients from stressful constraints. It is essential for such a rehabilitation system to be reliably safe, compact, and silent. To meet these needs, we have developed a soft metal hydride (MH) actuator utilizing the property of a hydrogen storage alloy for a part of the rehabilitation system.

The soft MH actuator consists of a soft bellows made from laminated aluminum film (PE/Al/PET, 0.1 mm in thickness) as an end effector, a container of a hydrogen storage alloy as a source of bellows motion, and a thermoelectric device such as a Peltier device for temperature control (Figure 1). A hydrogen storage alloy can reversibly absorb and release a large amount of hydrogen gas by thermal control, i.e. cooling for absorption of hydrogen and heating for releasing hydrogen from the hydride (Figure 2(a)). By converting this reversible chemical reaction into bellows stroke due to the inner hydrogen pressure change, the soft MH actuator can generate high force by a compact device and realize silent operation and
Methods: Using a robotic system, 5 controlled flexion/extension motions are employed at progressively faster speeds to collect biomechanical resistive force, position, and time data in real time. Motions are performed in the individual's sagittal plane similar to functional motions of raising an object to their head or face. A linearly separable model quantifies the velocity dependent component of resistance and statistical model demonstrates the effect MAS scores have on the new velocity dependent resistance metric. This study considered healthy controls (n = 44) and individuals with an acquired brain injury receiving treatment for spasticity (n = 39). To determine the best representation, the quantitative spasticity metric was calculated once with flexion data, once with extension data, and a final time with data from both motions.

Results: The MAS, while augmented with an additional value to indicate healthy controls, was found to be significantly effect the metric calculated from both flexion and extension motions. This was true for both MAS bicep and tricep scores. Table 1 lists fixed effects for each of the 4 models.

<table>
<thead>
<tr>
<th>Effect</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAS Bicep (Flexion/Extension)</td>
<td>16.25</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>MAS Tricep (Flexion/Extension)</td>
<td>11.55</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Extension Only Data</td>
<td>1.99</td>
<td>0.0987</td>
</tr>
<tr>
<td>Flexion Only Data</td>
<td>5.19</td>
<td>0.0008</td>
</tr>
</tbody>
</table>

The metric can also distinguish between the high MAS scores (MAS 2, 3) and low MAS scores (healthy controls, MAS 0, 1) with values that were statistically significantly different.

Discussion/Conclusions: MAS bicep/ tricep scores demonstrated effects on the quantitative spasticity metric. The strongest relationship was determined for metrics calculated from both flexion and extension motions together. Flexion only calculations also found that MAS had a direct effect, whereas it approached significance with extension data. More studies and data is required to determine if a stronger relationship is achievable. The robot’s controlled and varied speed motions allowed for a calculation of a velocity dependent effect to quantify spasticity. These values are determined only from biomechanical data directly relatable to the MAS scale. This data can potentially aid clinicians in making treatment decisions and measuring progress or changes in spasticity.
SP052 - Functional Neuroimaging and Neuronavigation

SP052.1 - From human neuron to human brain: Neurosurgical contributions to understanding the brain
Author(s): Taufik Valiante
Director Of The Surgical Epilepsy Program, Krembil Neuroscience Center, Toronto/ON/CANADA

In this talk I will review neurosurgical contributions to understanding the human brain, particularly in the context of surgery for epilepsy and movement disorders. I will review early studies that have led to the understanding of localized cortical function, which formed the basis of initial attempts at understanding information processing within the brain. I will then describe ongoing work using electrocorticography and single unit recordings to elucidate fundamental human brain function including memory, attention, and language. The investigations that I will review will span many levels of investigations, from the activity of single human cortical neurons, to small cortical microcircuits, and then up to large scale integration – largely as a byproduct of the clinical care afforded to people with epilepsy. I will conclude by attempting to outline the limitations of current technologies to record from and control the human brain.

SP052.2 - Modulation of event-related desynchronization and synchronization during right finger flexion in patients with Amyotrophic Lateral Sclerosis
Author(s): Nataša Bizovičar
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Introduction
Amyotrophic lateral sclerosis (ALS) is a progressive neurodegenerative disorder with signs of upper and lower motor neuron degeneration. Potential electroencephalographic (EEG) methods for studying upper motor neuron and other cortical motor functions during the preparation and execution of volitional movements are so-called event-related desynchronization (ERD) and synchronization (ERS). ERD is a relative EEG power decrease pre- and during motor activity and is described as an electrophysiological correlate of an activated cortical network. ERS is a relative EEG power increase after termination of the movement and is an electrophysiological correlate of cortical areas at rest. The brain has the capacity to change the architecture of the neural networks during learning or as a response to injury. Diseases that affect neuronal networks such as ALS could have an impact on the change in absolute and relative EEG spectral power, its topography and time course. Our aim was to study ERD/ERS related to finger flexion in patients with ALS.

Methods
Twenty-one ALS patients (aged 54-74 years) and nineteen matched controls (aged 48-72 years) were assessed for their hand dexterity and strength, spasticity and functional rating scales. EEGs (10-20 system, 30 channels) were recorded while patients and controls performed self-paced fast right index finger flexion motor task. EEG time-frequency analysis was performed in the alpha (8-12 Hz) and beta (13-30 Hz) bands.

Results
Patients performed significantly worse on all hand function tests and had decreased hand muscle strength compared to control subjects. Latencies of the ERD beginning did not differ between the ALS patients and controls. Patients generated significantly smaller resting alpha spectral power density and lower beta ERS compared to controls. There was a larger difference in ERS between the contra- and ipsilateral brain hemispheres in the ALS group. No significant correlations between ERD/ERS and clinical measures were observed.

Conclusions
There are different morphological and functional changes in the brain of ALS patients described in the literature which could explain some of the changes in ERD and ERS. The reduction of beta ERS could result from the loss of pyramidal cortical neurons and asymmetry of ERS in patients with ALS compared to controls could be the result of interhemispheric corticomotor network degeneration in ALS.

SP052.3 - Functional connectivity patterns associated with swallowing of fluids with various viscosity
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Thickened dietary fluids are commonly deployed to prevent ordinary thin liquids from entering the airway of patients with certain swallowing disorders. Their mechanism of action has thus far been attributed to two possible explanations. First, rheological properties of the thicker fluids, may render them less likely to elude in the poorly-closed airway during swallowing. Alternately, the thicker liquids may adhere to the pharyngeal mucosa thereby reducing their rate of flow. However the possibility that thicker liquids cause perturbations in central sensorimotor processing has not been considered or investigated. Therefore, we investigated the influence of fluid viscosity on associated swallowing brain networks. EEG signals were collected from 55 healthy adults who performed five water, five nectar-thick, and five honey-thick liquid swallows. Standard preprocessing of EEG time-series was utilized and pre-processed signals were filtered in the frequency bands of interest. Brain networks were formed using the time-frequency based synchrony measure. Results showed that increasing fluid viscosity resulted in higher clustering coefficients in all frequency bands (p<0.04) (Figure 1.A), while the characteristic path length tended to be lower in the Delta, Theta, and Alpha frequency bands (p<0.03) (Figure 1.B). Brain networks formed during swallowing of thicker liquids had higher small-world parameters in the Delta, Theta, and Alpha frequency bands (p<0.05) (Figure 1.C). These results provide intriguing possibilities regarding the effects of peripheral manipulations on central processing of swallowing sensorimotor function. Further investigations of the neural basis of dysphagia are warranted to elucidate this and related possibilities.
SP052.4 - Distribution of F-Latency (DFL) - a new nerve conduction parameter for early detection of radiculo-myelopathy

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Distribution of F-Latency (DFL) is a new nerve conduction parameter conceived and named by the author several years back and who has led many researchers over the period in improving the understanding of the parameter and its application in early detection of radiculo-myelopathy. The method has been found to work equally for the cervical and the lumbo-sacral regions, however bulk of the systematic work carried out so far is for the former, particularly using the median nerve. Described for the median nerve, DFL is basically a statistical distribution of latencies of F-responses obtained through electrical stimulation of the nerve at the wrist and recording of the evoked muscle responses from the Thenar muscle group at the base of the thumb. F-response is the secondary response occurring due to antidromic conduction of action potentials in the motor nerve fibres from the wrist to the spinal cord, and then through random backfiring in a few percent of cell bodies contributing to action potentials through these backfired nerve fibres. Because of random recruitment of nerve fibres with different conduction velocity values, the F-latencies due to multiple stimulations vary randomly and this has been used to advantage in DFL to get a picture of the distribution of Conduction velocity (DCV) of nerve fibres as an approximate mirror image of DFL, thus contributing to a practical method to measure DCV in a clinical setting, which was not possible earlier. It has been found by groups led by the author that for normal subjects DFL has a single sharp peak while for subjects with cervical radiculopathy (entrapment of the nerve roots near the spinal cord) or myelopathy (compression of the spinal cord due to a vertebral disc bulging or herniation) DFL has double peaks or broad peaks. Hypotheses have been put forward in explaining the causes of the observed patterns which have been verified to a great extent through MRI investigations on the same subjects. Some of the broad peaks are very close to a single peak and a special criterion has been set up, based on a learning process using MRI on the same subjects through a research carried out in Singapore, again led by the author, to identify these subtle broad peaks from single peaks. Recently improved detection has resulted from changing the bin starting values in calculating the statistical frequency distribution that result in the DFL and combining the outcomes of the two distributions. Further work has been carried out in order to assess the minimum number of F-responses needed to differentiate the patterns of DFL in radiculo-myelopathy. It has been found that about 15 F-responses are adequate to distinguish the DFL patterns in the above detection if the bin size is chosen as 2ms. Through the combined procedure, almost 80% correct prediction have been obtained through a double blind study, when evaluated using MRI. It is expected that this method of DFL would become a first line screening test in any peripheral neuropathy in the near future.

Figure 1: (A) Mean clustering coefficient for a different threshold percentage and for different frequency bands. (B) Mean characteristic path length for a different threshold percentage and for different frequency bands. (C) Small-world parameter for a different threshold percentage and for different frequency bands.
SP053 - Cardiovascular Instrumentation

SP053.1 - A Microfluidic cell culture Instrument for individual testing of therapeutics.

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The realisation of personalised medicine has been the target of many multidisciplinary scientific teams. A system that can individualise patient care diagnostics has the potential to revolutionise medical treatment. Currently, drug discovery uses 2-dimensional cell culture techniques as a test to monitor the cells reactions to drugs these models have provided the platform for most toxicity and drug testing. However, the requirement of sample containers such as dishes or flasks are a limiting factor and do not lend themselves to automation. With a desire to understand and diagnose disease and infection at a patient specific and cellular level, there is a pressing need to modify procedures to facilitate multi-experimental approaches that are cost effective, automated and use small amounts of patient sample and reagents. This has encouraged us to develop a microfluidic droplet cell culture platform. The proposed system will create droplet cultures and facilitate incubation and imaging of the cultures on one platform. This system facilitates the establishment three-dimensional culture conditions that more accurately mimics natural cell conditions and cell-cell communication. The culture droplets are created in a nano-litre range and multiple unique bioreactor droplets can be prepared and analysed on one system making this a time and cost effective instrument. This system can benefit cancer diagnosis as multiple assays can be mixed with individual culture droplets. This lends itself to drug cocktail testing tested against a specific sample making this a powerful instrument in understanding cells.

SP053.2 - A Bioinspired Catheter Harnessing Gecko Adhesion and Inchworm-Like Locomotion for Targeted Drug Delivery

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1Interdisciplinary Graduate School, Nanyang Technological University, Singapore/SINGAPORE, 2Material Science And Engineering, Nanyang Technological University, Singapore/SINGAPORE, 3Cardiology Clinic, Tan Tock Seng Hospital, Singapore/SINGAPORE, 4Vascular Surgery, Singapore General Hospital, Singapore/SINGAPORE, 5School Of Physical And Mathematical Sciences, Nanyang Technological University, Singapore/SINGAPORE, 6School Of Chemical And Biological Engineering, Nanyang Technological University, Singapore/SINGAPORE

Invented more than 250 years ago, modern catheters have developed into a technological diagnostic/therapeutic medical instruments used in myriad applications such as catheterization, colonoscopy, ureteroscopy, dilating balloon and stenting. Some of the larger devices are capable of carrying sophisticated imaging and sensing modalities with robotic ultra-fine surgical instruments.

In recent years, smart-materials and advanced micro-manufacturing techniques have enabled the construction of millimeter-sized catheters capable of robotic bending and rotation, allowing catheters to maneuver deeper inside the patient’s body. However, a fundamental drawback is that catheters are pushed from the outside by the surgeon. This works well for large diameter vessels but poses many challenging issues for small diameter vessels. As the artery diameter decreases, increasing forces between the catheter and the vessel inner wall causes the catheter to buckle rather than advance. Moreover, the high friction caused by pushing the catheter, especially at curvatures, may result in life-threatening vessel injuries.

To resolve this, we have developed an alternative principle for catheter locomotion, here named SmartCat, an inchworm-inspired µ-robotic catheter that is powered by saline pressure. This self-pulling catheter is 2.5 millimeters in diameter, and can autonomously navigate the vessel at a speed of 2 cm/sec. The robots are batch-fabricated, and are thus suitable for mass production.

For safe implementation of the inchworm locomotion, hemocompatible gecko-inspired balloon clammers were developed. This gentle, reusable adhesive enables a dramatic reduction in the force required to achieve adequate vessel grip. In addition, these balloon clammers can also be used to form a close-off region for localized drug delivery.

(A) Prototype of an inchworm-robotic catheter prior to encapsulation within elastic silicone-gecko cloak, shown in (B). (C) Schematic of the inchworm locomotion principle.

SP053.3 - Covered stent with perforated membrane for treatment of peripheral atheroembolic disease

Author(s): Foad Kabinejad1, Mercedeh Kaabi Nezhadian2, Fangsen Cui1, Pei Ho1, Hwa Liang Leo2

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We have recently developed a novel stent membrane design for covered stents that prevents emboli while preserving the side-branch flows. Our earlier in vitro studies in models of carotid arteries have shown that this novel design can maintain more than 83% of the original external carotid artery (ECA) branch flow and has the potential to considerably reduce the chance of emboli release as compared to bare metal stents. In the present study, the application of this novel stent membrane design in the treatment of atheroembolic disease in peripheral arteries is investigated. The novel stent design has been tested in a PDMS model of superficial femoral artery (SFA) and its performance has been evaluated in vitro under physiological pulsatile flow condition, utilizing flow visualization (dye injection), and particle image velocimetry (PIV) techniques. These evaluations include the assessment of emboli prevention capability, side-branch flow preservation, and influence on the branch flow pattern and velocity field.
The novel covered stent demonstrated significant emboli prevention capability, and the flow in the side branches was smooth and uniform. This study demonstrated the potential of this novel covered stent design for the treatment of atheroembolic disease in peripheral arteries. However, further in vivo investigations of biological effects and mechanical performance of this covered stent design is warranted.

SP053.4 - Nanostructuring Carbon Fibre Probes for Use in Central Venous Catheters

Author(s): Jolene Mchugh1, Meixian Li2, Marco F. Cardosi3, James Davis1 1Nibec, School Of Engineering, University of Ulster, Newtownabbey/UNITED KINGDOM, 2College Of Chemistry And Molecular Engineering, Peking University, Beijing/CHINA, 3Lifescan Scotland Ltd, Inverness/UNITED KINGDOM

Central venous catheters (CVCs) and peripherally inserted central catheters (PICC) are vital access lines through which to deliver life preserving agents whether nutritional or chemotherapeutic. Remedial treatment could be employed that would enhance the communication has sought to investigate the design of a probe that would provide an early warning signal in changes to the localised pH at the electrode and thus it could be envisaged that the probe would provide an early warning signal that bacterial colonisation and biofilm formation of the line will result in infection which can often necessitate the complete removal of the line to prevent re-infection.

While there has been extensive research into the development of antimicrobial materials to minimise biofilm formation, there are no point of care diagnostics available to provide an early warning for the onset of infection. In most cases, infection is only detected once gross symptoms (typically fever and rigor) appear and has traditionally relied on the expertise and vigilance of the healthcare staff. As most CVC lines are maintained by outpatients, there can be obvious reluctance to present a false positive, the conditions can be missed and thus it could be envisaged that the probe would provide an early warning signal that bacterial colonisation and biofilm formation of the line will result in infection which can often necessitate the complete removal of the line to prevent re-infection.

The processing algorithm developed and applied to the RF defibrillator voltage and current waveforms were digitally recorded at 250 kHz sampling frequency using a digital oscilloscope (Tektronix TDS 3014B) and a current probe (Fluke 80i-110s) during internal cardioversion of patients with persistent AF using a novel low-tilt rectilinear waveform (generated by a radiofrequency defibrillator device) following a step up energy protocol (50V to 300V in 50V steps). However, typically, the recorded signals are inherently corrupted by electrical noise. The objective of this work was to investigate if it was possible to develop an algorithm, using digital signal processing (DSP) in the MATLAB environment, to denoise the AF defibrillation voltage and current waveforms by applying spectral analysis and digital filtering techniques. Specifically, the MATLAB algorithm was developed to automatically handle the large data files recorded during defibrillation therapy. Patient number and case number were used to automate loading of the associated defibrillation voltage and current waveforms and deduce the sampling frequency; based on a-priori rectilinear pulse width (12ms). The algorithm is designed to then select the desired waveform segment (part of the rectilinear signal at time between 2ms and 10ms) and denoises, generates and plots the filtered waveforms. Finally, the algorithm calculates the dynamic resistance (ICl) and present associated parameters.

Results: Analysing the spectrum of the processed rectilinear waveform signals enabled finding the most appropriate normalized cutoff frequency estimation. The study results provided this being between 0.01 and 0.02 (normalised frequency), which corresponds to 1125Hz - 2250Hz. The evaluation results also indicated that Hanning windowing was more appropriate than Blackman windowing in the spectral analysis preservation of the rectilinear waveform signals. Furthermore, noise reduction of these signals using a 7th order Butterworth filter design was found to be more efficacious in denoising than a 200 order FIR digital filter.

Conclusion: The processing algorithm developed and applied to RF defibrillator waveforms was effective for denoising voltage and current signals. This provides a useful tool for studying large number of patient cases in the characterisation of intra-cardiac impedance and its potential relation to other factors such as the outcome of cardioversion treatment and defibrillation energy threshold.
SP054.2 - The Historical Role of Women in Medical Physics

Author(s): Magdalena Stoeva1, Virginia Tsapakis2, Simone Kodlu- lovich3

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Women have always played a key role in the development of science. The first recorded information for women scientists dates back to over 10-20 centuries BC. Leading women scientists and philosophers during the antiquity have contributed towards the development of various scientific branches - Enheduanna (Sumerian astronomer), Agamede (ancient Greek physician), Merit Ptah (Egyptian physician), Tapputi-Belatekallim (Babylon chemist).

Although for centuries the scientific world was dominated by men, there are many gifted women who made key discoveries, inventions or overall scientific contributions. Whilst discussing the role of women in science, this is indisputably dominated by Marie Skłodowska-Curie – the brilliant physicist and chemist, the first woman to win a Nobel Prize, the first person to win two Nobel Prizes and the only person to win Nobel Prizes in multiple scientific disciplines.

Many other brilliant women have made their contribution to science – some of them with a direct relation to Medical Physics - Irène Joliot-Curie, Goepert-Mayer, Rosalyn S. Yallow, Harriett Brooks, Chien-Shiung Wu.

To mark the 50th Anniversary of the IOMP, national and regional medical physics organizations nominated medical physicists and other closely related professionals who have made outstanding contributions to the advancement of medical physics and healthcare through research, clinical developments, education and training activities, service development, and to professional matters over the last 50 years. Women medical physicists have been included in this Outstanding Contributions list as recognition for their devotion and contributions to Medical Physics - Penelope Allisy-Roberts, Carri-dad Borras, Maryellen L. Giger, Anchali Krisanachinda.

The trends in the contemporary scientific and working environment and women's dedication to science and practical application of Medical Physics lead to the formation of a number of women scientific and professional societies dedicated to the advancement of Medical Physics.

SP054.4 - Women in Medical Physics; current status in Australia and New Zealand.

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According to the recent data by Australian Institute of Physics, Aus- tralian schoolgirls still prefer life sciences to physical sciences with a 2:1 ratio. This worsens at university to about 4:1. The proportion of women in senior science positions is improving at just 1 per cent per annum, and even going backwards at lower levels.

In the specific case of medical physics, in Australia and New Zea- land, there have been some positive developments in enrolment of women into medical physics training and females now account for 30% of trainee medical physicists. This is can be considered an achievement considering that 15-20 years ago many departments would not have any or only a few female medical physicists.

However, there is still underrepresentation of women at senior roles and consequently a potential lack of role models for women earlier in their career. There is also a lack of suitable part time positions (es- pecially at senior levels) for women who would like to balance family and work commitments.

Additionally, while the public service is generally accommodating for working mothers, private practice centres can be a different story (long hours, lots of travel). As the ratio of private to public radiation oncology services increases it may result in a more difficult environ- ment for women and there may also be a pronounced gender bias in recruitment.

In conclusion, more work needs to be done mentor and support young women into sustainable careers in the physical sciences and engineering, including medical physics and biomedical engineering. Strategies need to be developed that will allow women success- fully balance their family and work commitments both in public and private sectors.
SP055 - Cellular & Molecular Mechanics

SP055.1 - Neurite outgrowth induced by shock waves

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Neurite outgrowth is one of important factors to restore neurodegenerative diseases, such as Parkinson’s disease and Alzheimer’s disease. One way to stimulate the neurite outgrowth is mechanical stimulation. For example, mechanical stretches were demonstrated to stimulate the neurite outgrowth [1]. Although mechanical stimulations are expected to be superior in treatment targeting, minimally invasive way of mechanical stimulation is required for realizing medical applications. Shock wave is one of the noninvasive ways to introduce mechanical stimulations. In addition with Extracorporeal Shock Wave Therapy (ESWT), recent studies demonstrated that shock wave could stimulate revascularization noninvasively [2]. In this research, we hypothesized that shock wave irradiation could stimulate neurite outgrowth. To verify the hypothesis, PC12 cells, a cell line of pheochromocytoma, were irradiated with shock waves. Before shock wave irradiations, PC12 cells were cultured with DMEM supplemented with 10% FBS, 5% HS, 1% L-glutamine and 30ng/ml NGF for 2days. After that, shock waves were irradiated 10 times/day for 6 days. Peak pressure of shock waves was 3MPa and irradiation frequency was 1Hz. Neurite outgrowth was quantified with NeuronJ (ImageJ add-on software) by measuring the length of selected neurites which were longer than cell bodies. As a result, neurite outgrowth was stimulated with shock wave irradiations on PC12 cells (Fig. 1(a), Fig.1(b)). With the shock wave stimulation, average length of neurites reached 268μm±95μm compared to 213μm±88μm in control cells without shock wave irradiations (Fig. 1(c), ***p<0.001). Through this result, we knew that neurite extension can be promoted by shockwave. Although it was revealed that shock wave could stimulate neurite outgrowth in PC12 cells, further study is required to clarify the mechanical and biological mechanisms by which shock waves promote neurite outgrowth.

REFERENCES
SP055.3 - Collagen fibrils from overloaded tendons show sites of discrete plasticity and overall perturbation in molecular packing

Author(s): Samuel Baldwin1, Laurent Kreplak2, J. Michael Lee3
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Tendons show the ability to resist rupture and to retain partial mechanical function after overload, characteristics which may have evolutionary importance. Understanding the origins of such intrinsic structural toughness, and the mechanisms of cellular response to damage, may provide important insights into tendon trauma and its treatment. Probing the nanoscopic structure of overloaded tendon has revealed an intriguing candidate mechanism. This process, termed discrete plasticity, was revealed by scanning electron microscopy to involve periodic kink deformations along individual collagen fibrils within overloaded tendon [1]. The influence of discrete plasticity on thermal stability of collagen, its enzymatic susceptibility, and its cellular response have been studied; however, the localized, nanoscale mechanical properties of the kinked structure remain unknown [2,3].

Previous work with atomic force microscopy on hydrated collagen fibrils has demonstrated the ability of peak force quantitative nanomechanical mapping as a probe of molecular density, mapping lateral packing variations along individual collagen fibrils by measuring compression modulus at tip velocities above 100μm/s [4]. Applying this methodology to fibrils displaying discrete plasticity resulted in high resolution maps of the localized molecular density of kinked structures formed along overloaded collagen fibrils (Figure 1.A). The resulting data demonstrated that the topologically discrete kinks are coupled with a decrease in molecular density along the entire fibril. This decrease can be attributed to an increased uptake of water when compared to control fibrils. High resolution maps of the same fibrils in a dehydrated state clearly demonstrate retention of D-banding axial packing structure throughout the kinked fibril with the exception of periodic fault lines at kink locations (Figure 1, B). This suggests that the axial register of collagen molecules, characteristic of collagen fibrils, is retained in regions spanning the kinked structures of the discrete plasticity phenomenon in collagen.

Figure 1: High resolution maps of the same kinked fibril representing (A) its compression modulus in the hydrated state and (B) its height in the dehydrated state.

References:


SP055.4 - Mechanobiology of Hepatic Cells and Engineered Construction of Liver

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Liver microcirculation is unique due to its complicated structure of sinusoidal nodes, in which multiple types of hepatic and/or hematopoietic cells interact with each other under blood flow in a three-dimensional (3D) environment. Adhesion of flowing leukocytes to liver sinusoidal endothelial cells (LSECs) or Kupffer cells (KCs) is crucial in liver immune responses. While it is known that two b2 integrins LFA-1 and Mac-1 play distinct roles in the most of organ-specific microcirculations, Mac-1 seems to be predominant in neutrophil (PMN) adhesion and crawling in localized inflammation while the role of LFA-1 is controversial in liver. We first compared the binding kinetics of LFA-1 and Mac-1 to ICAM-1s on mouse LSECs or KCs and found that the binding kinetics between these two integrin molecules is different when ICAM-1s were expressed on distinct cells, supporting that Mac-1 predominantly mediates the adhesion between leukocytes and LSECs and KCs. Next, we tested the flow-induced crawling of mouse PMNs on LSEC monolayer and observed that PMNs tend to migrate along the direction of shear flow and yield high crawling velocity and moving displacement than those under static condition, mainly mediated by LFA-1. Then, we also quantified the impact of substrate stiffness and microtopography on hepatic differentiation of stem cells using 3D in vitro sinusoidal model and engineered liver bioreactor, in which physiologically-mimicking microenvironment is critical for implementing hepatic functions. This work provides an insight for quantifying the intrinsic binding kinetics and the blood flow-induced crawling features of hepatic cells and proposes a novel 3D supporting system for liver function, from a viewpoint of mechanobiology.

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SP055.5 - Modelling and Understanding Normal Pressure Hydrocephalus

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Up to 10% of all dementia patients may actually suffer from Normal Pressure Hydrocephalus (NPH), a disease whose pathogenesis is not yet understood. The ventricles enlarge in this particular form of hydrocephalus, although the mean intracranial pressure (ICP) is not elevated. In this paper, the two main biomechanical hypotheses for the formation of NPH are examined by critically reviewing biomechanical models investigating the onset of NPH: 1) A transmantle pressure gradient between ventricles and subarachnoid space (SAS) widens the ventricular space mechanically, stresses the ventricular walls and causes edema leading to tissue damage. 2) Disturbed dynamics caused either by reduced compliance, vascular disease, malabsorption or obstructions of cerebrospinal fluid (CSF) pathways cause tissue damage. The different models are analyzed and contrasted with clinical findings in order to summon what could be gained by biomechanical model based analysis. It is the goal of this article to identify open questions that can be answered by biomechanical models.
SP055.6 - Osteolytic tumour involvement modifies characteristics of Collagen-I within the vertebral bone matrix impacting mechanical behaviour

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Vertebral mechanical integrity is diminished in the presence of metastatic disease. Modelling of the biomechanical behaviour of metastatically involved (MI) bones, however, has to date focused on structural changes alone, without accounting for the potential impact of alterations in bone quality (tissue level changes). More specifically, changes in the organic components of the bone matrix. This study aims to characterize vertebral structure, modifications in primary organic constituent of bone: Collagen-I and mechanical consequences due to the presence of osteolytic metastasis.

Osteolytic (n=8) vertebral metastases were generated in an athymic rat model via intracardiac injection of HeLa cancer cells. μCT imaging was used to quantify the stereologic distribution of mineralized tissue. Transmission electron microscopy (TEM) and high power liquid chromatography (HPLC) were used to assess the organic phase of bone. And finally, mechanical testing of spinal motion segments was conducted through stepwise loading (axial compression) in combination with time-lapsed μCT imaging.

Osteolytic tumour involvement (TI) caused an increase in trabecular spacing; and a decrease in trabecular number, spacing and tissue & bone mineral density compared to healthy controls. This indicates that osteolytic involvement reduced both the amount of trabecular bone and the mineral density of the remaining bone.

TEM revealed fibril misorientation in osteolytic specimens and a decrease in the fibril diameter of the collagen fibril matrix on the surface of bone adjacent to tumour lesions. HPLC analysis showed no impact of osteolytic disease on the collagen content in bone, but revealed a decrease in specific enzymatic crosslinks (deoxy-pyridinoline) and an increase in non-enzymatic crosslinks (pentosidine) indicative of the operation of reactive oxygen species produced by tumour presence and the resulting oxidative stress.

Osteolytic motion segments when loaded to failure also showed reduced peak failure loads and stiffness with bone failure being focal in nature and not causing major deformation throughout the entire structure with continued loading.

Osteolytic tumour involvement both reduced bone mineral density and caused changes within the organic phase of bone, negatively impacting the mechanical behaviour of bone. Identifying changes in the material phase of (MI) bone and establishing correlations between such changes and the material & mechanical properties/behaviour is critical for the establishment of a fundamental knowledge base needed for modelling and evaluating fracture risk and guiding future treatment options.

SP056 - Image Guided RT: Part 2

SP056.1 - Imaging Dose and Dose Pattern in Image-guided Radiotherapy of Cancers

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Purpose: To systematically evaluate cumulative doses to organs-at-risk from various radiological imaging procedures in image-guided radiotherapy (IGRT) and corresponding dose patterns in a large cohort of cancer patients treated at one institution in past four-and-half years.

Methods and Materials: With IRB approval, 4832 cancer patients treated at our institution during past four-and-half years were collected with their gender, age, circumference as well as all the radiological imaging procedures performed, which may include computed tomography (CT), kilo-voltage portal imaging (kVPI), megavoltage portal imaging (MVPI) and kilovoltage cone-beam computed tomography (kVCBCT). Correlations between patient’s size and organ dose were first established via Monte Carlo dose calculations in patient anatomy, and then used for patient-specific organ dose estimation. BEIR VII models were employed for radiation-induced relative risk estimation based on one’s gender, age and radiation dose.

Results: There were a total of 5298, 24173, 30605, 35110, 37509 and 9322 procedures performed on 202, 938, 1056, 1117, 1165 and 354 patients in 2009, 2010, 2011, 2012, 2013 and 2014, respectively. Among them, 3.6%, 14.2%, 23.8 and 56.4% were from CT, kVCBCT, MVPI and kVPI, respectively. In total, 92.8%, 90.3% and 68.5% of patients received 30 Gy or less doses to brain, lungs and RBM, respectively. Yet, 80 Gy or more doses were deposited to brain, lungs and RBM in 273 small-sized patients (maximum 136, 278 and 267 cGy, respectively), due largely to repetitive procedures and non-personalized imaging settings.

Conclusions: The cumulative imaging doses and associated cancer risks from multi-imaging procedures were highly patient-specific and lesion-dependent, with much higher doses and risks in pediatric patients. With personalized dose estimation, the impact of radiological imaging procedures can be accounted for effectively for clinical treatment planning and decision-making. This study indicated a pressing need for personalized imaging to maximize its clinical benefits while reducing associated cancer risks.
Results: The mean RSE for 10 patients are shown in Fig 1b. A minimum error of approximately 1 mm occurred between C3 and C4 and increased for C5-C7. The largest error was observed on Pt #1 (5.6 mm at C7), which was in part due to in-plane rotations, not compensated for during treatment. The estimated cumulative Dmax and their relative increase from plan (ΔDmax) are presented in Fig 1c and Fig 1d respectively. For five patients, the delivered Dmax exceeded 45 Gy with a maximum of 47.6 Gy (Fig 1c). The largest increase of 13.4% (5.6 Gy) was observed in Pt #1 due to the largest RSE.

Discussions and summary: In regard to the cumulative dose, 5 of 10 patients had the Dmax between 45 and 50 Gy, which exceeded the dose constraint of 45 Gy. Structures beyond the C spine were not included in this study due to the limited length of CBCT images. These results indicate that caution must be exercised during daily positioning of patients with head and neck cancers. Proper PRV margins must be developed to ensure that the maximum cord doses from setup errors, such as flexion, are within the maximum dose constraint over the entire course of treatment. Further research in this area is warranted.

SP056.2 - Residual errors and dosimetric consequences related to the spinal cord in head and neck radiotherapy

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Purpose: To estimate daily setup errors related to the cervical spinal cord and associated dosimetric consequences during head and neck radiotherapy.

Methods and Materials: Ten oropharyngeal cancer patients (stage IV, squamous cell carcinoma) were retrospectively selected. All patients were treated with volumetric modulated arc therapy (VMAT) with two full gantry rotations. A total dose of 60-70 Gy was delivered in 30-35 fractions. The spinal cord dose was constrained to be less than 45 Gy using an expansion margin of 5 mm (PRV). Cone-beam CT (CBCT) imaging was used for daily patient setup, and patients were immobilized with a thermoplastic mask.

In order to measure quantities at each spinal cord level, the spinal cord contours were split into “level” segments (Fig 1a). For the calculation of cumulative dose to cords, 1) dose distributions were calculated on all CBCT images using the original treatment plan, and 2) transferred and accumulated in the corresponding planning CT space using a deformable image registration algorithm. The maximum doses (Dmax) in the segmented cord volumes were reported. In addition, the residual setup errors (RSE) were calculated by averaging the deformation vectors in the level segments.

SP056.3 - An automatic dosimetric and geometric tracking system for head and neck adaptive radiotherapy

Author(s): Chang Liu1, Akila Kumarasiri1, Mona Kamal1, Mikhail Chetvertkov2, J. James Gordon1, Hualiang Zhong1, Farzan Siddiqui1, Indrin J. Chetty1, Jinkoo Kim1

1Radiation Oncology, Henry Ford Health System, Detroit/MI/UNITED STATES OF AMERICA, 2Medical Physics, Wayne State University, Detroit/MI/UNITED STATES OF AMERICA

Purpose: The ability to track geometric and dosimetric changes in tumors and organs at risk, over the course of fractionated radiotherapy is essential for proper adaptive radiation therapy (ART). To that end, we have developed an ART engine that integrates clinical processes and groups (Fig 1). The ART engine is fully autonomous and consists of several modules; data import/export, automatic dose calculation, deformable image registration (DIR), interactive DIR/report review, and messaging. 1) The data import/export module transfers data between the Varian Eclipse TPS and the ART database, implemented via the Varian DICOM DB daemon and the Eclipse Scripting API (ESAPI). 2) The automatic dose calculation module calculates the dose of the day (DoD) on CBCT images. 3) The calculated DoD is then warped via the DIR module to the planning CT for cumula-
SP056.4 - Morphological Analysis of Tumor Regression and Its Impact on Deformable Image Registration for Adaptive Radiotherapy of Lung Cancer Patients


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Deformational and mass changes associated with regression of the visible tumor during the course of fractionated radiotherapy have confounded the ability to perform accurate deformable image registration, subsequently limiting the clinical implementation of adaptive radiotherapy. This study sought to investigate the impact of tumor regression on the accuracy of deformable image registrations (DIR) and then to find a solution to improve the performance of DIR for treatment of lung cancer patients. Specifically, daily cone-beam computed tomography (CBCT) images were acquired from three locally advanced NSCLC patients. DIRs were performed from fractions 1, 10, and 20 to fraction 25 using a B-Spline-based algorithm implemented within the VelocityAI platform. To improve the accuracy of the B-Spline-based registrations in the region of regressing tumors, a hybrid finite element method (FEM) was developed with a mesh defined in a bounding box surrounding the tumor in the target image. The constraints of the FEM model were derived from the displacements generated by the B-Spline registrations. Using the displacement vector fields (DVFs) of the B-Spline and hybrid registrations, the source images were warped to their targets. The accuracies of the two registration algorithms were evaluated, using landmark points identified on both the source and target images, as well as quantitative analysis of the generated DVFs. For the three patients, average tumor volumes were reduced by 53% between fraction 1 and fraction 25. Comparison of landmark points showed that the mean errors of the FEM-based hybrid registrations were 1.4, 1.6, and 1.7 mm for the three patients. The average displacement differences between the B-Spline and FEM-hybrid registrations for the three patients were 4.8, 6.2 and 3.9 mm with a maximum of 15 mm for patient 2. Lung tissue does not move consistently with the shrinking tumor. The more the tumor regresses, the larger the B-Spline registration error in the tumor region. The proposed hybrid method that consists of the intensity-based image registration and mechanics-based tissue modeling to correct geometric changes induced by anatomical deformation and tumor regression, respectively, may have the potential to improve the quality of adaptive radiation therapy for lung cancer patients.
**SP056.5 - Assessment of a 4D-CBCT system for managing respiratory motion in Radiotherapy**

**Author(s): Yudy Ascencion¹, Rodolfo Alfonso¹, Raul Argota², Haydee Linares³**

¹Nuclear Engineering, High Institute for Applied Technologies and Sciences (InSTEC), Havana/CUBA, ²Radiotherapy, Institute of Oncology and Radiobiology, Havana/CUBA

**Abstract:**

Four-dimensional image guidance for correcting baseline shifts of tumors, affected by respiratory motion, has become available in the motion management option implemented inside the Elekta’s Cone Beam Computed Tomography (CBCT) system. Using this 4D-CBCT is particularly relevant when the tumor is localized in thorax, allowing reduction of target margins. The aim of this study was to design and test a procedure for appraising the performance of a 4D-CBCT system, intended to improve accuracy in treatment delivery of Stereotactic Body Radiation Therapy (SBRT).

**Material and Methods:**

Volumetric reconstruction accuracy (VRA), target displacement accuracy (TDA) and patient positioning accuracy (PPA), resulting from the use of the studied 4D-CBCT system (Elekta XVI VolumeView SymmetryTM), was evaluated under different acquisition and reconstruction conditions. A CIRS008A Dynamic Thorax Phantom was employed, which allows simulation of a breathing human torso, including insertion of «tumors» of different sizes and shapes. Static and dynamic phantom scans were performed with the CBCT system in 3D and 4D (SymmetryTM) modes. Resource sparing settings were additionally tested, decreasing the number of reconstructed phases per breathing cycle (PPBC), increasing the gantry speed (GS) or reducing image resolution (IR). The impact on accuracy of these modifications was investigated.

**Results:**

The acquisition of 3D-CBCT with static phantom was used as baseline for some parameters, as VRA and PPA. The results obtained with the CIRS008A phantom (with 2 cm spherical tumor insert) are presented in table 1.

Using the default settings suggested by the manufacturer (No. 3 in table 1), the 4D-CBCT ensures an adequate VRA, compared with the conventional 3D-CBCT (±1mm). Reduction of PPBC from 10 to 5 significantly degraded the VRA, emphasized when the GS is increased. An IR increment does not produce substantial benefits in VRA. A preset “shark fin” waveform with known amplitude in the three main axis was used for analysis for the TDA, evidencing that setting 7 guarantees optimal TDA with faster data acquisition and processing and much less data storage requirement.

**Conclusions:**

The methodology implemented allowed to verify the capability of theSymmetryTM tool for optimizing target localization in dynamic conditions, including internal margin assessment, which is not considered in the XVI acceptance testing protocol. It could serve as comprehensive guidance for commissioning and optimizing 4D-CBCT systems intended for IGRT, in low resource environments.

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<th>Setting No.</th>
<th>CBCT Acquisition mode</th>
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<th>PPBC</th>
<th>GS</th>
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<th>VRA [mm]</th>
<th>TDA [mm]</th>
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Table 1: Results of evaluated parameters in the CIRS008A phantom
SP057.1 - Sensitivity of VMAT patient specific QC devices to linac calibration errors

**Author(s):** Eduard Gershkevitsh, Mihhail Gershkevitsh

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**Purpose:** The aim of this study was to investigate the impact of linear accelerator calibration (dose and MLC) errors on 3D gamma analyses performed by four different devices for VMAT patient specific QC.

**Methods and Material:** Different calibration errors were introduced to the Linac and fifteen different VMAT plans (5 prostate, 5 pelvic nodes, 5 head & neck) were measured. The errors include 1) addition of 1.6 mm MLC leaf gap to all leaves; 2) shift of both MLC banks by 1.6 mm in one direction; 3) increasing dose output by 3%, decreasing dose output by 3%. For all conditions the treatment plans were measured with ArcCheck (Sun Nuclear), Octavius 4D (PTW Freiburg), Delta 4 (Scandidos) and Compass (IBA Dosimetry) devices. 3D gamma evaluation using local and global settings were performed. The original measurement (without intentional errors) results were than compared to those with errors and the ability of devices and used metrics to detect the errors were analyzed. Student’s T-test was used to evaluate the differences at 0.05 level.

**Results:** In total 300 measurements were made. The best results for the devices were achieved using 3D gamma index with 2% local dose difference and 2 mm distance to agreement criteria which identified most of the introduced errors (Figure 1). ArcCheck was able to detect 50% of the errors introduced in the present study using 3D gamma metrics while other detectors were able to do so for more than 70%. Compass was able to pick-up the most errors while performing 3D gamma evaluation only on PTV volumes. Octavius 4D was not able to detect the introduced gap to MLC for the pelvic nodes plans, whereas ArcCheck and Compass were not able to do so for the prostate plans.

**Conclusion:** 3D gamma analyses with 2%/2mm criteria identified more errors than 3%/3mm. Different devices can detect various errors and sensitivity to the introduced errors depends on the anatomical site/modulation complexity. Since not all errors were detected by the tested devices using 3D gamma index the alternative metrics would have to be employed to increase the sensitivity.

*Figure 1. Percentage of detected errors with 3D gamma metrics*
SP057.3 - Development of a Radiochromic Film Dosimetry Imaging System

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As radiation therapy treatment modalities advance, dose deliveries for cancer treatments have become more and more complex. Due to their advanced nature, these treatments call for increasingly high spatial resolution dosimetry techniques to verify that a prescribed dose is delivered accurately and precisely. Radiochromic film dosimetry has been adopted in the clinic as a convenient option for quality assurance because it provides high resolution, two-dimensional measurements, is essentially energy independent, and is near tissue equivalent. Unfortunately, it is not always easy to use due to imaging challenges with current readout systems.

Gafchromic EBT3 film (International Specialty Products, Wayne, NJ) is typically read out using an advanced flatbed scanner. However, difficulties overcoming imaging artifacts on these scanners, related to such factors as directional dependence of the dosimetry results with respect to film orientation and non-uniform sensitivity over the scanner area, have prompted the development of strict protocols for film readout and sophisticated image correction techniques. Even with strict protocols, reliable and reproducible dosimetry can be a challenge. To overcome these challenges, a simple readout technique based on components of the Vista optical CT scanner (Modus Medical Devices, London, Canada) was investigated.

In this work, a film readout system consisting of a digital camera and diffuse light box, interfaced with computer image acquisition software has been developed and characterized for the purpose of imaging film. The optical properties of the system, light field flatness and stability, and various calibration techniques were studied and optimized.

Fils are rapidly read out by averaging 100 images in 7 seconds, producing submillimetre digitized film data with a high signal-to-noise ratio. Single channel and triple channel film readout algorithms have been implemented and applied for dose processing. Validation tests examining simple irradiations as well as more complex dose deliveries (from IMRT, VMAT, and SBRT) showed that film imaging using our imaging system is orientation independent, and that good agreement (< 1.5% dose difference) is found using single channel dosimetry methods with red light illumination in the central region (15 x 20 cm²) of the light field (see Figure). However, when films are imaged near the perimeter of the light box, large dose discrepancies can be produced due to the non-uniformity of the light field (see Figure). Studies are currently underway to improve uniformity.

Overall, this simple imaging technique shows good promise to simplify and improve on existing film dosimetry readout. Further optimization of the system is underway.

SP057.4 - Implementation of MOSFET detectors for in-vivo radiotherapy dosimetry.

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Background: In vivo dosimetry is an essential part of radiotherapy (RT) and is recommended by national and international organisations. For patient undergoes radiotherapy for brain tumours or head and neck cancers, lens dose is concerned. Recently, ICRP review the dose to organs at risk (OARs) and reduced the lens dose limit to 50cGy. IAEA suggested that proper eye protection should be used for these patients. For patients undergo total skin electron beam therapy (TSEBT), in vivo dosimetry is important to verify the trunk dose, to ensure appropriate dose is given with sparing effect to the underneath organs. At Guy's and St. Thomas' hospital (GSTT), TLDs were employed for in vivo dosimetry, while it involves complicated pathway. MOSFET is handy and easy to use, it has been widely used in vivo dosimetry in recent years.

Methods. MOSFET characteristics including calibration factor, linearity, post irradiation stability, reproducibility, dose rate, beam angulation, beam energy, field size, temperature and attenuation effect were carried out. Phantom study was performed using MOSFET to measure the lens dose for brain tumour or head and neck cancer and trunk dose for TSEBT. Finally, clinical study was performed for lens dose measurements for two 3D conformal, two IMRT, two VMAT and three tomotherapy patients. Trunk dose measurement was performed for one TSEBT patient.

Results and Discussion. MOSFET sensitivity met the manufacturer’s specifications for linearity post irradiation stability and reproducibility. Further study is needed to verify beam angulation and temperature dependence, as our setup used was different from that of the manufacturer’s recommendations.

In phantom study, measurements by MOSFET exhibited less variation against treatment planning system (TPS) in both lens dose and trunk dose measurement (max. 2.84cGy and 5cGy respectively) compared to the TLDs (max 5.43cGy to 16.6cGy) respectively.

In real time in vivo lens dose measurement, MOSFET exhibited similar measured dose difference against TPS compared to TLD in most of the cases. It showed higher measured dose difference in a few cases, where technical or patients challenges may be encountered. The measured dose difference in lens dose between TLD and MOSFET were within 4cGy in 78% of cases. For radiotherapy treatment for brain tumour or head and neck cancer, this would contribute no more than 120cGy dose difference over a standard course of 30fractions and is within the acceptance tolerance in GSTT, which is 200cGy dose difference over the whole course of treatment.

Conclusion. The use of MOSFET for in-vivo dosimetry has some advantages and disadvantages. It is physically small and provides accurate real time measurement with simple calibration procedure. Time required for pre and post processing is minimal compared to TLDs. It serves as a good alternative for lens dose measurement in radiotherapy for patients with brain tumour or head and neck cancer. However, practical issues may need to be resolved prior to the application of MOSFET in trunk dose measurement in TSEBT.
Purpose: 1) To elucidate the clinical implementation of our offline 3D in vivo dosimetry method for daily patient-specific QA, and 2) to test a method for terminating treatment delivery if the online measured 3D dose distribution would result in a strong overdose in the patient.

Methods: Automatic 3D in vivo dose verification has been implemented in our department using a-Si EPIDs in combination with a back-projection algorithm, and is applied for almost all IMRT/VMAT and palliative treatments. Comparison of the EPID-based reconstructed and planned 3D dose distribution is done offline. In our current clinical workflow we measure the 3D in vivo dose distribution during the first fractions of a treatment. When deviations are detected, alerts are raised automatically and actions scheduled. Furthermore, a software package for online dose reconstruction has been developed, which processes portal images in real time. Hot spots are then sought in which the average cumulative reconstructed dose exceeds the average total planned dose by at least 20% and 50 cGy. The complete processing of a single portal frame, including hot spot detection, takes about 220 ms, which is faster than the frame rate of about 2.5 frames/s of the portal imager. The software was tested by irradiating an Alderson phantom with two arcs from a head-and-neck VMAT treatment when various types of serious delivery errors were introduced.

Results: 5766 treatment plans were verified in 2013; alerts were raised in 1397 cases (24%). Non-optimal implementation of our method in the clinic, and limitations of the dose reconstruction algorithm are the main sources of alerts. About 50% of the alerts during lung treatments are caused by anatomy changes, while during breast treatments about 50% of the alerts result from patient setup variation. The online dose reconstruction tests with the Alderson phantom showed that it was possible to detect hot spots in real time before dose delivery was completed. This information was able to generate a trigger to halt the linac in case of gross errors (see figure). This method would be complemented by offline dose verification to detect more subtle errors.

Conclusions: Our automatic offline verification method enables large scale clinical implementation of 3D EPID-based in vivo dose verification. A prototype online 3D dose verification tool using portal images has been successfully tested for various kinds of gross delivery errors, allowing to stop an irradiation in case of serious errors even before a full fraction is given.

Methods and Materials: Advanced test cases were conceived based on strategy proposed by TECDOC 1583, for assessing main sources of inaccuracy in dose calculations, provided the RTPS has successfully passed the conventional tests proposed by TECDOC 1583. A total of 6 test cases were designed and tested, employing three phantoms and implemented on two different RTPS.

Test case 1 (IMRT) has the purpose of verifying calculations with intensity modulated static fields. A CIRS IMRT THORAX phantom, model 002LFC was employed. Target and avoidance structures, beam arrangement and goals were adapted from the “CShape (harder)” test proposed in AAPM TG-119.

Test case 2 (highly conformed arc) is intended to verify calculations with dynamically conformed arcs. The target is a very irregular structure, which demands rapid changes of the dynamic MLC shape with the gantry angle. The same phantom as test case 1 is used.

Test case 3 (SRS-head): is used for checking calculations in small field conditions with stereotactic positioning devices and dynamically conformed arcs. A home-made skull phantom was used.

Test case 4 (SBRT-frame-based) verifies calculations with small fields in low density tissues, including positional accuracy using stereotactic body frames. The same phantom as test case 1 is used.

Test case 5 (SBRT-IGRT): similar to case 4, but using IGRT system.

Test case 6 (4D-SBRT) utilizes a dynamic thorax phantom (CIRS S008A) for evaluating dose calculation features under respiratory motion conditions.

Results and Discussion: Results of test cases are summarized in Table 1. Relative errors are compared with agreement criteria adapted from AAPM TG-119 and TECDOC 1583, considering complexity of case analyzed.
**SP057.7 - Implementation of statistical tolerance for patient specific QA and independent monitor unit calculation**

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Département De Radio-oncologie, Centre intégré de cancérologie de Laval, Laval/QC/CANADA

**Purpose:** Standard and arbitrary tolerance for patient specific QA and independent monitor unit calculation were replaced by statistical tolerance based on past clinical results. The implementation of these tolerances was evaluated over a period of two years.

**Materials and Methods:** Patient QA results were collected and analysed statistically. They included ionization chamber dose difference, ArcCHECK (Sun Nuclear Corporation, Melbourne, FL) gamma factor passing rate, and radiochromic film gamma factor passing rate. Gamma factors were calculated with 3% absolute dose and 3 mm distance thresholds. Results from the ionization chamber and the ArcCHECK were divided in different categories based on the treatment plan complexity: 3D conformal (including wedge field), forward planning step and shoot, inverse planning step and shoot and VMAT. Radiochromic film were only used in patient QA when the modulation of the treatment plan was estimated to be very high, therefore the results were not divided into categories. For electron treatment plan, the difference between the measured and calculated depth of the isodose of prescription was also included. In addition, treatment field monitor unit difference calculated by the treatment planification system and the independent system were also included in the analysis and divided into several categories: open, wedge, forward planning step and shoot, inverse planning step and shoot and VMAT. Outliers were removed from each distribution. If the distribution was normal, parametric statistics were used, otherwise non-parametric statistics were used. A first set of tolerances was define has the 95% confidence interval of the dataset (or the range for 95% of the observation for non-parametric dataset). A second set of tolerances was defined at 99%. Results that were beyond the first tolerances required an investigation but were still deemed acceptable whereas results beyond the second tolerances were unacceptable.

**Results:** These new tolerances were tested for a period of two years. In most cases, test results that fall beyond tolerances were caused by a preparation error and were easily corrected. In other cases, the errors encountered were real and significant. For example, ionization chamber measurement would sometime fall outside tolerances when a plan was highly modulated. This situation led to the improvement of our QA procedure by using a smaller chamber less prone to this error. In another situation, large differences in the depth of the prescription isodose led to the discovery of a calculation error in our independent monitor unit calculation system in some conditions. In

### Table 1. Discrepancies of calculated and measured dose

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>1. IMRT</td>
<td>XiO</td>
<td>Target</td>
<td>209.9</td>
<td>204.4</td>
<td>-2.62%</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OAR</td>
<td>70.99</td>
<td>53.97</td>
<td>-8.11%</td>
<td>5</td>
</tr>
<tr>
<td>2. Highly Conformed Arc</td>
<td>XiO</td>
<td>Target</td>
<td>218.8</td>
<td>224.0</td>
<td>2.38%</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OAR</td>
<td>201.3</td>
<td>201.6</td>
<td>0.14%</td>
<td>5</td>
</tr>
<tr>
<td>3. SRS (head)</td>
<td>ERGO++</td>
<td>Target</td>
<td>206.0</td>
<td>200.0</td>
<td>-2.91%</td>
<td>4</td>
</tr>
<tr>
<td>4. SBRT (frame-based)</td>
<td>Precise-Plan</td>
<td>Target</td>
<td>288.0</td>
<td>292.0</td>
<td>1.39%</td>
<td>4</td>
</tr>
<tr>
<td>5. SBRT (IGRT-based)</td>
<td>XiO</td>
<td>Target</td>
<td>298.0</td>
<td>292.0</td>
<td>-2.01%</td>
<td>4</td>
</tr>
<tr>
<td>6. 4D-SBRT</td>
<td>XiO</td>
<td>Target</td>
<td>376.4</td>
<td>354.0</td>
<td>-5.95%</td>
<td>5</td>
</tr>
</tbody>
</table>

*Error [%] = 100*(Dcalc-Dmeas)/Dmeas,ref

**Conclusions:** Proposed test cases demonstrated being very useful not only for assessing RTPS dose calculation accuracy, but as comprehensive end-to-end verification of the overall process.
some rare instances, small calibration errors of the linac were detected using these new tolerances. None of these errors would have been detected with the conventional arbitrary tolerance.

**Conclusion:** Building new tolerances based on clinic statistical results provides an increased sensitivity of the QA program to errors that may otherwise remain undetected using conventional tolerance.

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**SP058 - Characterization of Detector Systems for Therapy Dosimetry: Part 1**

**TRACK 05: DOSIMETRY AND RADIATION PROTECTION**

**SP058.1 - Destructive backscatter-based readout of polymer gel dosimeters: proof of principle**

**Author(s):** Warren G. Campbell¹, Derek M. Wells², Andrew Jirasek³

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A new method is introduced for evaluating the radiation-induced polymer distributions in polymer gel dosimeters. Destructive backscatter-based readout (DBBR) involves the careful slicing and scanning of dosimeters using dual chromatic scans (e.g., red and blue). Spectral differences in scatter attenuation coefficients cause blue light to be more likely to be scattered by polymers than red light. Comparing the intensities of backscattered red and blue photons allows one to evaluate polymer density.

Two polymer gel dosimeters were irradiated, sliced and scanned using the DBBR method. Scans of central slices in two different irradiation patterns were acquired using a flatbed scanner, and ['blue channel' – 'red channel'] images were used to measure polymer distributions. DBBR scan results were then compared against dose distributions calculated by treatment planning software, and select regions of interest (ROIs) from each scan allowed for quantitative comparison between DBBR values and dose. For comparison, reconstructions were also obtained for the same dosimeters (prior to their destruction) using a fan-beam optical computed tomography (CT) scanner.

Results demonstrate that DBBR is a feasible method for polymer gel dosimeter readout. The new method shows great potential, especially in comparison to optical CT results. The following figures are provided for this short abstract. For more details and discussion, see the full paper abstract.

![Fig. 1: Dose images for two irradiation patterns – a star pattern and two dosages of a cross pattern – are shown in (a) optical CT reconstructions, (b) TPS-calculated dose distributions, and (c) DBBR scans. Circular ROIs, 5 mm in diameter and indicated in (b), were used for DBBR-to-TPS comparisons and DBBR calibration.](image)
Fig. 2: Plots of ROI comparisons between DBBR and TPS images are shown for (a) blue and red channels, and (b) blue minus red. Plot points are means and error bars indicate ±1 standard deviation.

SP058.2 - New Detector Systems for the Dosimetry in Radiation Therapy

Author(s): Viktor Iakovenko1, Stephan Brons2, M Campbell3, O Kov- alchuk1, Xavier Llopart3, Immaculada Martinez-Rovira4, S Pospisil5, V Pugatch1, Yolanda Prezado4, Iurii Sorokin1

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The main goal of radiotherapy is to deposit a high dose of ionizing radiation in a tumor while keeping the absorbed dose in the surrounding healthy tissue at a tolerable level. Current developments in radiation therapy require non-destructive beam profile monitoring devices providing dose distribution measurements and imaging in real time. For this purposes a Micro-strip Metal Detector (MMD) has been developed [1]. Physics and techniques of this detector for the dosimetry, measuring and imaging charged particles and synchrotron radiation beams are discussed. An extremely low thickness (~1 μm) of the MMD in combination with its high radiation tolerance (~100 MGy) introduces an opportunity to keep a device in the beam permanently [2]. MMD as well as metal-mode of micropixel detector TimePix have been successfully tested at the Minibeam Radiation Therapy (MBRT) setup (Bio-Medical Beamline ID17, ESRF) [3]. These detectors were explored also in recent studies at Heidelberg Heavy-Ion Therapy Center (HIT) devoted to the evaluation of the prospects of spatially fractioned hadron therapy. Hadron multi-beam structures have been created by the collimators with different shape. Holes or slits were made in aluminum, brass or tungsten (50 mm thick) samples to arrange different multi-beam structure shape (“MATRIX” or “SLIT” structure). Measurements were carried out at HIT with protons (86.72 MeV, 150.95 MeV), carbon ions (100.07 MeV/u and 200.28 MeV/u) and oxygen ion beams (233 MeV/u). MMD and TimePix were applied for the beam intensity and overall beam profile monitoring. For spatially fractioned techniques the peak-to-valley dose ratio (PVDR) is an essential value that defines the efficiency of the MBRT. Both detector types provided PVDR results in excellent agreement with the radiochromic films data.

MMD and TimePix have shown a reliable performance for online beam profile monitoring. Calibrated detector could be used for dose monitoring in real time. The results of our studies suggest the possibility of MMD application in clinical practice. Their implementation will improve beam delivery to tumor tissue, fast imaging and evaluation of data, optimization of treatment regimes.

References:


SP058.3 - Dose response evaluation of lung equivalent gel dosimeters by use of a new fitting algorithm

Author(s): Farideh Pak1, Hassan Ali Nedaie2, Abbas Takavar1, Hamid Salighedarad3, Vahid Vaezzadeh5

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Low signal to noise ratio (SNR) images of lung equivalent gel dosimeters compare to unit density gels, necessitate use of a different fitting method for data analysis. In this study a new fitting method (SQEXP) based on noise correction was introduced and its’ feasibility for quantifying absorbed dose in lung equivalent gels was investigated. The effect of new method was studied in term of dose sensitivity, linearity and correlation of calibration curve for both unit and low density gel dosimetry. The results were compared to conventional (Truncation) and a newly introduced method (VAREC).

Dose response of low density gel dosimeter showed wider detectable dose range (up to 20 Gy) against unit density gel dosimeter (10 Gy). It seems that reaction of excess amount of anti oxidant with hidden oxygen inside of styrofoam beads is responsible for this difference between low and unit density gel dosimeters. Relatively more sensitive calibration curve was obtained by SQEXP method in bothtype of gel dosimeters. Effect of signal denoising was more significant in low density gel dosimeters when high doses ≥10 Gy were absorbed by the gel. Detectable dynamic dose range of low density did not change by different fitting algorithms but in unit density gel dosimeters it was reduced by VAREC method. Dose sensitivity of low and unit dosimeters was reduced by use of VAREC method.

The SQEXP method seems to be more effective method than conventional algorithms for analysis of low density gel dosimeters especially where steep dose gradients exist such as in intensity-modulated radiation therapy (IMRT) and stereotactic radiosurgery (SRS).
Visible photoluminescence (PL) of pure LiF crystals irradiated with clinical proton and carbon ion beams has been investigated. The PL response was defined as the PL peak intensity measured at 670 nm when the irradiated pure LiF crystals were excited using the 458 nm line from an Argon laser operated in continuous mode at 25 mW. The emission band centered at 678 nm is due to the formation of F2 colour centres, stable at room temperature. Sets of three commercially available LiF crystals (5x5x0.5 mm³) were simultaneously irradiated. A custom-designed PMMA holder, diameter 30 mm, containing the LiF crystals, was positioned at 2 cm depth (dose plateau) in a PTW horizontal type water tank. The PL vs. dose (ab sorbed dose to water) was assessed for the intermediate energies of 148 MeV and 278 MeV/u for the proton and carbon ion irradiations, respectively. All irradiations were performed using a scanning beam system (AAA, Varian, Palo Alto, CA). The emission band centered at 678 nm is due to the formation of F2 colour centres, stable at room temperature. Sets of three commercially available LiF crystals (5x5x0.5 mm³) were simultaneously irradiated. A custom-designed PMMA holder, diameter 30 mm, containing the LiF crystals, was positioned at 2 cm depth (dose plateau) in a PTW horizontal type water tank. The PL vs. dose (absorbed dose to water) was assessed for the intermediate energies of 148 MeV and 278 MeV/u for the proton and carbon ion irradiations, respectively. All irradiations were performed using a scanning beam covering a 6x6 cm² field size. The PL vs. dose in the 2-20 Gy range exhibited a fairly linear behavior for both the proton and carbon ions irradiations, as shown in figure 1. In an independent set of irradiations, a test dose of 5 Gy was given to six sets of three LiF crystals at 62, 148 and 197 MeV for protons and 115, 278 and 380 MeV/u for carbon ions, in order to evaluate the PL signal dependence with beam energy. The response to the 5 Gy test dose for protons was within 3%, while the carbon ions response decreased systematically with increasing beam energy. The PL intensity observed at 115 MeV/u was 30% higher than the one observed at 380 MeV/u. In order to test the dosimetric capabilities of the LiF-PL system, two spread out bragg peaks (SOBP) irradiations were performed at 15 cm depth using beams in the 129-163 MeV and 248-316 MeV/u range for protons and carbon ions, respectively. The proton SOBP dose evaluation was correctly predicted by applying the proton calibration derived at 148 MeV, while the SOBP dose for the carbon ions was overestimated by 7% when using the 278 MeV/u calibration. The PL of LiF can be used for the accurate dose evaluation of clinical proton beams, while a more comprehensive investigation is required to effectively apply the PL of pure LiF crystals to the dose evaluation of clinical carbon ions.
SP059 - Drug Delivery and Control Release

SP059.1 - Nanotechnology applied in drug delivery

Author(s): Gabriela Barbosa¹, Pedro Augusto F.D. Silva¹, Glécia V.D.S. Luz², Lourdes M. Brasil³

¹Unb At Gama, University of Brasilia, Gama/BRAZIL, ²Pos. Engenharia Biomedica, UNIVERSIDADE DE BRASILIA, Brasilia/BRAZIL, ³Fga, UnB, Brasilia/BRAZIL

Nanotechnology is a multidisciplinary field that deals with the study, manipulation or rearrangement of particles at the nanoscale, which is equivalent to a billionth of meter, the material at this scale shows unlike physical, chemical and biological proprieties. This area has impacted a lot in the development of new products in various sectors and has been widely studied for offering effective solutions to several problems, such as pollution, energy rationing and cure of various diseases. What makes the field so promising is that the elements behave differently at the nanoscale, when compared to the macroscale. In this article it will be described how this field can be applied in the biomedical field, especially in controlled drug delivery systems using nanoparticles, nanobots and organometallic compounds, for greater effectiveness in the treatment of diseases.

Nanoparticles (NPs) are nanosized particles (3-200 nm), devices or systems that can be made using a variety of materials including polymers, lipids, viruses, and even organometallic compounds. The uses of NP with drug delivery systems have made a remarkable difference in site-specific release of drugs, owing to their physical and chemical characteristics and biological attributes. Various researches in this exciting area have been conducted and several formulations were released in the market and are now routinely used in clinics. In this review will be found a few nanoparticles more used in the medical area, as Solid Lipids Nanoparticles (SLN), Magnetic Nanoparticles, for instance. Nanobots or nanorobots is based on the creation of tiny machines that can do the functions of today’s machines, but more exactly, to develop projects that bring benefits in medicine, industry, and others areas. An ideal nanotechnology-based drug delivery system is a pharmacy: a self-powered, computer-controlled medical nanorobot system capable of digitally precise transport, timing, and targeted delivery of pharmaceutical agents to specific cellular and intracellular destinations within the human body. Some advances with these devices will be described in the review. Organometallic compounds are usually described as components having at least one metal-carbon bond. They also are considered nanoparticles. In the following review, will be discussed the application of Graphene and Carbon Nanotubes in drug delivery systems. Although some researches were not evaluated in vivo, there is a high expectation on this field. It is necessary study more about the behavior of nanoparticles at the organism, as well as figure manners to use these devices so that they do not exhibit toxicity to the body.

SP059.2 - Controlled electrochemical dissolution of iron alginate for smart drug release in micro devices

Author(s): Ashleigh Anderson, James Davis

Computing And Engineering, University of Ulster, Newtownabbey/UNITED KINGDOM

Smart devices that can routinely monitor patient’s health with little or no involvement from clinical staff have slowly begun to emerge over recent years and have arisen from significant developments in sensing and communication technologies. In cases where a rapid

seen in Figure 1, where the relative dose error decreases as a function of dose delivered.

Table 1: Mean dose differences for six gels in different dose ranges.

<table>
<thead>
<tr>
<th>Dose Range (Gy)</th>
<th>0-5</th>
<th>5-10</th>
<th>10-15</th>
<th>15-20</th>
<th>20-25</th>
<th>25-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Dose Difference (σ)</td>
<td>0.40 Gy (0.04)</td>
<td>0.33 Gy (0.03)</td>
<td>0.47 Gy (0.06)</td>
<td>0.55 Gy (0.08)</td>
<td>0.36 Gy (0.02)</td>
<td>0.55 Gy (0.05)</td>
</tr>
<tr>
<td>Mean Global Relative Dose Difference (σ)</td>
<td>1.42% (0.14)</td>
<td>1.16% (0.11)</td>
<td>1.67% (0.22)</td>
<td>1.96% (0.28)</td>
<td>1.27% (0.06)</td>
<td>1.96% (0.19)</td>
</tr>
<tr>
<td>Mean Local Relative Dose Difference (σ)</td>
<td>9.92% (1.00)</td>
<td>4.19% (0.40)</td>
<td>4.05% (0.53)</td>
<td>2.99% (0.43)</td>
<td>1.61% (0.08)</td>
<td>2.08% (0.20)</td>
</tr>
</tbody>
</table>

Conclusion: The establishment of an overall accuracy and precision of this system provides a framework for potential areas of application such as high dose SABR treatments.
response may be required, a much more effective substitute would be the development of a truly smart system that could autonomously act on the information received from the sensing component and, where appropriate, deliver a therapeutic agent in a controlled manner. This presentation details the result of an investigation into the development of electrochemically initiated transitions of redox gels. The hydrogel structure can be held together through chemical or physical bonds and it is within the resulting network that drugs can be entrapped.

The approach to delivery is highlighted in Figure 1 where there is an electronically controlled layer that separates the drug reservoir from the skin. The core methodology employed in this project will involve electrochemical control to influence the porosity of a redox hydrogel, typically sodium alginate.

A) Hollow microneedle Alginete release film
Porous conductive membrane
Drug reservoir

B) Release of drug
Transport of drug through film to needle pore

Figure 1. Microneedle patch with alginete release film. A) before release (-1.1V) and B) after release (+0.5V)

The use of the iron as the binding agent is of prime interest in the present context as, in contrast to the other metal ions, it can be electrochemically cycled (Fe^{3+}/Fe^{2+}). The formation of the film and its dissolution are both controllable through electrochemical means. The oxidation of the Fe^{2+} to Fe^{3+} in the presence of the alginate will activate the crosslinking process and enable site specific deposition at the electrode. While this is similar to the polypyrrole and polythiophene films, there is a crucial difference. The electrochemical reduction of the coordinated Fe^{3+} to Fe^{2+} will result not only in a simple swelling of the film but rather its dissolution. Ordinarily this would be expected to cause significant issues, especially for a film in contact with biofluids, but the alginate-iron system is inherently biocompatible (the alginate is readily hydrolysed under normal physiological conditions) and this may be a critical advantage in the future use of redox films.

SP059.3 - Next generation transdermal drug delivery – An electrochemical approach to pH manipulation for controlled release within smart patch technologies
Author(s): Ashleigh Anderson, James Davis
Computing And Engineering, University of Ulster, Newtownabbey/UNITED KINGDOM

The majority of conventional controlled release technologies tend to be based around encapsulant systems in which a polymeric binder or gel typically responds to changes in the local environment in which the delivery device has been placed. The contents are typically released when the particle, capsule, film or droplet is exposed to the appropriate physico-chemical trigger (typically a change in pH) with the time-release-dose delivery characteristics controlled through manipulation of the encapsulant formulation. In this communication, the adaptation of this core strategy for use in the next generation of transdermal microdevice or smart patch is explored. A key feature of the approach is the ability to electronically trigger the release of the drug on demand.

The strategy relies on the electrochemical properties of a carbon composite film in which micro-nanoscale pores are created through controlled laser ablation. The porous carbon layer is then combined with the cellulose ester barrier film to complete the prototype patch as indicated in Figure 1. Under normal conditions the enteric coating remains intact with no diffusion of the drug to the bulk of the solution. Upon imposing a reducing potential on the carbon film top layer however, the local pH within the pores is dramatically increased such that hydrolysis of the ester occurs with dissolution of the protective barrier releasing the drug.

The presentation covers three aspects: the design of an innovative microprobe necessary for monitoring the changes in pH within the pores, the structural and electrochemical characterisation of the carbon film and the proof of concept demonstration of a model drug release.

SP059.4 - Protein nanocages for stabilization of bio-inspired emulsions/gel systems and cutaneous drug delivery
Author(s): Sierin Lim, Sathyha Moorothy Bhaskar, Mridul Sarker
School Of Chemical And Biomedical Engineering, Nanyang Technological University, Singapore/SINGAPORE

Self-assembling protein nanocages forming hollow structures are explored as potential carriers in various nanotechnology applications. The fact that proteins are integral parts of a biological system makes them promising for use as carriers for drug delivery, cosmetics and food emulsifiers. E2 Protein from pyruvate dehydrogenase multienzyme complex of Geobacillus stearothermophilus have the capability to self-assemble into a hollow dodecahedral cage of a unique size about 25 nm. The nanocages are extremely thermosensitive and porus with 12 openings of 5nm each. These inimitable characteristics of E2 protein nanocage are suitable to encapsulate...
and carry foreign molecules inside its cavity. E2 protein nanocages are engineered genetically or chemically, to shuttle drugs into the skin cells such as melanocytes (Figure-1) and keratinocytes (Figure-2), protein conjugated to Alex fluor-green, nucleus stain-blue) for the treatment of pigmented disorders. The existence of both hydrophilic and hydrophobic patches on the surface of E2 protein nanocages molds it to be a surface active bionanoparticle. Our preliminary results show the deposition of E2 protein nanocages at liquid-liquid interface under TIRF microscope (Figure 3). Thus the E2 protein nanocages can also be used as a potential stabilizer of bio-inspired emulsion and gel system. This study can be very functional in designing emulsion-and gel-based pharmaceutical products for topical application, skin care products and food products.

Figure:1
Figure:2
Figure:3

SP059.5 - Image-Guided Predictions of Nanoparticle Transport in Solid Tumors
Author(s): Shawn Stapleton1, Michael Milosevic1, Christine Allen2, Ian F. Tannock3, David Jaffray4
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Due to the ability to preferentially accumulate and deliver drug payloads to solid tumours, nanomedicine, including liposomes, has emerged as an exciting therapeutic strategy for cancer therapy. Unfortunately, negligible increases in patient survival following liposome therapy have been observed in the clinical setting. This is due in part to the heterogeneous intra-tumoural transport of cytotoxic drugs, caused by chaotic tumour microcirculation and elevated interstitial fluid pressure (IFP). Here we explored the relationship between tumour microcirculation, IFP, and the intra-tumoural accumulation of liposomes using a combination of quantitative imaging and mathematical modeling. The combination of quantitative imaging and mathematical modeling presents a novel framework to guide nanoparticle drug-delivery in the clinical setting. A biological mathematical transport model, termed the intra-tumoural transport model (ITTM), was developed and used in combination with non-invasive imaging methods to predict liposome transport in solid tumours. The ITTM was validated using in vivo measurements of accumulation of a computed tomography (CT) liposome contrast agent made in three different tumour models. The ITTM attributed inter-tumoural heterogeneity of liposome accumulation to variations in IFP; however, several limitations were noted, including limitations in the accuracy of intra-tumoural liposome accumulation predictions based solely on IFP. These limitations were mitigated by developing a novel imaging method, termed Volume Fraction Imaging (VFI), to accurately measure additional key transport parameters, including microvascular permeability, perfusion, plasma volume and interstitial volume. VFI is based on the sequential injection of a nanoparticle and freely diffusible CAs. Simulations demonstrated that the VFI method substantially improves the accuracy and precision of plasma and interstitial volume, blood flow, and capillary permeability compared to standard pharmacokinetic modeling. In vivo experiments demonstrated that VFI substantially improves quantification of healthy and malignant tissue treated with Sorafenib, radiation, and mild hyperthermia. Using VFI we established that tumour perfusion and plasma volume are also key mediators of the intra-tumoural heterogeneity in liposome accumulation in several tumour models. We probed the relationship between tumour microcirculation using VFI, IFP using a novel image-guided robotic needle positioning system, and the intra-tumoural distribution of liposomes using volumetric micro-CT imaging where performed. A strong relationship between the radial distribution of IFP, metrics of tumour perfusion, and the intra-tumoural accumulation of liposomes was observed. Therefore, both tumour perfusion and elevated IFP play an integral role in mediating the intra-tumoural accumulation of liposomes, and strengthen the need to account for intra-tumoural heterogeneity in transport properties for guiding the use of nanomedicine in the clinical setting. This work provides a pivotal piece of the image-guided drug delivery schema whereby quantitative imaging can derive patient specific information on drug pharmacokinetics, biodistribution, intra-tumoural transport, biological targets, and mechanisms of resistance. Integrating image-derived information with an established mathematical framework based on the ITTM can conceivably predict drug-transport and treatment response. This represents a major leap forward compared to the conventional chemotherapeutic strategies whereby optimal dosing and scheduling strategies can be prescribed and adapted on a based on validated mathematical models of drug delivery that are informed by quantitative imaging methods.
**SP060 - SPECIAL SESSION: UNESCO International Year of Light**

**TRACK 12: MEDICAL DEVICES**

**SP060.2 - Design of Wireless Implantable Optogenetics System for Animal Studies**

*Author(s):* Fu-Yu Chen1, Peter S. Freestone2, Simon Malpas1, Daniel McCormick1, David Budgett1  
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Optogenetics uses light to manipulate neural activity which has several advantages over conventional electrical stimulation approach including specific cell-type targeting with precise temporal precision, simultaneous stimulation using different wavelengths of light and relatively harmless to target tissue. In optogenetics experiments, targeted neurons are transfected with photo-sensitive proteins (opsins) for subsequent exciting or silencing neurons with pulses of visible light.

Optogenetic stimulation offers the prospect of treating lifetime conditions; however, current optogenetics available commercially are mainly connected with wires coming out of head of the animal head which brings a risk of infection and is vulnerable to damage from chewing or scratching. Also, current light stimulation systems are generally not suitable for chronic use due to the risk of infection associated with components located outside the brain. This study aims to investigate the technical feasibility of implementing a fully implantable optogenetics system supporting long-term light stimulation as well as for feasibility of wireless transmission of recorded signals outwards.

A miniature LED die with dimensions of 280μm by 280μm has been sourced with an output wavelength of 470nm which is suitable for exciting the opsin ChR2. The power needed is about 6.4mW to deliver the required optical power for opsin excitation. This is an exciting proof-of-principle outcome showing adequate light from a small package of components consuming a manageable amount of electrical power.

In the experimental setup, the LED die coupled to a 200μm optical fibre is feasible and sufficient to activate ChR2 (~32μW). With 80% of the light transmitted with a bend radius of 2mm, the fibre can be tracked from the brain to the wirelessly powered telemeter located in the abdomen to form a fully implanted optogenetics system. Our results show that LED-fibre optic system is able to generate a cellular response in a ChR2-expressed cell with a short pulse (4ms) of light. The cellular response generated can also be sustained by long duration light stimulation (500ms). The amplitudes of the cellular response can be controlled by changing the light intensity emitted on the targeted cell. This can be achieved by modulating DC voltage supply using Pulse-Width Modulation (PWM) technique. This technique is favorable for implantable device because it is easy to implement using a microcontroller and does not increase the size of the circuit. This experiment motivates the use of the custom-made LED-fibre optic system in vivo chronic rodent studies in the future.

Critical questions for technical feasibility include size, optical power, heat generated and physical delivery of the light to the region requiring illumination have been considered.

The proposed module has been validated to measure individual cellular response to optical stimulation photosensitive rat brain slices performed. This experiment motivates the use of the custom-made LED-fibre optic system for future in vivo chronic rat studies including animal behavior as well as wireless transmission of recorded brain potentials during various treatment schemes. The implantable wireless optogenetics would have great potential to enhance basic neuroscience research and help develop interventions for various neurological disorders, such as Parkinson’s disease.

**SP060.3 - A method to determine the variation of irradiance in bilirubin lamps as function of the time of use**

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Hyperbilirubinemia is a pathologic process consisting of the abnormal increase of the amount of bilirubin in the circulating blood, which can cause jaundice. A common treatment is expose the premature newborn to the phototherapy treatment, with lamps that emit in a specific region of the electromagnetic spectrum (mainly 410-550 nm). In the present work we describe one irradiance analysis method to this type of bilirubin lamps (in the case a Phillips TL20W/52), based on the determination of the intensity variation as a mathematical function depends on time (hours) with which we can simulate this behavior. We used the Exhaustive Approximation method combined with the Distinguish region-curve method for the determination of the corresponding function.

Also, we compare the spectral irradiance of the lamp, with the solar spectral irradiance measured with a high quality double monocrystal Optronic 756 spectroradiometer, the day October 26 of 2012, at 12:49 local hour, in Rosario, Argentina. As a consequence, it was observed that the lamp intensity is very small compared with the solar one, which means that a careful analysis of the solar radiation incident on a given place needs to be made, if a treatment with natural radiation would be used for bilirubin reduction.

**SP060.4 - Study of the sensibility of induced heat effects in edible oil measured by interferometric techniques**

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Currently the use of edible fats and oils in the preparation of fried products has increased, it is known that excessive consumption of foods containing fats, can have a deleterious effect on the health of people, forcing increasingly strict control of oils and fats in fried foods to maintain quality of fried foods and ensure their safety, lack of laboratory facilities in fried food preparation establishments, limit the compliance of existing quality standards requiring new simple alternative methods to be used by the user.[1] Optical interferometers are instruments that can make very precise measurements of objects using the pattern of interference of two waves of light. These devices have been used to characterize materials and study their properties. This paper propose a new prototype of this application in order to reach a characterization protocol of fluids with low differentiation of components. Results in oil samples indicate that it is possible to make characterization using interferometric techniques.
SP060.5 - Design and study of Infrared-Guard
Author(s): Shanmugam Senthilkumar
Dept. Of Radiotherapy, Govt. Rajaji Hospital & Madurai Medical College, Madurai/INDIA

Introduction: Gantry - couch collision is a serious concern for cancer patient treatment planning of the radiotherapy machine. The radiotherapy machines moving parts may cause collision between the treatment couch and the treatment head, which affects the accuracy of the machine and sometimes a replacement of parts. If a patient interferes, it results in severe injuries. In this work we have developed Infrared Guard (IRG) to prevent gantry - couch collision in the Radiation Therapy machine.

Material and Methods: The Infrared Guard consists of a distance measuring sensor unit, composed of an integrated combination of PSD (position sensitive detector), infrared sensor and signal processing circuit. The infrared sensor is made up of the emitter (infrared LED) and detector (photodiode). The emitter emits IR light pulse and the receiver detects the corresponding light pulse. The infrared intensity of the emitter influences the detection range. On the IR receiver side, the desired output voltage depends on the detection distance. This output voltage signal connected to an analog amplifier, comparator, or Schmitt-Trigger, to control various functions. IRG device placed in the treatment machine gantry, which is inner side of the gantry and above to the gantry angle indicator. IRG device monitors the region between the collimator face and the treatment table (or) patient. The IRG provides an infrared invisible sensing shield, which covers the entire collimator face. The IRG device sensing area or protection zone distance can be varied according to the requirement with adequate clearance. If the potential collision is detected by the IRG device in the protection zone, the radiotherapy machine will stop the movement and the red LED will glow and also buzzer will produce sound. We have also provided the IRG OFF key in the machine. If you want to override or turn off to the power to the IRG device a blue light will glow and illuminating words Infrared Guard OFF will appear.

Results and Discussion: We have studied this IRG device to monitor the accuracy in the radiotherapy machine using phantoms and patients. Our method correctly confirmed clearance between the patient/treatment table and the gantry. This device is easy to handle, inexpensive and stops the machine movement when the gantry and the couch come nearer to each other. Infrared Guard provides an additional level of safety to automated radiotherapy machine operation. IRG monitors the closeness of the patient treatment couch to the treatment head during remote movements and restrain or stops machine movements prior to a potential collision. IRG provides an additional “set of eye” to monitor and minimize risk. IRG does not require physical contact to detect potential collision. IRG anti-collision device improves the performance of the machine and most importantly reduces the chance of collision.

SP061 - Improvement of Diagnosis and Therapies

SP061.1 - Development of heart sparing device for Left Breast Radiotherapy with deep breath-holding
Author(s): Shanmugam Senthilkumar
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Introduction
Breast radiotherapy is now part of the routine care of patients with early breast cancer. Adjuvant radiotherapy for post-mastectomy breast cancer patients consists of a pair of tangential photon beams treating the breast tumor bed. In addition, internal mammary chain (IMC) and supraclavicular (SCV) beams are also employed to treat the corresponding lymphatic nodes within the region. Radiotherapy has been shown to reduce recurrence and improve the survival rate for post-mastectomy breast cancer patients. However, the benefits of adjuvant radiotherapy is compromised by the secondary cardiac mortality that occurs 15 to 20 years after the therapy has completed. Therefore, it is critical to develop radiation techniques that retain the benefits but reduce late toxicity to the heart and other organs at risk. Patients with left-sided breast cancer who receive chest wall radiation have increased risk of treatment related cardiovascular morbidity. To reduce the dose to the heart, it has been suggested that electrons be used in the IMC beam. Another strategy to reduce cardiac dose is to employ breathing adapted radiotherapy, including the deep inspiration breath-hold (DIBH) technique. It has been demonstrated that employing the DIBH technique in tangential beams appreciably reduces cardiac dose. However, there has been no study on the effect of utilizing the DIBH technique in IMC electron beams. The aim of this study was to evaluate the effect of decreasing the irradiated cardiac volume in breast-conserving treatments (BCT) with indigenously developed deep inspiration breath-hold device (DIBHD) using breath-adapted radiation therapy (BART).

Materials and Methods
We have developed indigenously deep inspiration breath-hold device (DIBHD), which consist of laser sensor, in-house software, video goggles, a breath hold signal device, alarm and visual indicator. The sensor is used to display the breath-hold position of the chest wall in the computer monitor as graphical signal as well as digital. Patients can able to see their breath hold position while using the video goggles and maintain the uniform level without reducing the lung volume. Once the threshold level reduces, patient starts to exhale the radiation will be stopped, simultaneously alarm will produce sound and visual indicator glows.

Results
DIBHD has been used for the left sided breast cancer patients during the radiotherapy in deep inspiration breath-hold. The tangential fields were planned for each respiratory-gated CT image. The dose-volume histograms (DVHs) of the heart, lung, and breast of each respiratory phase were compared. Patient’s position during each breath hold was carefully monitored and make sure the heart is positioned away from the chest wall. Radiation was delivered during these repeated breath holds. A deep breath pulls the diaphragm and heart down and out of the radiation beam path. Delivering radiation treatment during these deep breath holds protects the heart from radiation. We concluded that radiotherapy using DIBHD facilitates a reduction of the irradiated heart volume which enables more complete cardiac sparing without any compromise of PTV coverage.
Health Technology Assessment (HTA), although having been routinely applied in drugs and surgery for a long time, is still quite challenging in medical devices. The reason is that the main objective of HTA studies for devices is not optimization of the cost-effectiveness ratio, but rather decisions about procurement and/or incorporation of the apparatus. The clinical benefit is not expressed in terms of quality of life, but in the rate of diagnostic yield, comfort of the clinician, or the extent to which the technology makes the therapy shorter and/or more patient-friendly. Utilization of multiple-criteria decision-making methods for evaluation of the aggregated clinical, technical and user’s effect (outcome) is recommended as the input to cost-effectiveness analyses. Different methods are derived for strategic and/or operational assessment of new technology.

Bacterial contamination of chronic wounds has long been a major concern for those involved in the management of diabetic foot disease (DFD). The latter is an increasingly common complication of diabetes whose treatment has a profound impact on both patient and healthcare resources. In 2013, global healthcare expenditure for diabetes totalled $548 billion. With the ever increasing population of people with diabetes expected to increase by 55% in 2035, we can expect expenditure to reach $627 billion and upwards. A study has estimated that a population with diabetes costs three to four times greater than a population without. The majority of these costs are due to the complications that arise from diabetes such as neuropathy, infection and ulceration. It has been estimated that approximately 25% of all diabetes related hospital admissions in the US and the UK are due to such complications and consequent limb threatening infections. Approximately 15% of patients with diabetes will suffer from foot problems and around 7% have a foot ulcer at any given time. Around 56% of foot ulcers become infected, making patients 30 times more likely to have an amputation compared to the general population making it the most common cause of lower limb amputation.

While there has been considerable activity in the development of wound dressings that aim to minimise bacterial contamination and aid the healing process, the majority are passive and possess little or no diagnostic capability. The present communication details the results of an investigation into the use of a smart bandage which can permit electrochemical interrogation of the wound environment and therein provide the possibility of more timely and effective interventions in the management of the wound.

Carbon loaded polyethylene films were selected as the base substrate for a mechanically flexible and conductive sensing material for use in wound monitoring technologies. The films were processed using laser ablation of the surface to increase the effective surface area of the electrode and were then subject to an oxidative electrochemical etch to improve the electron transfer kinetics. The surface morphology of the resulting film was analyzed and the electrode performance in relation to monitoring uric acid, a key wound biomarker, was optimized. A prototype smart bandage interfaced with a miniaturized potentiostat capable of monitoring the wound condition was developed and the response to urate harnessed to measure both the wound pH and wound severity. The viability of using urate for use in complex fluids was assessed using whole blood and other potential interferences. The mechanical flexibility of the polyethylene film is ideal for incorporation within existing dressing materials and could be produced in bulk at relatively low cost, a pre-requisite given the frequency with which dressings need to be replaced.

Carbon loaded polyethylene films were selected as the base substrate for a mechanically flexible and conductive sensing material for use in wound monitoring technologies. The films were processed using laser ablation of the surface to increase the effective surface area of the electrode and were then subject to an oxidative electrochemical etch to improve the electron transfer kinetics. The surface morphology of the resulting film was analyzed and the electrode performance in relation to monitoring uric acid, a key wound biomarker, was optimized. A prototype smart bandage interfaced with a miniaturized potentiostat capable of monitoring the wound condition was developed and the
We have developed a system that can produce 3-dimensional single photon emission computed tomography (SPECT) images from a handheld camera that can be moved freely by a surgeon around a patient. This system is called FreeSPECT, will better localize lymph nodes for sentinel lymph node biopsies (SNLB). With 3-dimensional image-guidance that can be linked to high-resolution anatomical images from CT or MR, surgeons will be able to more accurately remove lymph nodes and plan around sensitive tissues. The FreeSPECT system we have developed is based upon a SPECT system from NDI, which is small in size and MR compatible. Figure 1 shows the system including the electronics cabinet, gamma detector, and user interface. The silicon photomultiplier (SiPM) detector head has 16 pixels in a square 4x4 pattern, with a 5 mm thick CsI(Tl) scintillator. The detector efficiency is 149.7cps/MBq at 50 mm source distance, and signal multiplexing allows sampling of each pixel every 4 μs. In-house developed navigation platform “GTxEyes” provide gamma image acquisition, real-time tracking, navigation, visualization, and reality augmentation. This platform is developed based on open-source toolkits and libraries including VTK, ITK, IGSTK, and OpenCV, as well as our own proprietary image reconstruction and co-registration algorithms. Additional capabilities of this platform include critical organ monitoring with visual/audio alerts and image overlay of multi-modality images. Fast deformable Demon image registration algorithm is also available to register pre-operative images (and/or contours) to intra-operative images such as the proposed Free-Hand SPECT image. The prototype FreeSPECT system has integrated optical tracking technology (Spectra, Polaris, NDI), a reference tool affixed to the camera’s body for identifying the position and orientation of the gamma camera images in 3D. To precisely locate the gamma camera images in space, the spatial relationship between the tracking tool and camera space is first calibrated. In the localization process, the clinician uses the handheld gamma camera to scan above and around the region of interest. The software records the 6D position and orientation of the camera simultaneously with the gamma image acquisition at every instant. In the prototype system, this recorded information is saved in ASCII text format for subsequent tomographic image reconstruction. The SPECT image reconstruction is based on the ordered subset expectation maximization algorithm as implemented in the NiftyRec open source tomography toolbox. Preliminary results from the FreeSPECT prototype system are shown in Figure 2.

Alterations in the biomechanical properties of cells are important in many pathologies including cancer, neurodegenerative diseases, and autoimmune disorders. For example, the more aggressive molecular subtypes of breast cancer may express different biomechanical phenotypes due to subtype-specific mutations which code for proteins that regulate the cytoskeleton. Microtubule destabilization and other cytoskeletal dysfunctions play a pivotal role in neuropegenerative disorders such as Alzheimer’s disease. In autoimmune diseases, cytoskeletal changes in T cells are key to signaling, immune recognition, and activation. Our research at Utah Valley University is currently exploring the capabilities of high-frequency ultrasound for detecting variations in the biomechanical properties of cells. To date, high-frequency (10-100 MHz) ultrasonic spectra have been found to be sensitive to breast cancer cell types and chemical modification of the cytoskeleton in cell cultures. The cells are non-invasively probed using a pulse-echo measurement. Time-domain signals acquired from cells are converted into frequency spectra and analyzed for spectral features that correlate to biomechanical properties. Ultrasonic scattering models, experimental data, and data analysis methods such as principal component analysis have confirmed that high-frequency ultrasound can detect changes in the cytoskeleton. However, a critical problem with the current approach is the strong ultrasonic reflection from the well bottom of the cell culture plate, which interferes with the weak ultrasonic signals from the cells adhering to the bottom. The objectives of this study were to develop an approach to eliminate the well-bottom interference from the cell signals, and to provide a capability for probing cells in liquid suspension (thereby expanding application to cells extracted from tissue and blood). The approach uses acoustic levitation to induce free-floating cells into forming a thin, suspended, planar layer which can then be probed by high-frequency ultrasound. Acoustic levitation is accomplished by establishing an acoustic standing wave in the media using a low-frequency ultrasonic transducer. A significant challenge in the acoustic levitation of cells is the random motion of the cells about the node position of the standing wave. This paper reports on a new method for damping cell motion during acoustic levitation. The method uses harmonic modulation of the standing wave to create nodal regions of greater stability and cell localization as compared to a single-frequency standing wave. Numerical simulations indicate that such “acoustic wells” can be created using a multifrequency layered piezoelectric transducer to modulate the standing wave with an optimized set of harmonic frequencies. Breast cancer cells having distinct spectral signatures will be tested to validate the approach. The acoustic levitation system will consist of a 30-MHz function generator, an RF amplifier, and a multifrequency (0.1-1.0 MHz) layered piezoelectric transducer. The high-frequency ultrasound system will consist of a 50-MHz immersion transducer, a high-frequency square-wave pulse/receiver, and a 1-GHz digital storage oscilloscope. Our research group has developed a new method for stabilizing cell motion during acoustic levitation using numerical simulations. This new method promises to not only expand the capabilities of high-frequency ultrasonic testing of the biomechanical properties of cells, but also has applications as a 3D patterning approach in tissue engineering.
SP062 - Clinical Process Analysis, Optimization, Productivity and Benchmarking

SP062.1 - Guaranteeing the quality of rigid endoscopes with the ScopeControl
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As rigid endoscopes are re-used after minimal invasive surgery, they degrade over time. To guarantee the optical quality of a rigid endoscope for the next surgery, the ScopeControl has been developed to measure key optical parameters such as light transmission, color correctness, focus, fiber transmission, viewing angle and field of view. The ScopeControl is placed in the reprocessing cycle right after cleaning, before wrapping and sterilizing the endoscope. After a measurement has been performed, all parameter buttons/indicators should turn green. When, however, a parameter button/indicator turns red, its value falls below a pre-defined threshold (acceptation criterion) and the endoscope should be rejected for further processing.

In 2013 a pre-commercial version of the ScopeControl has been tested in six hospitals in the Netherlands. It proves to be stable, and able to measure optical parameters with sufficient precision that it can discriminate between good and bad endoscopes [1]. Since April 2014, the commercial version of the ScopeControl has been in use at the sterilization department of the UMC Utrecht (about 4000 minimally invasive surgeries a year). In this project we want to address several issues when introducing the ScopeControl in the clinical process:

1. What kind of training people of the sterilization department should get in handling and interpreting the results of the ScopeControl.
2. What kind of tracking is needed for endoscopes. Conventional basket tracking systems are often not sufficient as endoscopes are easily swapped between baskets. The ultimate goal is to track on endoscope level (e.g. using a data matrix or RFID).
3. What should be agreed between the departments of sterilization, OR and medical technology about rejecting/accepting endoscopes when reprocessing them or sending them in for repair or replacement. What can be said about the rejection/acceptation levels? Generally a repaired or new endoscope should have a higher quality than an endoscope that is still good enough for surgery. There should be some bandwidth where endoscopes may deteriorate slowly.
4. What kind of reports can be derived from such a system and how can these results be coupled to information from other electronic registration systems in the hospital like basket tracking and OR management systems.
5. Which steps in the reprocessing cycle may damage endoscopes and can we get an idea of their impact? Think of handling, transport, cleaning, disinfection and sterilization.

These issues are illustrated in two examples: The replacement of a large number of rigid endoscopes in a public tendering, and the large fall-out of large number of cystoscopes for children. We look forward to a live discussion to see whether these problems are recognized in other hospitals and which approaches other people have found to address these problems.

Reference

SP062.2 - Low-entry level CT exam times and availability in worldwide markets
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Context and background: Computerized Tomography (CT) is widely used for disease diagnosis, treatment planning, and follow-up. Currently, its state-of-the-art is a 320-slice equipment, but machines with one, two, four and 16 slices are still used in many countries. Exam speed (and, thus, number of exams per period of time) may change among models, but the smallest slice thickness is usually about 1mm regardless of the number of detector rows. However, most of the basic models already had their production discontinued, a situation that makes CT entry level more expensive, and, therefore, decreases its adoption in less developed countries.

Objective: To study the differences in productivity (exams/unit of time under real working conditions) between 1, 2, 4 and 16 slices CTs.

Methods: Four CTs (with one, two, four and 16-slices) were studied relatively to their performance in patient exam time, divided as: i) patient arrival; ii) patient initial preparation; iii) patient positioning in the equipment; iv) data scan; v) examination time and vi) time for patient departure. Times were measured in minutes and seconds by two researchers with an Android Tablet and a timer application. Equipment were located in Rio de Janeiro city or nearby cities in Brazil, 2013-2014. Additionally, an Internet search was performed among equipment producers trying to identify the supplier of the simpler models in the Asian, European and USA markets.

Results: A total of 85 exams were followed, and three had to be discarded, one due to equipment failure at the moment of the exam and two due to patient arrival delays. Average times for the arrival / preparation / positioning / scanning / departure stages did not differ markedly. As for the “scan” stage, the average time for the single slice case was 8‘38”, as opposed to respectively 2‘05”/ 2‘31”/ 2‘41” for the remaining models.

Concerning model availability, the Internet search identified that few older model options are still available, with the number of slices beginning at “sixteen” among USA and European manufacturers.

Conclusion: Despite their wide variations in technology, average time differences among the studied models were small for the “non-examination” stages, indicating that the general (including ergonomic) characteristics of the equipments did not change markedly. Regarding the “scan” stage, however, 2-16 slices models had a similar and clearly better performance relatively to the single-slice model, and, thus, a similar productivity could be achieved with the former models. This is an important consideration, given that productivity is important both for the public health sector (allowing for attending a larger patient population) and for the private sector. Therefore, these models, if still available, could satisfy the demand of many less developed countries, but the Internet search identified that entry level now refers to 16 slices and over. An alternative for keeping low cost models in production would be the development of “upgradeable platforms” by manufacturers, allowing for the acquisition of more simple alternatives that could be adequately upgraded along time.
SP062.3 - The critical evaluation of AV control features in modern pacemakers and cardioverters

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The modern prostheses of different vital systems of human body are equipped in many control features related to the physiological behavior of replaced systems. The critical evaluation of some algorithms for the synchronization of the heart conductive systems that are implemented in modern pacemakers and cardioverters is goal of our evaluation. We describe our clinical evidence that the algorithms should be customized to individual patients. Two of the most important pacing parameters: default atrioventricular interval (AVI) and AVI adapted to heart rate (HR) were evaluated by the authors. The criterion for enrolment to the both study groups was the 80% pacing recorded by the pacemaker holter systems and 100% pacing during the duration of the test.

The goal of the studies was to assess the differences between SV for optimal AVI and SVs for default AVI values proposed by two of the biggest word pacemaker companies and the impact of varying HR on the optimal AVI in two groups of 20 paced patients: first (mean age 74.0 years +/- 7.0 years) consists of 4 females (mean age 75.3 +/- 6.1) and 16 males (mean age 74.3 +/- 4.1) and second treated by DDR were enrolled into the study.

The mean value of SV for optimal AVI achieved in the first clinical study is pretty close to SV for default AVI' (150 ms) and differ from SV for the second default AVI“ (170 ms). Significant changes (p<0.05) were found for SV vs SV“. The high SD level of optimal AVI‘s (mean 148.50 msec., SD 41.07 msec.) shows wide range of its variations assessed for some patients. The estimated default AVI” may be based on a different population of patients for instant North American. All of the facts listed above prove the assumption that the default AVI values preset by companies can lead for nonoptimal settings for some patients. Such wrong settings can be especially important in group of patients with poor condition of cardiac muscle which limits the physiological adaptation of the heart to an intense exercise. The results of the second study of reaction of AVI to increase or decrease of HR lead to similar conclusion. The normal relationships between shorter AVI for faster HR and longer AVI for slower HR simply do not work for some, pretty significant in presented study, number of paced patients with impaired systole by atrophy of heart muscles geometry and non physiological systole of paced ventricles (the impulse is propagated from the apex of the heart in opposition to physiological direction of impulse propagation).

Conclusion: The presence of non physiological behavior of the heart conductive system should be taken under consideration during adjustment of parameters of pacing treatment.

SP062.4 - Assisted Reproductive Technology Center Design with Quality Function Deployment Approach

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Assisted Reproductive Technology (ART) is the technology used to achieve pregnancy in procedures such as fertility medication, artificial insemination, in-vitro fertilization and surrogacy. The paper shows an application of Quality Function Deployment method to Careggi Hospital ART Laboratory of Florence in order to give a prioritization order for ameliorative interventions.

SP062.5 - Study of the Sensitivity on the Measurement of the Prevalence of Total Cholesterol in Blood Serum by Interferometric Techniques

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Current blood testing techniques require the use of sensitive equipment and a constant consumption of specific chemical compounds in order to analyze fluid composition and concentration. It is known that optical interferometers are instruments that can make precise measurements of objects using the interference pattern of two light waves. These devices have been used to characterize materials and to study their properties. Interferometric studies results, prove that by this type of optical arrangements combined with image processing, enables a method that applies for fluid characterization. Being this a non-destructive protocol that could be used for different applications in engineering. This study, propose the use of optical interferometry to analyze blood serum in order to explore the possibility of developing an alternative method for blood sample analysis. The methodology consists of analyzing different blood serum samples previously quantized to determine the effect of the variability of its components in the acquired interferograms. The results show an unexpected behavior of the acquired interferograms in relation of the amount of total cholesterol included in the samples, this in relation with the information generally considered from the medical practice.

The scope of this paper seeks to apply technology and optical engineering also consider the effect of the prevalence of lipid components in blood serum in order to develop a standardized technique that allows the study of concentration information from acquired interferograms and thus validate the option as an alternative to the quantization of such compounds. Helping to complement the knowledge of the biochemistry of the blood and develop novel methods for quantization and analysis of its components by non-destructive techniques and less expensive methods known on the market.

SP062.6 - Critical role of sustaining technology and utilities in healthcare institutions facing disaster through development of an international center for information and training of health technology managers on disaster preparedness

Author(s): Yadin B. David, Caridad Borrás, Fred Hosea, Douglas Drepps

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Study/Objective

Promote awareness of critical role of sustaining technology and utilities in healthcare institutions facing disaster by exploring development and establishment of international center for information and training of health technology managers on disaster preparedness and situation-awareness methodologies.

Background

Review of disasters that affected healthcare institutions suggests a need to make technological systems more robust and better trained users about disaster preparedness. The burden is magnified due to ever growing critical dependency on technology, i.e. central oxygen, vacuum, nuclear, radiological equipment, communication systems.

Methods

The need for a training center based on a case study of the impact
on several hospitals: a flood from tropical storm affected several hospitals and their technological systems in Houston, Texas, 2001. The problems caused by rising water, the immediate response, the recovery efforts and the financial losses will be analyzed. This will also include the transfer of learned lessons to environment of resource-poor countries.

Results
Water caused shutdown of electrical, air, vacuum systems and submerged areas containing radiological equipment. Patients had to be evacuated, unfortunately four patients died, research animals, and years of investigation data lost. The case shows lack of technology-focused plans for triaging healthcare systems and of training programs. There was lack of understanding of systems (including networks) and devices’ vulnerability, especially when multiple systems crushed. The possibility of unique hazards like those from radiation-emitting devices and radioactive materials, other biomedical equipment such as mechanical ventilators were considered last. Prioritization of backup and strengthening resilience of technology prior to disaster and during disaster were a last minute approach. The recovery focused on commissioning technologies critical to life. Had the facility been better prepared, lives and financial losses would have been minimized.

Conclusion
Disaster preparedness plans in healthcare institutions must include knowledge of the vulnerabilities they may face and plans to mitigate risk of operations disruption due to technology and utility issues.

SP063 - Accreditation, Certification and Licensure Issues

SP063.1 - The Current State of Clinical Engineering Education and Career

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Today’s practice of healthcare has grown to depend on the deployment and integration of technological tools for the delivery of its services like never before. Furthermore, these technological tools are being integrated into systems requiring competencies and expertise that challenges conventional training. It is critical, for the practice of safe and effective healthcare services, that these systems and their integrated technological tools are well planned, managed and safely serviced throughout their complete life cycle. Not only the dependence on these systems has grown but even more so, the quality and the volume of the intelligence embedded within these technological tools. Intelligence that guides the management of patients’ conditions. As example, the emergence of the utilization of electronic medical records, of health informatics, surgical robots, 3-D medical imaging, smart infusion pumps, bedside telecommunications, wireless accessibility and mobile devices. It is clear, therefore, that clinical engineers for successfully managing their hospital’s clinical technology program require new knowledge and additional competencies.

In reviewing the academic preparation of engineers for career in the clinical environment, the clinical engineers, it seems obvious that most if not all are based in the biomedical engineering academic programs. While there are some joint sciences, the training of clinical engineer is different from training of biomedical engineer. The curriculum and the format of the clinical engineering programs must anticipate and train for the specific body-of-knowledge needed for practicing as clinical engineering professional. Therefore, helping its graduate to become successful practitioners that will pursue, after graduation, further professional development and certification supported by lifelong clinically related continuing education.

This presentation will provide a review of the healthcare technological tools and their integration into systems. It will further identify how these changes influence the body-of-knowledge that clinical engineers must have. It will summarize some suggestions on how to improve clinical engineering education programs so that their graduates will be successful in their career, happy as professional practitioners, and contributors to best possible care outcomes.

Objectives
1. To describe the relationship between changing healthcare and clinical engineers practice
2. To identify why changes in practice of clinical engineers impact their education and preparation
3. To link specific knowledge that must be part of future clinical engineering education and their career
The purpose of this presentation is to report on the progress towards Medical Physics becoming a regulated health profession in Alberta.

Medical Physicists in Canada have a nationally recognized certification system through membership with the Canadian College of Physicists in Medicine (CCPM). While most Medical Physicist employers desire this membership or its equivalent, it is enforced only voluntarily by hiring institutions and managers. There is no legal requirement for membership with the CCPM to work as a Medical Physicist. Many of the clinical activities performed by Medical Physicists that can have direct clinical consequences for patients in terms of detecting and treating disease can be legally performed by anyone. This lies in contrast with many of our professional peers (physicians, radiation therapists, nurses, etc.), where provincial colleges independently define a scope of clinical practice, regulate those who may conduct that practice, and restrict the practice of certain activities to those registered with the college.

By defining a scope of practice and requiring members of a profession to meet and maintain minimum standards of competence, professional regulation ensures both patient safety and a minimum standard of care. Root cause analysis commonly identifies lack of Medical Physicist involvement, training, or qualifications as a significant contributor to major radiation therapy accidents and near misses. This suggests a key link between quality and safety and the regulation of Medical Physics.

In Alberta there are approximately 40 qualified medical physicists. For over five years the Association of Medical Physicists in Alberta (AMPA) has pursued professional regulation under Alberta’s Health Professions Act. In 2011, AMPA submitted an application for professional regulation to the Government of Alberta. Government feedback identified small physicist numbers as a primary barrier to regulation: the administrative workload of operating a professional college, and the cost of potential investigations and disciplinary committee hearings (involving legal council) were deemed prohibitive. However, subsequent feedback suggested the potential viability of a joint application with the Alberta Association of Clinical Laboratory Doctoral Scientists (AACLDS), an organization also seeking regulation, but limited by similar membership numbers. AACLDS represents professions including clinical chemists, microbiologists, geneticists, and toxicologists who share several professional similarities with medical physicists. Its members complete PhDs, then do two years of clinical training before writing a national certification exam. In the newly proposed model, Medical Physicists and the professions represented by AACLDS would join and be administrated by the College of Physicians and Surgeons of Alberta. The CPSA is a natural choice because (i) this college is the provincial accreditation body for ionizing radiation devices below energies of 1 MeV and (ii) our groups share common professional ground with physicians and surgeons, including a balance of clinical and academic responsibilities, and the extensive training involved in our professions.

At the time of this abstract submission, AMPA and AACLDS are in the process of submitting this joint application to the Government of Alberta. If successful, Alberta would become the first province in Canada designating Medical Physicists as a regulated health profession.

This talk will present an overview of the objectives of the International Medical Physics Certification Board (IMPCB), progress made since its formation, and the results of recent discussions to assure that the IOMP will play a major role in IMPCB governance in the future. The IMPCB was established in 2010 with the assistance of the Certification Task Group of the IOMP Professional Relations Committee, with the goal of improving the quality of clinical medical physicists and the profession. To achieve this objective, the IMPCB will accredit existing national/regional Medical Physics Certification Boards and encourage and assist those countries/regions that currently have no certification programs to develop them. It also works towards conducting certification examinations for medical physicists practicing where local certification is not currently available. The first tasks of the IMPCB were to develop a model certification program (published in 2011), write the By-Laws (adopted in 2012), and elect the 1st Board of Directors (took office in January, 2014). An Accreditation Committee was established with the initial task of development of the requirements for certification and accreditation (completed in November, 2014). These include requirements for general education (a minimum of a Masters degree), medical physics education (general and specialty), and clinical training. These requirements adhere closely to those published in IOMP Policy Statement No. 2: Basic Requirements for Education and Training of Medical Physicists, and several IAEA documents. Medical physics certification examinations might be in three parts: Part I (a written exam on general medical physics to be taken by all candidates), Part II (a written exam for each specialty), and Part III (an oral exam for each specialty). But the IMPCB recognizes that there are national/regional variations to certification in medical physics based on differences in national/regional legislation and educational traditions, so it gives to national and regional certification bodies considerable freedom to decide on the manner in which a given organization seeking IMPCB accreditation conducts the certification process. The Board decided to initially restrict accreditation of Boards and IMPCB certification examinations for only the three specialties Radiation Oncology Medical Physics, Diagnostic and Interventional Radiological Physics, and Nuclear Medicine Physics, and begin accepting applications for accreditation of national or regional medical physics certification boards in January, 2015. The Board also approved collaboration with the IAEA to work on certification of experienced medical physicists working in countries which currently have no certification Board. For the latter, a Question Bank has been developed for Parts I and II of the IMPCB certification examination.

In Canada designating Medical Physicists as a regulated health profession.

The purpose of this presentation is to report on the progress towards Medical Physics becoming a regulated health profession in Alberta.

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In Canada designating Medical Physicists as a regulated health profession.
**Materials and Methods:** The RPTP implemented is based on 6 educational modalities: (1) oral classroom presentations on general topics, (2) bimonthly bulletin publication distributed both electronically and on paper form, (3) computer-based training, basically interactive modules, with questions and answer to ensure and assess understanding of the notions developed, (4) posters display, (5) practical training on routine tasks and, (6) simulations of emergency situations in working environment. A registration methodology is used to verify the level of knowledge and competence of each worker to safely perform their job. After 5 years of the RPTP implementation, an internal audit was conducted with a 10-question survey designed with Survey Monkey to measure the training effectiveness and perception among users.

**Results:** Readiness of our informative bulletin alone is equal or higher than 70% for the past 4 years with highest rates among technologists. 73 people answered to the satisfaction survey, among them 74% were technologists, 11% were physicists, 11% were physicians and 2.7% and 1.3%, service techs and oncology residents respectively. The preferred educational supports were the interactive modules and the bulletin respectively, while posters are majorly disregarded. Interestingly enough, people are highly attached to classroom format and were very interested in emergency situations simulations. Respondents majorly stated to read the bulletin’s “always” for 68.5 % and “often” for 13.7%, independently of workers category. The answers are more divergent by work categories when asked about bulletin frequency appropriateness. Technologists are majorly satisfied with the actual bi-monthly rate while radiation oncologists are heaven distributed between status quo and frequency reduction. Contrariwise, for a majority of the physicists, frequency should be reduced. When asked about perception level of RP knowledge with regards to routine tasks, all physicists and physicians answered “adequate”. Answers were more mitigated among technologists where 68.5% answered “adequate”, 29.6% “basic” and 1.9% “thorough”. Interestingly, the commune highest confidence knowledge in all workers categories was found in RP specific to treatment machines, and the lesser in RP in non-medical related areas. Annual completion of electronic modules was majorly accepted.

**Conclusion:** As stated in the NSCA and other regulations, it is the licensee direct responsibility to ensure that workers receive appropriate training related to their specific jobs. Since its inception, the RPTP was well received and closely monitored. Users’ compliance and feedback helped to better meet their needs while continuously developing a radiation protection culture as proposed by the IRPA. It is possible to conclude that overall department stakeholders feel they have sufficient RP knowledge for their daily duties.

**Methodology**

2015 survey was sent to over 3200 contacts using WHO medical devices listserv tool. The survey was divided in four parts: country profile, educational institutions, professional societies and international organizations. Each part aimed to collect specific information on the topic and was aimed to be completed by the professionals holding section-specific information. Additionally a question regarding female presence within the profession was added in each section in order to measure the proportion of women actively working (in different sectors) or recently graduated in BME or related field. All collected information (including the four stages) is expected to be published in WHO Global Health Observatory (GHO), the World Health Statistics 2015 and ideally in ISCO-18.

**Results**

Research is ongoing but anticipates disclosing the presence of biomedical engineers by country (country profile), the number of educational institutions per country and the percentage of women actively present in the field. Additionally the presence of biomedical engineers in international organizations (e.g. UN agencies, Red Cross, development agencies, NGOs) and international professional societies is expected to be unveiled.

**Conclusion**

New information regarding the presence of biomedical engineers is now being collected and is aimed to be publicly available by June 2015. The dissemination and promotion of this information aims to strengthen biomedical engineering recognition in order to improve health care delivery.

**SP063.5 - Where to find biomedical engineers worldwide? Mapping biomedical engineers around the world**

**Author(s):** Daniela Rodríguez Rodríguez, Adriana Velazquez Berumen, Megan M. Smith, Ricardo X. Martinez

His/emp/pau/medical Devices, World Health Organization Headquarters, Geneva/SWITZERLAND

**Background**

Within health systems around the world trained and qualified biomedical engineering (BME) professionals are required to design, evaluate, regulate, acquire, maintain, and train on the safe use of the medical healthcare technologies. Nevertheless the profession is often left out from the health workforce in various countries, and biomedical engineers’ recognition and classification by the International Labour Organization (ILO) is still pending due to lack of statistical information of the current number of biomedical engineers around the world. Therefore with the intention of: a) promoting the role of biomedical engineering and related disciplines in healthcare, b) disseminating information about BME educational programmes and societies; and c) acquiring recognition of the profession at country/international level (e.g. International Standard Classification of Occupations (ISCO) by ILO) WHO started efforts to track biomedical engineers’ presence worldwide since 2009 and in four different stages: 1- 2009: in collaboration with the University of Campinas, work coordinated by professor S. Calli. 2- 2010: C. Long and R. Magiarevik 3- 2013-2014: D. Desai, J. Barragan, S. Mullally and N. Jimenez 4- 2015: on-going

On January 2015 WHO launched an extensive survey that aims to map biomedical engineers’ presence at a country level. Additionally information on existing professional societies, educational institutions in the field of BME and women’s role within the profession is being collected.

**Methodology**


By the end of 2013 Croatia’s health care sector had a permanent work force of about 74,500, around 13,750 medical doctors among whom approximately 9,700 specialists, and about 750 university degree health associates including clinical medical physicists and biomedical engineers. The objective of this paper is to present one national example of medical specialists grandfathering in favor of improved regulation of medical doctor profession, but all in wider context of global efforts towards better perception and regulation of clinical medical physics and biomedical engineering profession worldwide. Equal opportunities of continuing professional education and training, as well as career advancement (internship, residency, subspecialization, postgraduate specialist programs, etc.) should be facilitated and provided to all clinical scientists. Grandfathering is
certainly a usual step to give initial momentum, but grandfathering under the same criteria for all health professionals. For the maximal benefit of the patients, health professionals, health institutions and national health system, it appears that there is an urgent need in Croatia to make decisive actions towards much better perceiving and regulating the status of clinical scientists with background in natural, technical, biotechnical and social sciences.

SP063.7 - Biomedical Engineering Education and Training and Accreditation of Bachelor-degree Biomedical Engineering Programmes

Author(s): Min Wang
Department Of Mechanical Engineering And The Medical Engineering Programme, The University of Hong Kong, Hong Kong/HONG KONG

Hong Kong, like other advanced economies in the Asia-Pacific region, has an aging population and hence high-quality healthcare is required for its citizens. There is therefore an increasing demand for well-educated and well-trained biomedical engineers in Hong Kong. Hong Kong has a well-established system for tertiary education and professional training of engineers. In 2012 in Hong Kong, the British style 3-year university education was changed to the North-American 4-year one, giving local universities various opportunities for reforming their curricula, enhancing teaching and learning, improving student exchange programmes, etc. Biomedical engineering (BME) is a constantly expanding and intrinsically interdisciplinary field. The US and Western Europe as pioneers in the field have provided exemplary BME educational programmes. How to learn from these programmes and then set up their own programmes with distinct features for local students is not an easy task for BME educators in other countries. Currently, four universities in Hong Kong provide bachelor-degree level BME education: The Hong Kong Polytechnic University (PolyU), The University of Hong Kong (HKU), The Chinese University of Hong Kong (CUHK), and City University of Hong Kong (CityU). The 3-year curriculum BME programmes (which started in different universities at different times and will all end in 2015) in PolyU, HKU and CUHK have been fully accredited by the Hong Kong Institution of Engineers (HKIE) which is a signatory of the Washington Accord. The accreditation in Hong Kong of 4-year curriculum BME programmes was started in 2013, and in 2014 HKU’s 4-year curriculum Medical Engineering Programme became the first BME programme to gain HKIE’s provisional accreditation. (A BSc or BEng engineering programme can only gain provisional accreditation, not full accreditation, before it produces its first cohort of graduates.) Another university’s BME programme is currently going through the accreditation exercise. All 4-year curriculum engineering programmes put forward for HKIE’s accreditation must use the outcome-based approaches in student learning and hence the programme’s preparation for accreditation and the accreditation itself (criteria, documentation and presentation, process, etc.) are different for those used in the 3-year curriculum accreditation exercises. With these programmes as the foundation, a three-tier BME education is now in place in Hong Kong: the bachelor-degree level education (BSc or BEng), the taught-master degree (MSc), and research degrees (MPhil or PhD). Beyond the university education at these three levels, professional training in BME can be obtained in different organizations in Hong Kong. Government departments and the private sector alike contribute to BME engineer training. This presentation will give an overview of BME education and training in Hong Kong and briefly compare the BME programmes. It will also discuss various aspects of BME programme accreditation, drawing the author’s experience as the Programme Director to lead the HKU BME programme through its accreditation and also as the Visiting Team member for HKIE’s accreditation of a BME programme in another university.

SP063.8 - IOMP initiative for Validation and Accreditation of MSc courses

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The Education and Training Committee (ETC) of the IOMP guides and supports a number of educational courses, workshops and projects around the world. One of these projects developed a Model Curriculum for post-graduate (MSc level) courses on Medical Physics. It also presented guidance on the organisation of such courses. The next stage of this activity is the initiative of international Validation and Accreditation of MSc courses in Medical Physics. These were briefly described in the book with educational experience from 26 countries (Medical Physics and Engineering Education and Training, available free from: http://www.emerald2.eu/mep/e-book11/ETC_BOOK_2011_ebook_s.pdf).

The Validation and Accreditation of MSc courses will be performed by the IOMP ETC. It will include assessment of the curriculum; assessment of the teaching methods; assessment of the examination process and assessment of the research activities (MSc project). The IOMP Model Curriculum will be used for the purpose and a number of expert medical physicists will be attracted to the validation process. The initial phase of the project will be guided in English and will be based on assessment of an English translation of the MSc Curriculum.

This IOMP activity will allow for a small country with limited expertise to set-up a post-graduate course in Medical Physics. This will boost the profession in many developing countries. The Validation and Accreditation of MSc courses will be used also for supporting the future Professional Certification of professionals. It is expected the first MSc courses to be accredited during 2015-16. The paper will present the application form and will discuss the application of the process.
Habiba Bougherara

Discussion:

3 modular necks (i.e. 39%, 31%, 30% change from intact femur from intact femur, p<.001) vs. short stem implants with any of the p>.05). Stress shielding existed for short and long stem implants Altering implant orientation had no significant advantage (α=.05, stem (slope=0.731, R=0.948) and long stem (slope=0.743, R=0.859).

Implants with shorter stems and longer necks have a greater chance reduce stress shielding. Results indicate some stress shielding in ing vs. long-stem implants. Anteverted and retroverted necks further ed into the femoral canal. Short-stem implants reduce stress shield ing vs. long-stem implants. Anteverted and retroverted necks further.

A finite element (FE) model employed laser scanned implants and a
axial loading in flexion, neutral, and extension phases of the gait
ditional femurs remained intact as controls. Femurs were mounted
ed, and retroverted – were assessed in each short stem. Three ad
ditional femurs remained intact as controls. Femurs were mounted
in cement blocks in 7 deg adduction and underwent quasistatic
axial loading in flexion, neutral, and extension phases of the gait
cycle. Strains were collected from surface-mounted strain gauges.
A finite element (FE) model employed laser scanned implants and a
previously validated femur model. Experimental strains were used to
validate the FE model. After validation, the full range of implant types
and physiologically possible orientations (i.e. varying anteversion
and anterior-posterior offset) were simulated (i.e. n=25 orientations
for each implant) under clinical-level loads. Stress was computed in
the calcar region and was compared between implants and across
each implant’s range of orientations. Stress shielding was the overall
stress change vs. an intact femur.

Results: FE model strains vs. experimental strains linear graphs showed an excellent fit for no implant (slope=0.898, R=0.943), short stem (slope=0.731, R=0.948) and long stem (slope=0.743, R=0.859). Altering implant orientation had no significant advantage (α=.05, p>.05). Stress shielding existed for short and long stem implants (p<.001), but was higher in the long stem implant (i.e. 63% change from intact femur, p<.001) vs. short stem implants with any of the 3 modular necks (i.e. 39%, 31%, 30% change from intact femur for standard, anteverted, and retroverted necks; p<.001 for differ ence between all stems except anteverted and retroverted). Long stems showed more distal-dominant stress transfer vs. short stems (p<.001), whilst peak stress was concentrated at the tip of the stem.

Discussion: Implant orientation via anteversion or anterior-posterior
offset does not alter stress shielding if the implant is properly insert ed into the femoral canal. Short-stem implants reduce stress shield ing vs. long-stem implants. Anteverted and retroverted necks further reduce stress shielding. Results indicate some stress shielding in correctly implanted hip stems in patients with realistic activity levels. Implants with shorter stems and longer necks have a greater chance of maintaining calcar bone strength, but these parameters may reduce short-term stability because of increased proximal loading.
There is currently no objective parameter to define bone fracture union. This makes it difficult for orthopedic care providers to properly treat fractures in areas that are prone to complications such as the tibial shaft. Additionally, the lack of an objective scale for fracture union complicates the comparison of the endpoints of various clinical studies on novel fracture treatments. The Radiographic Union Score for Tibial fractures (RUST) is gaining popularity as a standardisation of an objective parameter to be used in clinical practice and studies.

This study aims to validate RUST as a predictor of biomechanical properties of a fractured bone at different stages during healing using a rat model. A group of 45 male rats will undergo standardised osteotomy of the left tibia and the insertion of an unlocked and unreamed intramedullary nail. Orthogonal radiographs will be taken of the rat’s tibia on a weekly basis and each rat will be assigned a RUST score. The first 9 rats to reach RUST scores of 8, 9, 10, 11 and 12 respectfully will be sacrificed and the left tibia will be dissected. Subsequently, the intramedullary nail will be removed from the bones. The imaging and mechanical testing results will be compared with the rats’ RUST score and a score will be identified as a point when a bone can clinically be considered healed. This will allow for the standardization of an objective parameter to be used in clinical practice and studies.

Fractional flow reserve (FFR) is a well-known gold-standard for stenting decision in a coronary artery. Aim of this study is to present the influences of stenosis on pulsatile flow in multi-scale coronary modelling with virtual narrowing. A further purpose is to better understand the co-relation between fractional flow reserve and biomechanical factors for improving the decision-making strategy of stenting. In the present study, we present a patient-specific 3D coronary arterial modeling by coupled with lumped parameter coronary vascular bed outlet models. The computations of pulsatile flows in coronary artery were performed using a high-speed Navier-Stokes solver based on a finite element method. In this study, we analyse the haemodynamics in terms of various mechanical facetors (velocity, pressure, wall shear stress, etc.) with FFR and some other Index. Hybrid FFR-biomechanical factors could play a positive role on decision-making strategy for better diagnosis and prognosis.
SP065 - Conebeam CT

SP065.1 - Towards Functional C-arm CT Imaging in the Interventional Suite: Progress and challenges
Author(s): Rebecca Fahrig
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When C-arm CT entered the interventional suite in the late 1990’s, the reaction from interventional radiologists ranged from ‘we don’t need it – we can easily create 3D images in our heads’ to ‘wow! that’s the first time I’ve been able to see that vessel clearly!’ Now, 3D C-arm CT imaging is done routinely during neuro- body- and even cardiac-interventional procedures. Technical advances in system components (faster rotation speeds, digital flat panel detectors with readout rates of 80 frames/s, variable trajectories) have enabled a progression from simple, high-contrast vessel imaging to detection of low-contrast soft-tissue lesions. It is now appropriate to explore what further advances are possible given the rapid evolution of the imaging hardware and software, and what these changes would bring to the interventional suite. We will examine these issues with the goal of providing functional information for intra-procedure and endpoint evaluation.

As a first step towards functional information, significant effort has been expended to improve the quantitative accuracy of C-arm CT reconstructions. The challenge is to improve image quality while providing very short turnaround between data acquisition and volume/data visualization. Corrections for x-ray scatter, view aliasing and patient motion that require no more than 2 iterations keep processing time short while reducing artifact. Additional challenges include detector non-linearity/saturation and restricted field of view.

Fast, multi-sweep acquisitions can be used to image blood flow in the brain and liver, permit assessment of left ventricular function, and visualization of radiofrequency lesions created to treat arrhythmias. Workflows for each imaging goal have been developed and validated against gold standard clinical CT or histology. The challenges, opportunities and limitations of the new functional imaging techniques will be discussed.

SP065.2 - 2D/3D Registration for Motion Compensated Reconstruction in Cone-Beam CT of Knees Under Weight-Bearing Condition
Author(s): Martin Berger1, Kerstin Mueller2, Jang-Hwan Choi2, Andre Aichert1, Andreas Maier3, Rebecca Fahrig2
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Introduction: Over the last decade, increased effort has been made to acquire three dimensional images of knee joints under weight-bearing condition. Cone-beam CT systems are popular because of their high flexibility with respect to patient position and scan trajectory. However, scans in a standing or squatting patient position are affected by involuntary patient motion during the acquisition, which results in streaking and blurring artifacts in the reconstructed volumes.

Previous work suggested the use of fiducial markers to estimate and compensate for motion artifacts. However, marker placement on the skin might not accurately reflect the motion at the center of the joint.

Method: We propose a marker-free, data-driven motion compensation method that is based on 2D/3D rigid registrations of segmented bones from a prior, motion-free scan.

The Figure above gives an overview of the pipeline of our method. The segmentations are roughly aligned in 3D with respect to an initial motion corrupted reconstruction. Motion parameters are estimated by 2D/3D registration of each bone to each projection image. After combining the individual bone motions to a global deformation, we can generate a corrected reconstruction.

Results and Discussion: To verify our approach we used a simulated dataset from previous work [1]. Our numeric phantom is based on segmentations of real anatomical structures. Real motion of healthy volunteers was incorporated into the phantom using an optical tracking system.

Our results show great improvement over images without correction. In particular the bones’ outlines are accurately restored. This is important because most relevant structures in the knee joint are located close to the bones, e.g., the cartilage. Incorporating smooth-
ness constraints into the registration cost-function further improved the results.


SP065.3 - Direct Scatter Estimation and Separation for Cone-beam CT Images Utilizing Monte Carlo Simulation

Author(s): Yu Wang, Chaobin Chen, Ruifen Gao, Lijun Hu
University of Science and Technology of China, Hefei/CHINA

Objective: The scatter radiation degrades the reconstructed Cone-beam CT(CBCT) images quality, which limits the application of CBCT images into the re-optimization of treatment plans for Adaptive Radiotherapy (ART). This paper estimated the scatter distribution in the CBCT projections directly utilizing the Monte Carlo simulation. In addition, the scatter separation was taken into account to determine the corresponding scatter fraction introduced by different parts of the system.

Methods and Materials: Using EGSnrc Monte Carlo program, the ELEKTA XVI CBCT system was modeled including the x-ray tube, water phantom with different thickness and flat-panel detector. The LATCH option was adopted to record the particles information, including the fluence, energy, weight, weather a secondary particle and which modules it had interacted with. The model was validated by percentage depth dose (PDD) and lateral profiles measurements. A program based on Visual C++ was developed to extract the primary particles and calculate the total scatter radiation at the scoring plane. At last, the corresponding scatter fractions introduced by different parts of the system were separated.

Results: The calculated PDD and lateral dose profiles were compared against the dose measurements under 1cm water. The dose difference of PDD was better than 1% within the depth of 10cm. More than 85% points of lateral dose profiles was within 2%. For CBCT system, the phantom produced the larger part of the scatter radiation, almost 50% with water thickness of more than 25cm.

Conclusions: The CBCT system has been fully modeled including x-ray tube, phantom and flat-panel detector and the model was validated by the PDD and lateral profiles measurements. The scatter fractions introduced by the phantom with thickness of more than 25cm should be corrected to improve the images quality. This study is expected to be applied to the scatter radiation correction for improving CBCT images quality and optimizing the CBCT modules design.

SP065.4 - Automatic Motion Estimation and Compensation Framework for Weight-bearing C-arm CT scans using Fiducial Markers

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Cone-beam CT systems are widely used because of their high flexibility with respect to patient position and scan trajectory. In the last years, C-arm CT systems have been used to acquire images in weight-bearing conditions in order to expose, e.g. the knee joint under realistic loads. Straight standing or squatting patient positions lead to involuntary patient motion during the acquisition. In this paper, a fully-automatic motion estimation and compensation framework to mitigate knee-joint motion during weight-bearing C-arm scans is presented. Our framework consists of three major steps: marker detection with outlier removal, motion estimation and correction, and marker removal. The marker detection is based on an initial estimate of the marker position extracted from the motion-blurred filtered backprojection (FDK) reconstruction and on the fast radial symmetry transformed (FRST) 2-D projection images. The motion is estimated by the alignment of the forward projected 3-D initial marker positions with the actual detected 2-D marker positions. The motion is then corrected in the filtered backprojection step. Finally, the detected markers are removed in the 2-D projection images by simple interpolation. The framework was evaluated on three C-arm CT datasets from one volunteer in a straight standing, moderate squatted and deep squatted position. All 3-D reconstructions show a large improvement in image quality compared to the non-corrected 3-D reconstructions.
SP065.5 - Evaluation of two-pass view aliasing artifact suppression algorithm using clinical data
Author(s): Meng Wu, Kerstin Mueller, Michael P. Marks, Rebecca Fahrig
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Purpose: In brain perfusion CT imaging, state-of-the-art C-arm CT systems can rotate up to 100 degrees / second, which permits CT imaging with high temporal resolution. However, the read-out rate of the flat panel detector often limits the number of projections acquired in the fast scan and causes view aliasing artifacts in the reconstruction. We propose to suppress aliasing artifacts in decomposed projections through feature preserving interpolation.

Methods: The high frequency structures that cause streak artifacts are hidden within the total line integral. Thus, the interpolation-based method for angular up-sampling often fails to correct for these high frequency structures. We propose an FBP-based algorithm using multi-resolution reconstruction to identify the structures in projection space that may cause the artifacts. The adaptive multi-resolution FDK reconstruction adaptively selects the bandwidth of the ramp filter in the FDK method to reconstruct regions of the image at maximal frequency without view aliasing artifacts. A feature preserving interpolation in projection space is used to increase the angular sampling rate. The restored high frequency structures are then added back to the view aliasing-free reconstruction. The proposed method’s performance is assessed using real patient C-arm (Artis zee biplane system, Siemens AG, Germany) head scan data. Only 124 out of 248 projections are used for the reconstruction to mimic the sparse-view data in the fast scan. Our results are compared to those with and without linear interpolation method.

Results: As shown in Figure 1, the proposed method can effectively reduce the view aliasing streak artifacts. The structural similarity (SSIM) indices of the brain tissue region using the FDK, linear interpolation, and proposed methods comparing to the ground truth are 0.7428, 0.7686 and 0.8060, respectively. The proposed method also reduces the standard deviation of the brain tissue without contrast (which is assumed to be uniform) from 56.2 HU to 35.7 HU while the linear interpolation method has a standard deviation of 42.5 HU. The proposed method is compatible with a projection-based motion compensation technique to further improve the image quality.

Conclusion: Distinct from other blurring-based and iterative reconstruction methods, our method maximally preserves image spatial resolution with only two iterations. Future investigations will incorporate the technique for noise reduction and compare to sparse view iterative reconstruction.

Figure 1, reconstruction results using FDK, linear interpolation and the proposed method. The display window is [-500 500] HU.

SP065.6 - A simple algorithm to remove metal artifacts in frame based radiosurgical treatments
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Purpose: To show a simple method to remove metal artifacts generated during imaging for treatment planning purpose. Materials and Methods: A human head shaped phantom made from acrylic material was fixed to stereotactic Leksell frame for artifact simulation purpose. Four metal screws aided in holding the metal frame to the phantom with carbon fixation posts. An ion chamber positioned in the middle portion of the phantom determines point dose measurement. In this study same ion chamber setup generated artifacts at the phantom center which required artifact removal. CT scans of the phantom were acquired using following scanning parameters: Tube voltage-110 kV, Slice thickness-1 mm and FOV-240 mm. Image slices with severe artifacts were selected for image processing using in-house developed matlab codes. Pixels in the phantom image affected by noise were isolated and digitally post processed by applying threshold value to the hounsfield units (HU).

Results: The images showed more than 95 % improvisation after implementing correction algorithm. Before image correction the HU present in the phantom image due to metal frame and pins was found to be more than 3000 HU. After applying correction algorithm, HU of ion chamber region, metal frame and pin region were restored.

Conclusion: The TPS system of Gamma Knife (GK) performs convolution algorithm based calculation on CT images with HU values range between -1000 to +1024. Any HU values beyond these values are automatically ignored by the TPS during calculation. It means that the TPS ignores the artifact affected region for calculation irrespective of where it is present. This is one of the major limitations of convolution algorithm based planning in GK. The artifact removal method shown in this study is a simple, effective technique which overcomes these limitations and is a valuable tool for GK.
SP066.1 - Fingertip touch adjust postural orientation during perturbed stance  
**Author(s):** Aizreena Azaman, Shin-Ichiroh Yamamoto  
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Additional sensory information; especially from touch, was suggested to improve stability by reducing body sway. However, it is less known about the effect of touch on the body’s joint movement during perturbed standing; which is commonly experienced by public transport users. In this study, subjects were asked to try to maintain their standing position with their fingertips on a rigid surface, while surface perturbation was applied at four different perturbation frequencies (0.2, 0.4, 0.6, and 0.6 Hz) and different vision input. Motion of joint (ankle, hip and head) and relative centre of mass (COM) were recorded and analysed. The results show that fingertip pressure was higher without vision. Furthermore, different fingertip moment directions were recorded between with vision and with no vision. This possibly indicates a preferred fingertip position that can provide better sensory information to replace sensory loss; especially vision. The range of motion of joints also decreased with fingertip touch - except for head motion. Furthermore, even though there were no significant differences observed between with touch and without touch, the relative COM displacement was less with touch. Thus, even with a very light touch, subjects were able to reduce body sway even in a perturbed stance. Further investigation is needed to determine the changes in centre of pressure (COP) and significant position of fingertip, which can enhance stability.

SP066.2 - Design and Evaluation of a Prosthetic Knee Joint based on Automatic Stance-Phase Lock (ASPL) Technology for Children with Transfemoral Amputations  
**Author(s):** Calvin Ngan, Jan Andrysek  
Bloorview Research Institute, Holland Bloorview Kids Rehabilitation Hospital, Toronto/ON/CANADA

**Introduction:** Lower extremity amputation strongly affects an individual's mobility and quality of life, as well as creating a socioeconomic burden for society. Studies have shown that amputations in children have a particularly significant impact on their physical and psychological developments. Therefore, it is important to provide child amputees with a well-functioning prosthetic knee joint to restore their mobility function and enable them to partake in physical activities with peers and family.

**Problem:** Many paediatric prosthetic knee joints in the market incorporate four- or six-bar linkage mechanisms that offer good stance phase control, but their added size and weight make them unsuitable for very small children. Furthermore, to accommodate these size constraints, many designs exclude swing phase control and extension assist mechanisms, negatively impacting user’s gait characteristics such as energy expenditure and gait speed. Therefore, the objective of this project is to design and evaluate an original paediatric prosthetic knee that will provide good stance phase stability by incorporating the novel, patented Automatic Stance Phase Lock (ASPL) mechanisms developed in Holland Bloorview Kids Rehabilitation Hospital, and integrating frictional components and extension assist mechanism to offer better swing phase control for the user.

**Method:** We focus on three major areas: (1) knee design and proto-
type development, (2) structural testing, and (3) functional evaluation via a pilot study. We will use 3D Computer Aided Design (CAD) and Finite Element Analysis (FEA) software to develop and structurally optimize the prosthetic knee joint model. A prototype will then be constructed and a series of bench-top structural tests will be performed following the ISO 10328 to test for structural integrity. In the pilot study, a single subject with an unilateral transfemoral amputation will perform six-minute walk tests and gait assessment tests with his/her current prosthetic knee, as well as our prototype. Gait characteristics such as walking velocity, kinetics profiles including knee flexion angle and knee moment, and energy expenditure will be measured and analyzed in both trials. Differences in the key parameters listed above between the prototypes and the conventional knee will be used as an indicator for how functional the prototype is and indicate which design changes may improve areas of concern.

**Results:** In the current stage of the project, we designed and developed a 3D computer model of the paediatric prosthetic knee. In the model, our prototype is estimated to be 120mm tall and weighs about 355g, which is similar to current commercially available products. It also includes mechanical friction control and extension assist to facilitate the swing phase control for the user. Multiple iterations of FEA on the model were completed, and the results suggested that the design is capable of supporting the specified load listed in the ISO structural test. Therefore we will proceed to fabricating the prototype and performing the structural test imminently. The goal of this project is to prove the feasibility of implementing ASPL technology in a paediatric prosthetic knee, so ultimately it would be possible to provide well-functioning and affordable prostheses for child amputees around the globe.

**SP066.3 - Frontal plane gait during cross-slope walking for able-bodied and transtibial amputees**

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Cross-slope surfaces are slopes in the frontal plane. Unlike level and inclined surfaces, cross-slope walking requires an asymmetrical gait pattern to keep the body vertical while adapting to different ground heights and angles. Although cross-slopes are a common real-world surface, cross-slope walking literature is predominately on the able-bodied population. For individuals with a lower limb amputation, lack of lower limb musculature may pose a greater challenge for maintaining balance and forward progression on cross-slopes. This research investigated compensatory adaptations in the frontal plane for able-bodied individuals and individuals with a transtibial amputation when walking on moderate cross-slopes.

Fourteen able-bodied (AB) and 14 unilateral transtibial amputees (TTA) participants in this study. Participants walked on a level and +5° cross-slope treadmill at a fixed speed while full body kinematic data were captured within a CAREN-Extended virtual reality environment. Gait outcome measures included, speed, step width, and frontal plane joint angles (ankle, knee, hip, pelvis, and trunk) and sagittal plane joint angles (ankle and knee) at foot contact and during stance. Data were examined using a linear mixed model with a treadmill speed covariate. Post-hoc t-tests with a Holm-Bonferroni correction (p<0.05) were performed to examine differences between groups and walking conditions.

TTA participants walked slower than able-bodied (AB = 1.29±0.06 m/s, TT = 1.11±0.15 m/s; p<0.001). Step width (14.7±0.6cm) was not significantly different between walking conditions and groups. Compared to level walking (LW), the limb at the top of the cross-slope (TS) had less ankle inversion at foot contact and ankle angle trans-}
SP066.5 - The influence of the aquatic environment on the control of gait initiation

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**Background:** Gait initiation is a common functional task defined as the transition from stationary standing to steady-state walking. It is vastly investigated in healthy subjects and in individuals with disability. The complex interaction between neuromuscular and biomechanical factors during gait initiation has been investigated mainly in two phases, anticipatory postural adjustments (APAs) and execution of the step. Despite the frequent use of therapy pools for walking training in early stages of locomotor recovery, the effects of immersion on the control of gait initiation have not been reported yet. The objective of the present study is to analyze the center of pressure (COP) trajectories, the vertical and horizontal forces and trunk acceleration (ACC) during APAs, as well as during execution of the first and second steps during gait initiation.

**Method:** Able-bodied young adults (3 female and 2 male) were requested to initiate gait from a waterproof force plate (AMTI OR6-WP-1000, Watertown) and to continue walking for 5 steps. Individuals performed 10 consecutive trials, on land and in water, on two consecutive days. Subjects initiated gait with the same foot position following a visual cue. Two inertial sensors (Physilog, BioAGM, Lausanne) were attached to L5/S1 vertebrae and to the shank of the initial stance limb. COP landmarks were used to identify APAs and execution of the first step. Shank ACC was used to mark the toe-off and heel strike of the second step. Lower trunk (LT) horizontal ACC (anteroposterior – AP and mediolateral – ML) during APAs and execution phases was computed. The parameters used for evaluation were: peak of anticipatory COP trajectory (APA_Peak); COP length during APAs; length and velocities of COP trajectories during execution of the first step; impulse forces in vertical and AP directions; root mean square (RMS) ACC of trunk during first and second steps. Wilcoxon Matched-Pair Signed-Rank test was used for comparisons between land and water conditions.

**Results:** Percentage of body mass offloading in water varied between 49% and 57%. COP movements during APA and execution of first step were significantly larger in water compared to land: APA_Peak in ML (5.1±1.7 vs. 3.7±1.5 cm); ML length of COP trajectory when body weight was transferred to the stance limb (22.8±4.2 vs. 18.2±3.5 cm); and ML length of COP during first swing (5.4±1.8 vs. 2.8±1.1 cm). COP velocity in AP during the first swing was slower in water (16.7±4.2 vs. 26.7±4.9 cm/s). The vertical impulse of the stance limb was smaller in water compared to land (340.7±31.1 vs. 425.4±54.2 N.s). LT ACC were smaller in water compared to land with more accentuated change in AP RMS of LT ACC during first step (0.6±0.3 vs. 1.8±0.7 m/s²) and second step (0.7±0.2 vs. 1.6±0.3 m/s²).

**Conclusion:** Immersion in water increases mediolateral body displacement, and reduces trunk acceleration and vertical impulse force during gait initiation, suggesting potential implications for aquatic rehabilitation.
SP067 - Characterization of Detector Systems for Therapy Dosimetry: Part 2

SP067.1 - Reaction of three UV exposure to gafchromic EBT-2 and EBT-3

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Gafchromic films (GAFs) are used for the X-ray dose measurement in the diagnostic examination. It is begun to use for the three-dimensional X-rays dose measurement using the high-resolution characteristic in computed tomography. However, it is necessary to solve a problem of unevenness of active layer of GAFs. It is suggested that the ultraviolet (UV) is substitute as an X-ray. However, wavelength of appropriate UV are unidentified. This study is to decide a wavelength of the UV.

Peak wavelength of 245 nm, 310 nm and 365 nm UV were irradiate to the EBT2 and EBT3. The UV rays were irradiated for 5, 15, 30 and 60 minutes, and irradiation was repeated afterwards until 360 minutes every 60 minutes. The images were split in RGB, and R images were used. ROI of the diameter 1/2 inch was set in the center of subtracted GAF images, and the graph of UV irradiation time and the mean pixel value were made.

There was a reaction in front and back of GAF EBT3 and back of EBT2 in UV-A and B. However, UV-C had few reactions with both aspects of GAF EBT2 and EBT3.

It should be used UV-A for a fact because a wavelength of UV-B may affect the human body.

SP067.2 - Characterizing FujiFilm CR Signal Storage Decay Rates

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Introduction

In this work we outline a method for characterizing x-ray signal retention on Fujifilm CR photostimulable phosphors (PSPs). In order to use CR plates as dosimeters and to ensure the accuracy of image quality and dose indicator metrics, the behavior of x-ray signal storage needs to be characterized. Based on electron-hole storage of PSPs, it is known that in addition to specific frequency light stimulation overcoming the band gap and releasing the stored signal, thermal processes can do likewise, but at slower rates [Rowlands].

Methods/Results

The same FujiFilm CR plate was exposed repeatedly to 700 (±20) uGy at 120kVp and readouts were spaced out between immediate and 20days, as shown as the blue dots in A. Raw pixel values were extracted from image data and converted to dose as per [Bjarnason1]. When exposures were performed on separate days, all data were normalized using image data scanned immediately on that day. CR plates were sandwiched between 4 mm lead to minimizing background radiation exposure during the measurement time delay. The resulting decay was fit (black line in A) using a sum of exponential decays as per [Bjarnason2], which makes no a priori assumptions as to the number of exponentials present. The resulting relaxation distribution was found (B) and the following decay components were identified: 0.014 @ 2.8min, 0.045 @ 10.3min, 0.126 @ 2.1hr, 0.046 @ 15.9hr, 0.48 @ 40days.

Discussion/Conclusions

In this work we characterized 20 days of CR signal retention. Signal fading of 25% is expected between 10min and 8hr, and then slower after [AAPM 93], but this behavior has not been fully characterized before. We found the signal decay to be multiexponential and can conclude that the first two decay components at 2.8 and 10.3min should minimally affect the CR dose indicator values because even though staff often quickly read the images while signal is being lost due to these decay times, their intensities only account for 5% of the total signal loss occurring after about 1hr. By characterizing the signal loss over longer times, we can use these data to calibrate CR plates for use as area dosimeters. Future work includes testing inter-
plate variability, assessment at different kVps, and assessment of different vendors using different PSP chemical compositions.

References


SP067.3 - Angular dependence of diode detectors and PinPoint ionization chamber in Gamma Knife dosimetry

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Dosimetry for Gamma-Knife radiosurgery beams requires detectors with high spatial resolution, minimal angular dependence of signal and linear dose response. Angular dependence for shielded (PTW60016 Diode P) and unshielded (PTW60017 Diode E) p-type silicon detectors and PTW31006 PinPoint ionization chamber was measured indirectly with 18, 14, 8 and 4 mm collimator for the Leksell Gamma Knife Model C. Weighted angular dependence correction factors were calculated for each detector and collimator helmet. For Gamma-Knife beams angle range of 84°-54° Diode P detector shows considerable angular dependence of 9% and 8% for the 18 mm and 14, 8, 4 mm collimator, respectively. For Diode E detector this dependence is about 4% for all collimators. Compared to Diode E, Diode P shows stronger angular dependence which may be explained by the increase of electron backscattering from the metal shield of silicon active volume as the angle of incident photon beam decreases, i.e. more photons are entering silicon chip perpendicularly. PinPoint ionization chamber shows angular dependence of less than 3% for 18, 14 and 8 mm helmet and 10% for 4 mm collimator which is probably due to volumetric averaging effect in a small photon beam. Diodes P and E represent good choice for Gamma-Knife dosimetry, while PinPoint ionization chamber is not recommended for dosimetry with the 4 mm collimator helmets. When used for absolute and relative dosimetry of Gamma Knife beams, diodes and PinPoint ionization chamber response should be corrected for angular dependence.

SP067.4 - Determination of a correction factor to mitigate long term reader fluctuation of the Optically Stimulated Luminescence dosimetry system at the International Atomic Energy Agency

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Introduction

The Dosimetry Laboratory at the International Atomic Energy Agency is commissioning an Optically Stimulated Luminescence (OSL) dosimetry system to provide radiotherapy dosimetry audits. The OSL readers’ (Microstari, Landauern) internal mechanism consists of a high powered light emitting diode (LED), optical components and a photo-multiplier tube (PMT). Inbuilt PMT response Quality Assurance checks along with standard measurements from control OSL dosimeters allow the daily performance of the readers to be monitored. Extensive measurements were conducted during a period of 6 weeks. In this time the PMT response showed a fluctuation of 1.7% and the control OSL dosimeters’ results exhibited a fluctuation of 1.4%. A correction factor to mitigate this magnitude of reader fluctuation is necessary and was calculated with two separate methods.

Materials/Methods

In the first method, PMT response QA checks were periodically performed directly preceding measurements of a control batch of OSLDs. A linear correlation of the magnitude of deviation of OSL dosimeter readout values from postulated theoretical values, as demonstrated on an earlier model system [1]. These deviations were deemed attributable to reader fluctuations and the magnitude was correlated to PMT response data to determine a correction factor. In an iterative approach, this method also allowed a more accurate theoretical model to be calculated.

Results

Reader fluctuation correction factors were determined by both methods and applied to daily control OSL dosimetry data. The two methods of determination of reader fluctuation correction factors resulted in reduced long term fluctuation in control OSL readout values to 0.9% and 0.2%, respectively, over the 6 week period. Longer term investigation may allow this to be improved as more data is acquired.

Conclusion

To mitigate the influence of long term reader fluctuation on the determination of OSL dosimetry audit values, a reader correction factor has been determined from two methods. The application of this correction factor has achieved a substantial decrease in the magnitude of reader fluctuations over a period of 6 weeks and will be the basis of protocols to also reduce fluctuation on the short term.

References


SP067.5 - Reference and relative dosimetry of standard and small photon fields with new commercially available detectors

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Two new detectors, the PTW microDiamond synthetic diamond detector and the Exradin W1 plastic scintillation detector (PSD), are now available that were designed for the dosimetry of small radiation fields. We investigate the performance of a single version of each detector when used for reference dosimetry of standard fields and relative dosimetry of small fields placing specific emphasis on the determination of associated uncertainties.

Measurements of detector response are made under reference conditions in 6, 10 and 25 MV photon beams from the Elekta Pre-
cise linear accelerator in 10x10 cm² field sizes relative to secondary standard reference chambers, calibrated in terms of absorbed dose directly against the National Research Council of Canada (NRC) primary standard water calorimeter. These absolute calibrations are used to derive detector energy dependence as well as short- (hours) and long- (months) term repeatability. Profiles are measured with these detectors in fields as small as 0.6x0.6 cm² shaped by the Elekta photon jaws and used for accurate detector positioning in small fields. Once detectors are properly positioned on the beam axis, small field output factors are measured, keeping the detector position constant and modifying the photon jaw settings. Measurements of output factors are repeated to investigate uncertainties caused by jaw positioning repeatability, detector positioning and the repeatability of the detector response and/or associated noise.

For both detectors, energy dependence is less than 1% comparing calibrations over the range 6-25 MV. The repeatability of the PTW microDiamond response for calibrations under reference conditions is within 0.3% after a period of almost two months. The repeatability of the response of the Exradin W1 PSD is generally also at this level, although sometimes unexpected differences of 1-2% were observed, which require further research for explanation. Profiles measured with the two detectors are in good agreement although the very small signal from the Exradin W1 is much noisier. The attached figure shows small field output factors (i.e., readings normalized to the value obtained in a 10x10 cm² field) with error bars representing type A uncertainties and variations in repeated measurements of output factors. For both detectors, standard uncertainties in reference dosimetry measurements are within 0.4% and are less than 2% for relative dosimetry measurements in very small fields.

Both detectors investigated in this work exhibit very impressive behavior for both reference and relative dosimetry measurements.

SP067.6 - Evaluation of detectors response for small field output factor measurement using multichannel film dosimetry

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**Introduction**

Most irradiation technics require dose computing from TPS. Calculation accuracy highly depends on the measurements used for beam modeling. Depending on their characteristics, available detectors may be best suited for specific field sizes when measuring Output Factors (OF). Recent studies compare several active with passive detectors and Monte Carlo calculation.

The goal of our study is to evaluate the response of several active detectors exposed to 6 MV X-ray beams of different sizes, down to 1x1 cm², while considering EBT3 Gafchromic films as reference.

**Materials and methods**

Eight EBT3 films were irradiated with field sizes ranging from 1x1 to 10x10 cm². Measurements were done in a home-made RW3 solid water phantom. Multichannel film dosimetry was used for film opacity-to-dose conversion. All films (including background) were irradiated and scanned simultaneously using the efficient protocol described by D. Lewis et al.

Among available active detectors, two ionization chambers and two diodes were studied. Measurements were carried out in a water phantom.

OF measurements were also done by placing both chambers in the solid water phantom, in the same condition as the films. Results were compared to measurements done in water in order to verify scattering components correspondence for all field sizes. This allows active detectors irradiated in water to be compared to the films in RW3 slabs.

**Results**

OF obtained with the ionization chambers placed in the water and solid water phantom are identical for field sizes smaller than 15x15 cm².

As described in P. Andreo publication, active detector response for each field size was normalized with respect to the reference data. Figure 1 shows results. Concerning ionization chambers, the influence of partial volume averaging is similar to the published results. The three major effects mentioned for the diodes also appear in our results: the charged particles equilibrium between detector material and water, the over-response of the unshielded diode in broad beams and the partial volume averaging.

**Conclusion**

Our study confirms that partial volume averaging is not the only undesirable effect for OF measurement. Thus, the detector having the best spatial resolution is not systematically the best suited for small fields OF measurements.
SP068 - Development of New Methods in Therapy Dosimetry

SP068.1 - A Farmer ion chamber as reference to the calibration of CT chambers

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Introduction: Computed tomography (CT) is among the largest sources of collective radiation dose. The absorbed dose in CT exams can be ten times higher than in other common procedures of radiographic imaging. To assess the dose of radiation, the necessary meters should be properly calibrated in beams and setups like those measured in field [IAEA, Dosimetry in Radiology: An International Code of Practice, TRS 457, 2007]. AAPM TG111 report [AAPM, Comprehensive methodology for the evaluation of radiation dose in X-ray computed tomography. AAPM report 111, 2010] has proposed improved metrics for CT dosimetry, using a small ion chamber, mainly considering helicoidal and multislice scanning. This study aimed to improve the methodology for CT ion chamber calibration in standard dosimetry laboratories, inspired on IAEA and AAPM recommendations.

Methodology: Initially, CT standard beams (RQT) have been characterized, using a calibrated PTW Farmer chamber as reference. Then, we have investigated some options to the setup to calibrate CT “pencil” type chambers in Air kerma-length product (PKL) by substitution: without any collimator (A) or with a reference collimator of aperture L=2cm (B.2) or L=5cm (B.5) in front of the chamber to be calibrated (Fig.1). Additionally, homogeneity of the pencil chamber response was checked shifting the chamber perpendicularly to the beam, behind the collimator, 1 by 1cm, and repeating the calibration with B.2 setup.

Results and Discussion: Table 1 summarizes the obtained results for 100mm PTW chamber calibration coefficients. Results showed differences up to 2% in the obtained calibration coefficients, depending on the aperture of the used collimator. In the following additional tests, pencil chamber homogeneity just kept up to 3.5cm from the chamber center. Results were very similar for other CT chambers from Radcal Co.

<table>
<thead>
<tr>
<th>Standard beam</th>
<th>PPV (kV)</th>
<th>HVL (mmAl)</th>
<th>NPKL-user (A)</th>
<th>NPKL-user (B.2) (L=2 cm)</th>
<th>NPKL-user (B.5) (L=5 cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQT 8</td>
<td>100.07</td>
<td>6.90</td>
<td>1.003(27)</td>
<td>0.983(20)</td>
<td>0.982(17)</td>
</tr>
<tr>
<td>RQT 9</td>
<td>120.03</td>
<td>8.40</td>
<td>1.023(26)</td>
<td>1.001(19)</td>
<td>1.004(16)</td>
</tr>
<tr>
<td>RQT 10</td>
<td>149.80</td>
<td>10.10</td>
<td>1.008(27)</td>
<td>0.987(19)</td>
<td>0.992(17)</td>
</tr>
</tbody>
</table>

Figure 1 — Setup detail for the CT chamber calibration.

SP068.2 - Determination of the Uncertainty in the Cross-calibration of an Ionization Chamber Used in Radiation Therapy

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It was performed an analysis of the uncertainties involved in a cross-calibration procedure of an ionization chamber used in Sírio-Libanês Hospital, according to the methodology proposed in IAEA-TECDOC-1585, based on ISO GUM. The overall uncertainty obtained was 2.55% (coverage factor k = 2), which meant an increase of 0.04% compared to the reference ionization chamber uncertainty reported by the dosimetry laboratory of LCI-GMR-IPEN/CNEN-SP. In such cases where the uncertainty of the calibration coefficient of the reference instrument is high, this uncertainty dominates the overall uncertainty of the cross-calibration. It was performed an analysis of the uncertainties involved in a cross-calibration procedure of an ionization chamber used in Sírio-Libanês Hospital, according to the methodology proposed in IAEA-TECDOC-1585, based on ISO GUM. The overall uncertainty obtained was 2.55% (coverage factor k = 2), which meant an increase of 0.04% compared to the reference ionization chamber uncertainty reported by the dosimetry laboratory of LCI-GMR-IPEN/CNEN-SP.
SP068.3 - A study of uncertainties in the half-value layer measurement of a miniature kV x-ray source

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Air kerma standards for low energy x-ray devices used in electronic brachytherapy or intraoperative radiotherapy critically depend on accurate knowledge of the primary spectrum of the source. A model of a low energy x-ray source (INTRABEAM, Carl Zeiss) using the EGSnrc Monte Carlo (MC) code has been developed. To validate the model in-air, half-value layer (HVL) attenuation measurements were performed and compared with calculated values. For a meaningful comparison, the uncertainties in both the calculated and measured HVL must be well understood. In this work, we discuss the statistical and systematic uncertainties in HVL calculation.

The INTRABEAM source was modeled using the EGSnrc user code cavity. Photon fluence spectra emitted by the source were scored for the bare probe and spherical applicators of 3.5 cm, 4.0 cm, and 4.5 cm diameter. HVL was determined analytically from the simulated spectra by calculating the attenuation of air-kerma for a given thickness of aluminum and source-to-detector air gap. Beam collimation was provided by a lead cylinder surrounding the INTRABEAM source. Foils of high purity aluminum were placed at the exit of the collimator, and attenuation measurements were performed using a PTW 23342 parallel-plate chamber. The measured HVL was determined by curve fitting of the experimentally determined attenuation data. The statistical uncertainty in the MC-calculated HVL was determined by propagating the fluence spectrum uncertainty across the calculation of air-kerma ratio, taking into account photon cross-section uncertainty. The sources of MC systematic uncertainty considered were: the variation in polyetherimide (applicator material) density, collimator positioning error, and source-to-detector positioning error. In the experimental HVL measurement, the uncertainty was estimated by the tolerance of aluminum attenuator thicknesses and the 95% confidence interval of the fitted attenuation curve. The accuracy of the HVL determination is a critical step in the reference dose calibration of the INTRABEAM source. Our results indicate that the presence of the lead collimator, due to the emission of fluorescent x-rays, had a non-negligible effect on HVL measurement for the spherical applicators. In the MC calculation of spherical applicator HVLs, the collar positioning error was found to be one of the dominant contributions to uncertainty (ΔHVL = 0.03 mm Al). For the simulated bare probe HVL, statistical errors and source-to-detector positioning contributed equally to the overall uncertainty. Upon comprehensive analysis of sources of experimental errors, we conclude that the simulated HVLs were in good agreement with measurement for the bare probe and spherical applicators.
SP068.4 - Low Energy Therapeutic X-Ray Calibration Methods

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The application of low energy X-rays has recently increased in the dermatology workspace, with the generating tube potential of these radiation beams spanning from 10 to 70kV. Absolute calibration of these low energy radiation units from three different manufacturers has been conducted. Various low-energy calibration protocols were considered for calibrating the low energy beams of the X-ray tubes from three different manufacturers. These protocols included the American Association of Physicists in Medicine (AAPM) Task Group 61 Report (for 40-300 kV beams), the UK Code of Practice from the Institution of Physics and Engineering in Medicine and Biology (IPEMB) for very low-energy X-rays (8-50 kV), International Atomic Energy Agency (IAEA) Technical Reports Series No. 398 (for X-ray up to 100 kV), and Report 10 of the Netherlands Commission on Radiation Dosimetry for low energy X-ray (50-100 kV). Review and comparison of the methodology of these protocols, pertaining to the energy range of Grenz-rays to superficial X-rays, is conducted.

In general, standard calibration laboratories provide an in-air calibration factor, Nk (air-kerma in Gy), and/or an in-water calibration factor, ND,w,Qo (absorbed dose to water in Gy). These factors can in turn be used in air or in a phantom in a clinical setting. The aforementioned protocols allow one or more of such calibration conditions. Because of the wider availability of Nk calibration factors from the US-based standard calibration laboratories and ease of using an in-air calibration technique for low-energy X-ray beams in a clinical setting, the AAPM-TG61 protocol and the data extracted from the British Journal of Radiology Supplement No. 25 were found to be the most practical for the calibration of low energy X-ray units for dermatological applications.

The issues with calibrating such low energies radiation units include having the appropriate equipment, creating a precise physical setup for measurements, and the low SNR when performing HVL measurements. The HVL setup needs to be stable and precise, due to the sensitive nature of these measurements. An air gap between the chamber and the source at these low energy units can change the results significantly. For example, a one millimeter air gap between a specially designed parallel-plate chamber and one of these low-energy X-ray producing units can cause an error in the order of 3%.

SP068.5 - Energy response of a thimble-type ionization chamber for Ir-192 and Co-60 radiation beams

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A new international comparison for primary determinations of reference air-kerma rate using Ir-192 brachytherapy sources has been established by the Bureau International des Poids et Mesures (BIPM) and registered in the BIPM Key Comparison Data Base (KCDB) as an ongoing key comparison under the reference BIPM. Rli(K)-K7.

The participants in this key comparison, the National Metrology Institutes NMs, calibrate a thimble-type ionization chamber, model NE 2571, under reference conditions following the corresponding protocol. The comparison result, and thus the degree of equivalence between the NMI and the BIPM, is based on the ratio of the NMI calibration coefficient to that of the BIPM, the latter chosen as the Key Comparison Reference Value (KCRV).

As the BIPM has no primary facility for Ir-192 brachytherapy sources, the reference value is evaluated from the calibration coefficient of the ionization chamber determined in the BIPM reference Co-60 beam, with a correction factor kN applied to account for the energy dependence of this type of chamber.

This correction factor is calculated using the Monte Carlo code Penelope [1]. The simulation of the chamber (dimensions, shape and materials) was made using the geometry code Pengeon, based on the manufacturer data sheet for the chamber. Using this code, a typical Ir-192 source used for therapy with its encapsulation was simulated.

In the first step the user code simulates the energy spectrum of the Ir-192 source and creates a phase-space file at 5 cm from the source reference point, recording the energy, spatial coordinates and direction of each particle. This file is used in the second step as an input to calculate the calibration coefficient of the ionization chamber at 1 m from the source.

Similarly, the calibration coefficient of the ionization chamber is evaluated for the Co-60 beam, using as input the existing phase-space file corresponding to the BIPM reference beam.

The correction factor kN for the NE 2571 ionization chamber is determined as the ratio of the calibration coefficient evaluated for Ir-192 to that for Co-60. Supporting calculations are made to estimate the uncertainty of kN. The results are compared with published work.


SP068.6 - Kilo-voltage X-Ray tube dosimetry Correction factors for in-water measurement in TG-61

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For x-ray tube potentials > 100 kV, the AAPM TG-61 protocol for 40-300 kV x-ray beam dosimetry in radiotherapy recommends an in-water measurement which is based on ionization chambers calibrated in air in terms of air kerma. We studied the variation of the overall correction factor (PQch) and its components (known as corrections for the change in the chamber response due to the change in the spectrum distribution in phantom compared to that used for the calibration in air (kQ), displacement of water by the ionization chamber (Pdis) and displacement of water by the stem (Psheath)) as well as the correction for a waterproofing sleeve (Psheath) with depth and field size for 6 different beam qualities in the orthovoltage x-ray range (100 kV < tube potential < 300 kV). Based on TG-61, the absorbed dose to water at the reference depth (2 cm) is given by: Dwater = Mair Nk PQch Psheath ([μν]water/air) water, where PQch is the calibration coefficient of the ionization chamber determined in the BIPM reference Co-60 beam, with a correction factor kN for the NE 2571 ionization chamber.

As the BIPM has no primary facility for Ir-192 brachytherapy sources, the reference value is evaluated from the calibration coefficient of the ionization chamber determined in the BIPM reference Co-60 beam, with a correction factor kN applied to account for the energy dependence of this type of chamber.

This correction factor is calculated using the Monte Carlo code Penelope [1]. The simulation of the chamber (dimensions, shape and materials) was made using the geometry code Pengeon, based on the manufacturer data sheet for the chamber. Using this code, a typical Ir-192 source used for therapy with its encapsulation was simulated.

In the first step the user code simulates the energy spectrum of the Ir-192 source and creates a phase-space file at 5 cm from the source reference point, recording the energy, spatial coordinates and direction of each particle. This file is used in the second step as an input to calculate the calibration coefficient of the ionization chamber at 1 m from the source.

Similarly, the calibration coefficient of the ionization chamber is evaluated for the Co-60 beam, using as input the existing phase-space file corresponding to the BIPM reference beam.

The correction factor kN for the NE 2571 ionization chamber is determined as the ratio of the calibration coefficient evaluated for Ir-192 to that for Co-60. Supporting calculations are made to estimate the uncertainty of kN. The results are compared with published work.

factor is insignificant. The new values agree well with TG-61 values which demonstrates that the systematic uncertainties in EGS4 cancelled out since the factors are all ratios. Due primarily to its high-z electrode, the variation of PQch with depth and field size for the Exradin A16 ionization chamber is up to 10 percent and the variation with beam quality is up to 40 percent. This suggests ionization chambers with high-z electrodes should not be used for x-ray dosimetry. Depth and field size dependance of the PQch for the Exradin W1 scintillator detector are also being studied.

SP069 - Novel Detectors, Phantoms and Software, Diagnostic Techniques

SP069.1 - Synergistic Action of Ionizing Radiation with Platinum-based Chemotherapeutic Drugs: Soft X-rays and Low-Energy Electrons

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The biological impact of ionizing radiation results predominantly from the induction of a variety of lesions in cellular DNA via energy deposition into the DNA itself (direct effect) and its surrounding molecular environment (indirect effect) [1]. The most numerous of intermediate species arising from the direct effect of radiation are non-thermal secondary electrons [2], most of which having energies below 30 eV (i.e., low-energy electrons, LEEs). In the present study, we report results to evaluate the direct effect of ionizing radiation on the formation of both single and cluster lesions in a supercoiled plasmid DNA covalently modified by the platinum anticancer drugs (Pt-drugs) cisplatin, carboplatin and oxaliplatin. Since these Pt-drugs sensitize malignant cells to ionizing radiation, they are currently used in concomittant chemoradiotherapy for cancer treatment; however, the specific mechanisms of the interaction between these Pt-drugs bound to DNA and radiation still remain to be determined [3,4].

Freeze-dried nanoscale films (~10 nm) of either pure DNA or a Pt-drug covalently bound to DNA were prepared onto two different types of substrates, i.e., tantalum and glass surfaces. Samples were exposed to 1.5 keV X-rays, in the presence of dry nitrogen gas and no humidity [5]. The yields of single- and double-strand breaks (SSBs and DSBs) and interduplex cross links (CL) induced in both types of films by X-rays and the spectrum of photo-electrons emitted from tantalum were determined from the initial linear slopes of respective exposure-response curves. In addition, the ratios of the yields from the two different films were determined and referred as an enhancement factor (EF) to represent radiosensitization by the Pt-drugs.

Results presented in Table 1 clearly show that Pt-drugs substantially enhance the formation of DSB and CL in DNA irradiated by X-rays and LEEs, but have virtually no effect on SSB formation. Furthermore, the EFs for DSB and CL are larger for LEEs than X-rays in the presence of Pt-drugs. Since LEEs constitute a major portion of the secondary species generated by high-energy radiation, our finding suggests that in the presence of Pt-adducts, LEEs are the main secondary species responsible for the increase of DSB and CL in the irradiated platinated DNA via the direct effect. According to the linearity of the exposure-response curves, these damages result from a single-event process. Despite similarity between Pt-drugs in the enhancement of the DNA lesions, carboplatin and then oxaliplatin have higher efficiency than cisplatin in the radiosensitization of DNA.
Current electron beam dosimeters face two major challenges. They are not water/tissue equivalent, and therefore require conversion to dose to water/tissue. Moreover, they must be placed in the radiation beam, which results in beam perturbation and dose averaging. These challenges limit their spatial resolution for intensity-modulated delivery or *in vivo* dosimetry. Yet, Cherenkov radiation by high-energy charged particles is emitted in water and in tissue, can be detected outside the beam, and is inherent to all high-energy radiotherapy beams. Despite these advantages, Cherenkov dosimetry has yet to be implemented for clinical dosimetry. The work presented here investigates via first-principles derivation and Monte Carlo simulation the feasibility of absolute Cherenkov dosimetry for electron beam radiotherapy. A quantitative model for predicting absolute dose from Cherenkov intensity in a phantom was derived from first principles for high-energy charged particles of known incident energy with the assumption that all collisional energy loss is absorbed and all radiative energy loss escapes. The model was validated via simulation of 260 keV - 18 MeV electrons incident on water. Monte Carlo simulations were carried out in Geant4. The absolute Cherenkov dosimetry model presented here was able to predict absolute dose from Cherenkov intensity to within a clinically viable uncertainty of less than 3%.

**References**


**SP069.3 - Detection of melanoma through image recognition and artificial neural networks**

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The incidence of malignant melanoma has significantly increased in the last four decades. Dermatologists are rarely present in rural or remote areas to perform an early detection of malignant melanoma. Our contribution is a low cost software that automatically and objectively differentiates between a melanoma lesion and a benign nævus in a simple, noninvasive manner. Our approach is based on the “ABCDE” classification of lesions, image processing, and artificial neural networks. The software was developed using images of previously diagnosed malignant melanomas and non-malignant suspicious moles, obtaining a sensibility of 76.56% and a specificity of 87.58%.

**SP069.4 - Clinical Implementation of an Intraoperative Radiotherapy Program**

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**Purpose:** To outline the process for setting up an intraoperative radiotherapy (IORT) program and its clinical implementation, including dosimetric data, radiation safety aspects and clinical procedures.

**Background:** IORT has been used in the past for clinical indications such as in the management of localized abdominal tumors. Where applicable, it is efficient and convenient as the radiation treatment is completed at the time of surgery. The modality was almost abandoned except for select large institutions due to the high cost incurred in installing dedicated linear accelerators and orthovoltage units and the requirement for extensive shielding of specially designed operating rooms.

Advances in design of miniaturized x-ray tubes operating at 50 KVP initiated resurgence of interest in this modality. The Zeiss system (Zeiss Inc., Jena, Germany) consists of a portable 50 KVP x-ray tube that is mounted on a robotic arm with 6 degrees of freedom. A sterile applicator is mounted on it and the latter is placed at the tumor bed for dose delivery. Accuracy of applicator position is verified using ultrasound image guidance. A 1 mm sterile tungsten (W) shield is wrapped around the applicator. The shield reduces the radiation levels in the room by a factor of 103. The procedure can be safely performed in a regular operating room.

**Methods:** The dosimetric characteristics of the system are confirmed using a parallel plate chamber connected to an electrometer. Measurements are made in a specially designed water phantom. Clinical dose calculations are carried out using these parameters. A check list is developed for quality assurance and safety measures consistent with institutional requirements and manufacturer’s recommendations for safe and accurate delivery of radiation treatment following accepted treatment protocols.

Importantly, a radiation survey is carried out around the operating room where IORT procedures take place to ascertain safe levels of exposure to personnel who are not classified as radiation workers. This is easily achieved using the W shield alluded to above.

**Results:** Dose delivery to patients undergoing IORT using the procedure outlined above can be carried out safely in a regular operating room. The exposure levels in adjacent areas are comparable to background. The procedure is cost effective due to the portability of the system and the low energy of the x-ray emission. Clinically, the system has been used to treat localized early breast tumors and abdominal sites. Detailed dosimetric, radiation safety and clinical data pertaining to the program will be presented.

**Conclusion:** An IORT program has been implemented at the University of California, Irvine Medical Center for the treatment of breast and abdominal tumors. The approach is convenient to patients as it delivers the radiation treatment at the time of surgery. This is espe-
Conclusion:
A new back-etched silicon detector array has been developed and characterised. Initial testing of the array integrated into a real-time microbeam monitoring system, shows very promising results.

SP069.6 - Dynamic Mechanical Characterization of a Poly(vinyl alcohol) Breast Palpation Phantom

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Breast phantoms model quantitative and qualitative parameters of bulk tissues to provide a foundation for the calibration and design iteration of different imaging methodologies, particularly for breast cancer screening. Existing breast phantoms can accurately emulate specific properties of tissues for conventional imaging modalities such as MRIs or ultrasound, but are inadequate for the large deformations associated with mechanical palpation. Polyvinyl alcohol (PVA) cryogels provide a unique solution because of stability at large deformations, although current cryogel processing methods suffer from inhomogeneity for large structures such as tissue phantoms. Established cryogel fabrication protocols tune the specific mechanical properties of PVA cryogels by varying concentration of PVA in the solution and the number of freeze-thaw cycles that the cryogel undergoes. Chaotropic salt inclusions in PVA promote amorphous behavior in the cryogels, resulting in an increase in the homogeneity to the bulk mechanical properties of the phantom. This study evaluates the effects of varied salt concentrations on the dynamic mechanical properties of cryogels to improve the stability of mechanical breast tissue phantoms. The elastic and viscoelastic properties of conventional cryogels are compared to cryogels with salt inclusions using dynamic loading. To characterize the tissue analogs for clinical utility, the experimental protocol uses simple compression, large deformations, and strain rates equivalent to those used in clinical palpation. Results are compared with literature values for both fatty and fibroglandular breast tissues. By improving the homogeneity of PVA cryogels with the use of salt inclusions, this work builds on existing tissue analog technologies. Further development of mechanically-accurate and multi-modal breast phantoms will provide low-cost and safe alternatives to clinical trials for the validation of developing breast imaging technologies.
SP070 - Molecular Imaging PET/SPECT: Part 2

SP070.1 - Optimal Pixelated Crystal for a Molecular SPECT Scanner: A GATE Monte Carlo Study
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Objective: It is well-known that resolution-sensitivity tradeoff is the most challenging design consideration in small-animal SPECT. In the present work, we addressed such a compromise from pixelated crystal point-of-view for HiReSPECT system, a high-resolution SPECT camera, developed at Research Center for Molecular and Cellular Imaging.

Materials and Methods: For this purpose, we performed GATE Monte Carlo package to simulate the HiReSPECT scanner and to assess the impact of various crystal configurations on tomographic resolution and system sensitivity, using a 99mTc point-like source and a flood-field phantom, respectively. The crystals differed in material, pixel-size, and Epoxy pixel-gap. Point-spread-functions (PSFs) were iteratively reconstructed using a dedicated 3D OSEM algorithm. Equal importance factors were assigned to the two conflicting objectives, and pixelated crystal was then optimized using the weighted-sum method. In addition, the Monte Carlo simulations were validated by means of comparisons with the experimental data.

Results: A good agreement (4.3% difference) between simulated and measured tomographic spatial resolutions at 30 mm radius-of-rotation is observed. Likewise, there is a maximum 9.1% difference, at 120 mm source-to-collimator distance, between our Monte Carlo calculations and the experiments for system sensitivity, all for a 1 × 1 mm² pixel-size and 0.2 mm Epoxy gap CsI(Na) configuration. The results show that CsI(Na) exhibits the highest sensitivity compared to NaI(Tl) and YAP(Ce) as well as a slightly higher spatial resolution, and therefore is the crystal of choice. A sensitivity of 1.61 cps/μCi is achieved for a 1.5 × 1.5 mm² pixel-size and 0.1 mm Epoxy gap CsI(Na)-based camera. Changing pixel-size from 0.5 × 0.5 mm² to 2 × 2 mm² leads to a 35.7% loss in tomographic resolution while sensitivity improves by a factor of 1.52. Based on our Monte Carlo optimization, the 1.5 × 1.5 mm² pixel-size and 0.1 mm Epoxy gap CsI(Na) is the optimal configuration by providing the best tradeoff between spatial resolution and system sensitivity. The crystal-optimized HiReSPECT system also offers a tomographic resolution of 2.98 mm, in terms of FWHM.

Conclusion: Our findings highlighted that performance of a preclinical SPECT imaging can be highly affected by the pixelated scintillator configuration, and therefore searching for an optimum configuration is mandatory in order to obtain a more qualified SPECT image.

SP070.2 - Spinning Knife-Edge Slit-Hole: a Novel Collimation for High-Sensitivity Molecular SPECT
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Objective: While conventional collimation systems are widely used in molecular SPECT, such collimators usually limit performance of the camera due to owing a low geometric efficiency. In the present study, we addressed this challenge by proposing a novel collimator offering a high-sensitivity HiReSPECT system, a high-resolution SPECT camera, developed at Research Center for Molecular and Cellular Imaging.

Materials and Methods: For this purpose, we performed GATE Monte Carlo toolkit to design and simulate the collimator for the HiReSPECT scanner. The prototype consists a centered single camera’s head, with 30 mm collimator’s depth. Planar spatial resolution and in-air sensitivity were assessed at various distances using a 99mTc point-like source and a flood-field phantom, respectively. At each regular SPECT angle, 16 spin-projections over 180° were then acquired each with 3.75 s time-per-spin. The planar images were iteratively reconstructed using a dedicated MLEM-based algorithm. To speed up our Monte Carlo simulations, a variance reduction technique by ignoring transport of the secondary electrons was also implemented.

Results: Slit-hole geometry give rise to an increased background-subtracted sensitivity of 12.4 times that observed with parallel-hole collimator at 30 mm source-to-collimator distance. System sensitivity with slit-hole collimator falls off as filed-of-view of the camera increases and reaches to a value of 4.6 cps/μCi at 120 nm distance while sensitivity of the system with parallel-hole collimation remains approximately constant over all distances from the collimator and has a value of 1.32 cps/μCi. Slit-hole collimated HiReSPECT scanner provides a magnification factor of 3 and offers a planar spatial resolution, in terms of FWHM, of 3.32 mm compared to 2.91 mm obtained by a parallel-hole collimation, at 10 mm source-to-collimator distance. Implementation of the variance reduction technique in our Monte Carlo simulations results in a 1.51 acceleration factor while imposes no significant effect on spin-projection data.

Conclusion: Our preliminary findings highlighted that the spinning
slit-hole is a promising alternative for parallel-hole collimators with acceptable planar spatial resolution, and therefore the proposed collimator provides a better resolution-sensitivity tradeoff.

Comparison of system sensitivity for the parallel-hole and the slit-hole collimated HiReSPECT scanner. For the slit-hole collimation, the sensitivity is background-subtracted.

SP070.3 - Simultaneous estimation of the radioactivity distribution and electron density map from scattered coincidences in PET: A project overview  
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Quantitatively accurate PET images require correction of measured data for scattered coincidences. Additionally, an anatomical image is required to provide accurate attenuation correction and to facilitate the interpretation of the activity distribution. By taking advantage of accurately measured photon energies and the kinematics of Compton scattering, a 2D surface described by two circular arcs (TCA), which define the possible scattering loci and encompasses the annihilation position, can be identified. In 3D the annihilation is confined to the volume encompassed by the surface obtained by rotating the 2D arc around its axis. Using this premise, we have developed novel iterative reconstruction algorithms which use the scattered coincidences to 1) improve the activity distribution and 2) obtain an electron density map. The results have demonstrated the feasibility and benefits of incorporating scattered coincidences into the image reconstruction process. Incorporating scattered coincidences directly into the radiotracer reconstruction algorithm eliminates the need for scatter correction, and could improve both image quality and system sensitivity. The electron density map reconstructed from scattered coincidences can be directly applied to attenuation correction of the activity distribution, which removes energy scaling and registration problems.

**Introduction:** It is well known that prostate imaging is one of the killer applications of PET/MRI systems. The main challenge of the current PET/MRI systems in this region field is inaccurate attenuation map (µmap), due to the fact the attenuation coefficients of the tissues are considered as soft tissue or fat in the generated µmaps. This issue leads to overestimation of the tracer uptake in the air cavities of rectum and bowel as well as underestimation of the tracer uptake in bone and adjacent areas to bone in the corrected PET images, especially in regions with thick cortical bones. The aim of this study is to increase the number of tissue classes of µmap in the pelvic area from one class or two classes in currently available PET/MRI scanners to four classes, namely cortical bone, air, soft tissue and fat, by means of a full automatic method. The proposed method consists of a combination of imaging technique, along with an image segmentation protocol.

**Material and Methods:** The proposed imaging technique was STE (short echo time) that set on a clinical 1.5T scanner in the pelvic area of two volunteer. The acquisition parameters were 1.31 ms and 60 ms for TE and TR, respectively, with Ernst angle of 15°. The image processing protocol includes five major steps as follows: (I) intensity-inhomogeneity correction; (II) separation of cortical bone and air from other regions using a region-base level set method; (III) separation of cortical bone and air areas using shape analysis method, based on morphological characteristic including level of circularity and symmetry; (IV) separation of soft tissue and fat using thresholding and (V) generation of µmap. The validation of the proposed method was based on comparison with the µmaps generated by CT images as gold standard.

**Results:** Figure 1, shows acceptable performance the proposed method in segmentation and generation four-class µmap. Quantitative analysis on dice and sensitivity factor are 71% and 65% respectively in cortical bone segmentation as well as 78% and 76% in air segmentation and 82%, 93% respectively, for fat segmentation.

Fig 1. MR image(rowA); segmented image(rowB); µmap(rowC)

**Discussion:** The proposed strategy in this study showed that the four-class µ-map can be successfully generated from only one STE-MR image in order to save time, following by the proposed six steps protocol. The proposed method can be a potential alternative to Ultra short echo time (UTE) MR-based attenuation correction, particularly in more common hybrid PET/MRI systems.
SP070.5 - Extracting PET activity distribution from scattered coincidences for non-ideal energy resolutions by modeling the probabilities of annihilation positions within a generalized scattering reconstruction algorithm

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Scattered coincidences degrade PET images contrast and compromise quantitative accuracy, and corrections for this are required in conventional PET reconstruction algorithms. In contrast to this approach, we have developed an algorithm that extracts the radioactivity distribution by incorporating scattered coincidences into the reconstruction. Using the kinematics of Compton scattering, two circular arcs (TCA), as shown in Fig.1(a), describe the locus of all possible scattering positions and encompass the annihilation position for a scattered coincidence. PET images can be reconstructed from scattered coincidences by projection and backprojection within the area confined by the TCA if the detectors have perfect energy resolution. In our previous work, the varying probability of the annihilation position within TCA is not modeled and a uniform distribution is assumed. In practice, the estimated annihilation position is sensitive to the energy resolution of the detector, which limits the implementation of the proposed algorithm on existing clinical PET scanners. In this work, the probability map of annihilation positions within the TCA is modeled in a normalized coordinate system (See Fig. 1(b)). This map was blurred in the vertical direction to account for the non-ideal energy resolution of the system (see Fig.1(c)), and was incorporated into the generalized scattered (GS) reconstruction algorithm. The results demonstrated that by modeling the probabilities of the annihilation position within the TCA in a normalized coordinate system and by introducing this probability map into the reconstruction, the convergence of the reconstructed activity distribution is improved. The contrast for images generated from scattered events improved by 7% compared to those that did not include the probability distribution in the reconstruction (see Fig.2). For non-ideal energy resolutions of up to 6%, the proposed method improves the contrast and noise properties of the reconstruction.

SP070.6 - Quantitative Functional Imaging with Hybrid PET-CT Via Improved Kinetics Modeling: Application to 18F-Fluorochocline PET Imaging of Prostate Cancer

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**Motivation:** ¹²⁴F-Fluorocholine (FCH) PET imaging is of interest for the localization of prostate cancer and has the potential to allow more accurate targeting for both biopsy and intra-prostatic radiation dose escalation. However, studies using the standardized uptake value (SUV) have been unable to differentiate prostate cancer from benign prostatic hyperplasia. We hypothesize that this is due to the confounding effects of blood flow and blood volume in the local vasculature, which cannot be discriminated using the SUV. Quantitative kinetic analysis of FCH PET can account for this confounding effect by estimating the k₃ parameter, which represents the activity of the choline kinase enzyme, but this is difficult because high parameter covariance reduces the robustness of the k₃ estimate.

**Methods:** We developed a hybrid DCE-CT/PET kinetic model, which uses DCE-CT functional maps to reduce the effect of parameter covariance. Furthermore, this linearized model form is solved with a non-negative least squares algorithm which has only one possible solution and is computationally efficient. Simulations were conducted to investigate the accuracy and precision of k₃ estimates and an FCH PET imaging study of a PC-3 mouse model was analyzed to show proof of concept.
Cancers are highly hypoxic, and (iii) there is no significant correlation between perfusion and hypoxia in our cohort of patients.

**Conclusions:** In summary, we have developed a computationally efficient technique for accurate estimation of $k_3$ from noisy dynamic PET data that may be capable of differentiating malignant prostate cancer from benign tissue.

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**SP070.7 - Simultaneous Measurement of Perfusion and Hypoxia in Pancreatic Cancers with Dynamic PET-FAZA Imaging**

**Author(s):** Ivan Yeung¹, Cristiane Metran-Nascente², Doug Vines¹, Ur Metser¹, Neesha Dhani², David Green¹, Michael Milosevic¹, David Jaffray¹, David Hedley²

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**Background:** Pancreatic cancers are believed to be poorly perfusion and hypoxic, and these characteristics have been suggested to explain in part their aggressive biology and poor response to standard treatment. **Method:** We have developed a method to quantify perfusion and hypoxia in pancreatic cancers with dynamic PET imaging post injection of $^{18}$F-fluoroazomycin arabinoside (FAZA). A cohort of 20 patients with pancreatic cancers were scanned with the scanning protocol involving dynamic PET acquisition in the first 60 min followed by a single static scan at 2 hr. The dynamic data were binned for image reconstruction with intervals starting from 10s up to 5 min whereas the static scan was scanned with 2 bed positions of 15 min each. The images were viewed and tumor contoured by a radiologist. To quantify the perfusion component of the tracer kinetics of FAZA, the dynamic data (of 19 patients) were analyzed with a two-compartment model with which, ‘Ktran’ was calculated as a surrogate of perfusion. Repeated analyses were done on data over 1.5, 5.5 and 15 min to investigate the length of data required to estimate Ktran. The static images were analyzed with the ‘Mortensen’s method’ for hypoxic fraction. The method determines, for each patient, the tumor to mean muscle (skeletal muscle) uptake ratio for each voxel in the tumor; those voxels with uptake ratio higher than unity plus 3 times the standard deviation of the population normalized muscle uptake will be classified as ‘hypoxic’. The percentage of ‘hypoxic’ voxel within the whole tumor will give ‘hypoxic fraction’. The method determines, for each patient, the tumor to mean muscle (skeletal muscle) uptake ratio for each voxel in the tumor; those voxels with uptake ratio higher than unity plus 3 times the standard deviation of the population normalized muscle uptake will be classified as ‘hypoxic’. The percentage of ‘hypoxic’ voxel within the whole tumor will give ‘hypoxic fraction’. **Results:** Ktran estimates of 1.5 min data are found to be poorly correlated ($r=0.60$, 0.62) based on the Pearson correlation test with those of 5.5 min and 15 min, whereas the ktran estimates of the latter two are found to be highly correlated ($r=0.98$). The mean Ktran of 5.5 min data is $0.384±0.108$ ml/min/g and the hypoxic fraction ranges from 0.0 to 57.6% with median hypoxic fraction of 2.2%. The Pearson correlation between Ktran values and hypoxic fractions gives a negligible slope of $-0.001$ and $r=0.0016$ as shown in the figure. **Conclusions:** The preliminary results suggested that (i) data of 5.5 min are sufficient to provide robust estimates of Ktran, (ii) The preliminary results do not support the notion that pancreatic cancers are highly hypoxic, and (iii) there is no significant correlation between perfusion and hypoxia in our cohort of patients.
SP071 - Scaffolds in Tissue Engineering

SP071.1 - Optimization of Crosslinking Parameters for Biosynthetic Poly(vinyl-alcohol)-Tyramine Hydrogels

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Photo-polymerizable hydrogels have been widely researched as tissue engineering matrices. When designing a new photo-crosslinkable, biosynthetic hydrogel system, a number of parameters need to be optimized, such as the polymerization conditions and amount of biological polymer included. This study aimed to investigate the crosslinking parameters (i.e., choice of initiator, light intensity and irradiation time), as well as the biological polymer (i.e., gelatin) content, for a degradable tyramine functionalized poly(vinyl alcohol) (PVA-Tyr) system. This PVA-Tyr can be photocrosslinked using a visible light initiated process composed of ruthenium (Ru) and persulfate compounds. Comparison of ammonium persulfate (APS) and sodium persulfate (SPS) showed that SPS supported fabrication of higher quality gels at lower concentrations than APS. The initiator concentration and irradiation conditions that were found to produce the best quality PVA-Tyr gels were 2 mM Ru/20 mM SPS and 3 minutes of 15 mW/cm² of visible light. Moreover, incorporation of gelatin into the PVA-Tyr gels successfully facilitated attachment of Schwann cells on the gels. The Schwann cells were able to survive and proliferate over 3 days on the PVA-Tyr/gelatin gels. Overall, this study showed that PVA-Tyr gels have high potential as biomaterials for tissue engineering applications.

SP071.2 - A synchrotron radiation microtomography study of wettability and swelling of nanocomposite Alginate/Hydroxyapatite scaffolds for bone tissue engineering

Author(s): Francesco Brun1, Gianluca Turco2, Sergio Paolotti3, Agostino P. Accardo4
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3Department Of Life Sciences, University Of Trieste, Trieste/italy

Wettability and swelling properties play an important role in a tissue engineering scaffold. An effective methodology for the characterization of these aspects is here presented and applied to nanocomposite Alginate/Hydroxyapatite scaffolds for bone tissue engineering. The methodology exploits synchrotron radiation computed microtomography and image analysis. Wet conditions with both water and simulated body fluid (SBF) were applied to the synthesized 3D constructs and the structure alterations were investigated after 21 days and 60 days of embedding. A quantitative analysis of wettability and swelling behavior through time is also presented and discussed.

SP071.3 - ECM production and distribution in regenerated cartilage tissue cultured under traction loading.

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An arthrodial cartilage covers sliding surfaces of a diarthrodial joint, and it has important mechanical functions, such as impact absorption, friction reduction, etc. Mechanical stresses and strains exerted in articular cartilage during daily joint movements can stimulate the metabolism of chondrocytes. For the cells embedded in the cartilage, they play an important role to sustain the health and homeostasis of the cartilage tissue. Especially, upregulative effects of the cyclic compression and the hydrostatic pressure on the chondrocytes biosynthesis of extracellular matrix (ECM) have been studied extensively and utilized in the cartilage tissue engineering. However, the regenerated cartilage does not have sufficient dynamic functionalities compared with the normal arthrodial cartilage. The load which arises in a living body is not the simple in fact. The chondrocyte would be exposed to the dynamic and complicated strain field consisting of compression, tension and shear that exerted by both joint loading and friction at the cartilage surface. In this study, the relative motion between cartilage surfaces in a synovial joint is simulated by the rolling-sliding motion of the plastic roller on the cultured chondrocyte-agarose construct and its effects on the formation of regenerated cartilage tissue was investigated.

Chondrocytes isolated from cartilage tissues harvested from metacarpal-phalangeal joints of steers were seeded in agarose gel and cultured 2 or 3 weeks with a traction loading applied to the surface by a roller in the original traction loading machine. This machine consists of upper oscillating plastic roller and lower reciprocating specimen stage. Vertical movement and oscillation of the roller and horizontal reciprocation of the stage were independently driven by three AC servomotors, which were controlled by PC through a control board. The specimen fitted into the culture dish was mounted on the stage and the roller was rolled over its upper surface with a defined slip/roll ratio to apply the traction loading to the construct.

After the culture period, we evaluated the amount of Type II collagen and Glicosaminoglycan (GAG) and also observed the distribution on these ECM molecules in the construct. To identify effects of the traction loading, a control specimen with a same initial cell density and same dimensions was also prepared and cultured simultaneously under the free swelling condition. After the culture experiment, constructs cultured under the traction loading had a clear traction track on the upper surface. Therefore, samples for the analyses were divided into three groups, traction track, outside of the traction track and free swelling condition.

The experiment showed that the traction loading applied to the surface of chondrocyte-agarose constructs could not increase the amount of ECM molecules accumulated in the regenerated cartilage tissue. But, it brought the anisotropic nature in the elaborated cartilaginous tissue and ECM rich layer was formed in the articulating surface of the construct cultured under the traction loading. Therefore, the traction loading on the surface may have a/potential to make the structural anisotropy like a natural articular cartilage in regenerated cartilage tissue.
SP071.4 - Alginate encapsulation: a solution for controlled infiltration of cells within artificial fiber constructs

Author(s): Oleksandr Gryshkov, Holger Zernetsch, Nicola S. Hofmann, Birgit Glemmacher
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Introduction

Tissue-engineered constructs containing living cells are promising in the field of regenerative medicine and cell-based therapies. The application of tissue engineering presents an engineered polymeric-cell construct as an attractive option to treat cardiovascular disorders. A seeded scaffold faces the problem of the growth of cells only on the surface. On the other hand, by combining the encapsulation of cells within alginate beads with scaffold structures, one can develop 3D scaffolds with encapsulated cells [1]. The advantage of this approach, in contrast to direct cell seeding, is in the potential of alginate beads to protect encapsulated cells from shear stress, which occur upon seeding and culture.

Methods

The developed high voltage method was utilized to encapsulate NIH 3T3 cells in 1.5% sterile-filtered alginate solution at concentration of 3x106 cells/ml. After encapsulation alginate beads were washed twice with washing solution (WS, 10 mM HEPES, 1.5 mM CaCl2 at pH = 7.4). Polycaprolactone/polyactic acid fiber mats (PCL-PLA) were generated using electro-spinning. The embedding of alginate beads into PCL scaffold was performed manually at sterile conditions. Afterwards, PCL-PLA fiber mats with entrapped alginate beads containing 3T3 cells were washed twice with WS and cultured in a humidified incubator at 37°C, 5% CO2 for 24 days. Medium was exchanged every second day with a fresh one. The membrane integrity of 3T3 prior to encapsulation and after dissolution of alginate structure was analyzed using Trypan Blue exclusion method. The viability of encapsulated cells in alginate beads immediately after encapsulation and their presence within the scaffold was assessed using CalceinAM/EthD-1 live-dead viability assay. The presence of embedded alginate beads into fiber mats was confirmed using a scanning electron microscope.

Results

NIH 3T3 cells can be encapsulated into alginate beads (diameter 300 μm) using high-voltage electro-spraying without significant effect of high voltage on the viability of encapsulated cells post-encapsulation (immediate viability 92% vs. initial 95%). In turn, electro-spinning process allowed generating multi-layered PCL-PLA scaffold with previously incorporated alginate beads containing living cells. Analysis of SEM images proved the presence of alginate beads in the scaffold. Long-term culture of these constructs for 24 days revealed the simultaneous degradation of alginate beads, release of encapsulated 3T3 cells and their attachment to PCL-PLA fiber mat within the scaffold. On the other side, no viable and adherent cells were observed, if the alginate structure was treated with sodium citrate prior to long-term culture.

Conclusions and outlook

This work shows the perspectives of applying the high-voltage process to generate cell-containing tissue-engineered constructs for regenerative medicine, cell-based therapies and cardio-vascular applications. Further work will be performed to optimize the seeding process including its automatization, as well as to investigate the behavior of such constructs at dynamic conditions.

Acknowledgments

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References


SP071.5 - Biomineralization and In vivo-Compatibility of LnPO4 Nanorods with Enhanced MR and Luminescence Imaging

Author(s): Zhongbing Huang
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Introduction: The biocompatibility of nanomaterials with dual-functionalities is very important for their clinical applications.

Methods: Eu-doped LnPO4 nanorods (NRs) in the template of silk fibroin (SF) peptides, including GdPO4, SmPO4 (named as SF-NRs), are successfully synthesized via a biomineralization process.

Results: lengths of Eu-doped GdPO4 and SmPO4 NRs with SF peptides (SF-NRs) are ~150 and 250 nm, respectively, and their diameter is ~10 nm. Compared to pure NRs, SF-NRs have stronger cell luminescence and higher T1 signal-enhancement of in vitro/in vivo MRI due to their higher ratio of Eu/Gd (~0.9/5) or Eu/Sm (~1.3) and more Eu⁺/Eu³⁺ in SF-NRs. The images of cell ultrathin sections indicate that endocytosis of SF-NRs into the cytoplasm did not influence mitochondrial architecture at the NR concentrations of 100 mg·mL⁻¹ after 3 d of culture, because PBS/calf serum immersion tests indicate that SF peptide coating could slow metal-ions release and the crystal degradation from NRs. The histological analysis and bio-distributions in tumor-bearing nude mice suggest that, compared to pure NRs, SF-NRs have lower tissue/organ toxicities and could be safely cleared away through renal and fecal excretion in 3 days, especially the existence of more SF-NRs in the tumor field due to SF coating layer in NR surfaces. Furthermore, Eu-doped SF-NRs not only exhibit a higher T1 signal-enhancements (the longitudinal relaxation r₁ value is 1.32 (Gd mM·s⁻¹) and 0.0145 (Sm mM·s⁻¹) under a 7.0 T MR imaging system, and a series of in vivo T1-weighted MR images between pre- and post-injection in tumor regions in 9 h indicate that average intensity of post-injection of SF-NRs is enhanced 71%, higher the increased value of pure NRs (15.5%), but also show the better luminescence imaging of living cells under the fluorescence microscope.

Conclusions: Our results indicate that Eu-doped SF-NRs have potential as T1 MR imaging contrast agents and optical imaging probe in tumor-detection field.

Acknowledgement: This study was supported by the National Natural Science Foundation of China (No. 51273122).

SP071.6 - Additive Manufacturing for Creating Multifunctional Tissue Engineering Scaffolds

Author(s): Min Wang
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Tissue engineering has great potential in solving many medical problems that are currently unsolvable or in offering better and long-term solutions as compared to current medical treatments. For human body tissue regeneration, different approaches can be adopted: cell-based, factor-based or scaffold-based tissue engineering. In scaffold-based tissue engineering, cells are encapsulated in the matrices or seeded on the surface of 3D scaffolds, with the scaffolds serving as the extracellular matrix to direct cell adhesion, proliferation and differentiation and thus promote tissue
regeneration. Over the past two decades, many materials and scaffold manufacturing techniques have been investigated by numerous groups around the world for regenerating different body tissues. So far, materials for tissue engineering are predominantly biodegradable polymeric materials, natural or synthetic, and scaffolds are produced using either non-designed manufacturing techniques (solute casting/particulate leaching, phase separation, gas foaming, electrospinning, etc.) or designed manufacturing techniques. Using designed manufacturing techniques, which include a host of additive manufacturing technologies (the so-called “rapid prototyping (RP) technologies” in previous decades), for making tissue engineering scaffolds has distinctive advantages over some commonly used chemical engineering methods in scaffold fabrication and hence has been attracting increasing attention in the biomedical field. Some additive manufacturing technologies impose stringent requirements for stock materials and studies are thus conducted on preparing stock materials and on evaluating the physical and mechanical properties of scaffolds made of these stock materials. Realizing the shortcomings of common biodegradable polymers as materials for tissue engineering scaffolds with regard to some specific tissues, various research groups now investigate new, more appropriate materials for the regeneration of targeted tissues, which include biodegradable ceramics (including glasses), composites and even metals. Considering the extracellular matrix of bone is a natural nanocomposite comprising nano-sized apatite and collagen fibrils, it is natural to develop polymer-based nanocomposites containing nanoparticles of bioactive and biodegradable ceramics as novel scaffold materials for bone tissue regeneration. Furthermore, mesenchymal stem cells (MSC) are increasingly used in tissue engineering. In this presentation, for illustrating developing biomedical nanocomposites and using additive manufacturing to form multifunctional scaffolds, our research in employing selective laser sintering (SLS), a well-established additive manufacturing technology, for obtaining osteoconductive and osteoinductive scaffolds for bone tissue engineering is introduced. Microspheres of nanocomposites (CHA/PLLA or Ca-P/PHBV) are firstly prepared as raw materials for SLS. Scaffold models of required features can be designed using computer-based medical imaging techniques (e.g., MRI). That established with two different dosage. The third dosage with the same ions and energy need to be tested.

Hypothesis:

Ion beam implantation onto random oriented fibrous scaffold produced by the electrospinning will promote radial artery cells adhesion, migration, differentiation and proliferation. This is the first step towards the successful tissue engineering.

Materials and Methods:

In this study, Collage Rat tail –Type-1 is the material in used to fabricate the electrospinning fibers. These electrospun collagen fibers are crosslinked using a physical approach via ion implantation. Broad energy He⁺ (Helium) and N⁺ (Nitrogen) ion beams are used. Energies of 1.7 MeV and 520 MeV of N⁺ ion and He⁺ ion, respectively were used to surface modify the collagen nanofibrous scaffold. The dose of these ions with similar energies, where varied from (4*10¹⁵ ions/cm² - 1.2* 10¹⁶ ions/cm²)

Results

These cross-linked scaffolds (nanofibrous) displayed stability in both water and cell culture media with controllable degrees of swelling, where established with two different dosage. The third dosage with the same ions and energy need to be tested.

Discussion and summary

So far, with one of the energy of 1.7 MeV N⁺ of dose of 1.2 * 10¹⁶ ions/cm² and 520 MeV He⁺ of dose of 8 *10¹⁵ ions/cm² at room temperature. The X-ray photoelectron spectroscopy (XPS) shows that with nitrogen implantation, two new chemical functional groups, amine and amide, are introduced, which could promote cell adhesion. And, these functional groups were not found in He⁺ implantation.

Introduction:

Engineering methods to construct biological tissue substituted has been inspired due to the shortage of donor organ transplantation. Where, the scaffold plays an important role as of assisting, an artificial extracellular matrix to accommodate cells and support three-dimensional tissue regeneration. An ideal scaffold should be biocompatible, biodegradable, malleable, mechanically strong, and highly porous with a large surface to the volume ratio. Such, ideal scaffolds are highly in demand, for surgical application, regenerative medicine, cell based therapy. An electrospun nanofibrous collagen scaffold is desirable for tissue engineering application, but as prepared, it is unstable in an aqueous environment including cell culture media. Stabilization of these nanofibers has been achieved to varying degrees of success using a chemical crosslinking approach with crosslinking agent such as glutaraldehyde, but they are cytotoxic.

Comparison of different dosage of Ion implantation on electrospun collagen fibers to improve aqueous stability

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Comparison of different dosage of Ion implantation on electrospun collagen fibers to improve aqueous stability

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¹ Biomedical Engineering Graduate Program, ² Department of Chemical and Biochemical Engineering, ³Department of Medical Biophysics Western University, London, Ontario, Canada

Introduction:

Engineering methods to construct biological tissue substituted has been inspired due to the shortage of donor organ transplantation. Where, the scaffold plays an important role as of assisting, an artificial extracellular matrix to accommodate cells and support three-dimensional tissue regeneration. An ideal scaffold should be
SP072 - Imaging

SP072.1 - Variations in geometric distortion using static and moving table acquisition for radiotherapy treatment planning applications

**Authors:** Amy Walker¹, Gary Liney¹, Lois Holloway², Jason Dowling³, David Rivest-Henault³, Peter Metcalfe² ¹Medical Physics, Liverpool and Macarthur Cancer Therapy Centres and Ingham Institute for Applied Medical Research, Liverpool/ AUSTRALIA, ²Centre For Medical Radiation Physics, University of Wollongong, Wollongong/AUSTRALIA, ³Commonwealth Scientific And Industrial Research Organisation, Australian E-Health Research Centre, Brisbane/QLD/AUSTRALIA

**Purpose:**
Geometric accuracy is essential when imaging patients for radiotherapy treatment planning (RTP). An increased use of MRI for RTP requires consideration of inherent geometric distortions. This study compared variations in geometric distortions observed during image acquisition utilising a continuously moving table, compared to a conventional static table. Continuous moving table acquisition allows for imaging of a longer scan length than static acquisition, a potential benefit for RTP.

**Methods:**
A new full field of view (FOV) phantom for measuring MRI geometric distortion for the purposes of RTP was designed in-house. Constructed from Dotmar Uniboard, 5830 vitamin E capsules were placed systematically throughout. Phantom dimensions were 500mm x 350mm x 513mm (x,y,z respectively). The phantom was scanned on a Siemens 3 T Skyra with a spoiled gradient echo (GRE) sequence (vendor 3D-correction applied). The phantom was imaged with a static couch and a continuously moving table (TimCT). The MR images were registered to a CT of the phantom to obtain distortion maps.

**Results:**
Table 1 compares the geometric performance of images acquired with and without a moving table. TimCT enabled imaging of the whole phantom. TimCT acquired with a table speed of 1.1mm/s resulted in the best geometric accuracy. However, the acquisition time was over 9 minutes compared to 2 minutes for the static acquisition. Increasing the table speed to 2mm/s decreased acquisition time, but resulted in increased blurring of the capsules by 170% at the FOV edges. TimCT was limited to 2 possible imaging sequences.

**Conclusions:**
MRI acquisition utilising TimCT offers a potential alternative for imaging large scan lengths which may be required for RTP, particularly for long FOVs. Both static and moving table image acquisitions are viable scanning options for imaging for RTP. Selection of the acquisition method would depend on the anatomical region under investigation.

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Table speed (mm/s)</th>
<th>% phantom imaged</th>
<th>% phantom with distortion &lt; 2 mm</th>
<th>Distance from isocenter where distortion ≤ 2 mm</th>
<th>Maximum distortion (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TimCT</td>
<td>1.1</td>
<td>100</td>
<td>87</td>
<td>147 mm</td>
<td>4.4</td>
</tr>
<tr>
<td>TimCT</td>
<td>2</td>
<td>100</td>
<td>61</td>
<td>140 mm</td>
<td>5.8</td>
</tr>
<tr>
<td>Non TimCT</td>
<td>0</td>
<td>71</td>
<td>47</td>
<td>55 mm</td>
<td>6.1</td>
</tr>
</tbody>
</table>

**Results:**
Increasing the table speed to 2mm/s decreased acquisition time, but resulted in increased blurring of the capsules by 170% at the FOV edges. TimCT achieved the best geometric accuracy with a table speed of 1.1mm/s, but was limited to 2 possible imaging sequences.

**Conclusions:**
MRI acquisition utilising TimCT offers a potential alternative for imaging large scan lengths which may be required for RTP, particularly for long FOVs. Both static and moving table image acquisitions are viable scanning options for imaging for RTP. Selection of the acquisition method would depend on the anatomical region under investigation.

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SP072.2 - Translation of biomechanical deformable image registration (MORFEUS) to the RayStation radiotherapy treatment planning system

**Authors:** Michael Velie³, Joanne L. Moeley¹, Stina Svensson², Björn Hårdemark¹, Kristy K. Brock³, David Jaffray¹ ¹Radiation Medicine Program, Princess Margaret Cancer Centre, Toronto/ON/CANADA, ²RaySearch Laboratories, Stockholm/SWEDEN, ³University of Michigan, Ann Arbor/MI/UNITED STATES OF AMERICA

**Purpose:**
Deformable image registration accuracy can vary widely between imaging modalities and even implementations of similar deformation models. Biomechanical model-based deformable registration was implemented in a commercial radiotherapy system and validated on multi-modality imaging.

**Materials and Methods:**
MORFEUS is a MATLAB-based registration algorithm previously developed and validated in-house. A multi-organ tetrahedral mesh model is generated from contours in the reference image, while a subset of additional surfaces is created from body, liver and spleen contours in the target image. These three organs undergo individual surface deformations to align the contours between images and serve as boundary conditions. Finite element analysis (FEA) solves the internal displacements including all of the remaining organs and tumors. Under research collaboration with RaySearch Laboratories, MORFEUS was implemented in a commercial radiotherapy treatment planning system. Results shown are from a pre-clinical release of RayStation (v4.4.100). The organ-specific material properties were optimized separately between implementations. The Poisson’s ratios applied in-house (range: 0.4-0.499) differ by <10% from those applied in RayStation-MORFEUS. Variable Young’s moduli are applied in-house (range: 1.5–500 kPa), whereas RayStation-MORFEUS effectively applies a uniform stiffness. Boundary conditions are achieved using guided-surface projections for the in-house MORFEUS, whereas RayStation-MORFEUS uses model-based segmentation which adapts a common mesh to corresponding contours. Different third party components are also used for mesh generation and FEA solver, although these function similarly. For 32 patients in total, registration of abdominal images was performed from exhale to inhale 4DCT (or MR), or exhale CT to MR. One patient with 4DCT and MR was previously evaluated in a multi-institution accuracy study, allowing for a comparison to other algorithms. For evaluation between deformed and actual target images, the target registration error (TRE) was quantified as the residual distance between anatomic liver landmarks (median: 5, range: 4-25). For 4DCT and MR-MR, the residual mean distances of the stomach and kidneys surfaces (organs excluded as boundary conditions) were additionally quantified.

**Results:**
The Table demonstrates the registration accuracies of both MORFEUS implementations differ by <1 mm, and both accuracies
are similar to each image resolutions on average. In the multi-institution comparison, for 4DCT both MORFEUS implementations’ TRE were within 1 mm of the best-performing algorithm. For CT-MR, the in-house and RayStation-MORFEUS TRE was 1.0 and 1.2 mm lower than the best-performing, non-biomechanical algorithm.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Data</th>
<th>Region</th>
<th>Mean (maximum) registration accuracy, in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Baseline rigid</td>
<td>In-house Morfeus</td>
</tr>
<tr>
<td>TRE</td>
<td>4DCT (n=10)</td>
<td>Liver</td>
<td>7.8* (12.7)</td>
</tr>
<tr>
<td></td>
<td>CT-MR (n=18)</td>
<td>Liver</td>
<td>6.1* (10.7)</td>
</tr>
<tr>
<td></td>
<td>MR-MR (n=5)</td>
<td>Liver</td>
<td>17.9* (23.5)</td>
</tr>
<tr>
<td>Mean surface distance</td>
<td>4DCT (n=10)</td>
<td>Rt. kidney</td>
<td>2.6* (4.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lt. kidney</td>
<td>2.0* (3.0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stomach</td>
<td>2.8 (4.1)</td>
</tr>
<tr>
<td></td>
<td>MR-MR (n=5)</td>
<td>Rt. kidney</td>
<td>4.1 (6.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lt. kidney</td>
<td>3.7 (4.9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stomach</td>
<td>5.8* (7.2)</td>
</tr>
</tbody>
</table>

*p≤0.05 versus RayStation-Morfeus

Conclusions: MORFEUS biomechanical registration was implemented in RayStation. Its registration accuracy and difference from the original implementation are on average within the voxel sizes on multi-modality abdominal imaging.

SP072.3 - Phantom Validation of a Point-Set Deformable Registration Method using Pig Bladder

**Author(s):** Roja Zakariae1, Ghassan Hamarneh2, Colin J. Brown2, Ingrid Spadinger3

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**Introduction**

Deformable image registration (DIR) is widely used for registering medical images. While the main goal of registering images is to correspond different regions of interest (ROI) within the body, surrounding objects and image artefacts can confuse the DIR algorithm. This occurs, for example, in image-guided multi-fraction gynecological brachytherapy treatment, which uses an intracavitary applicator. Therefore, in applications like dose accumulation for these treatments, an alternative approach is to non-rigidly register delineated ROI contours. However, validating the registration outcomes and accordingly choosing a suitable registration algorithm is challenging, especially for highly deformable ROI with no discriminating features or anatomical landmarks. In this work, a point-set deformable registration technique, called coherent point drift (CPD), is evaluated for registering the bladder surface across treatment fractions.

**Methods**

A house-made pelvis phantom was used with a freshly harvested pig bladder to model the human anatomy. Multiple plastic and rubber fiducial markers were glued onto the bladder surface at twelve different locations. The bladder was filled with varying amounts (90cc, 180cc, 360cc, and 480 cc) of a water-contrast mixture and CT-scanned each time. The variously filled bladder was contoured manually on each scan using the MIM Maestro software (MIM Software Inc.). In addition, the fiducials were identified on each scan and their positions recorded. The CPD toolbox for MATLAB (Mathworks Inc.) was used to register the contour point-sets of the three smaller bladder sizes to the largest size. The toolbox takes the target and moving structure coordinates and outputs the de-
formed moving structure coordinates. The fiducial positions were used as landmarks to calculate the target registration errors (TRE) for different points on the bladder surface. Optimized input parameters for CPD registration were found experimentally by searching over the parameter space for values which minimized average TRE over all landmarks.

Results

The appearance of the phantom and the fiducial markers in the CT images was very satisfactory (Fig. 1). The average TRE value obtained for the 480cc-bladder as the target structure was 6.4±2.3 mm. TRE values were obtained for alternate target structures, with the 360cc-bladder yielding the lowest TRE value of 5.5±2.1 mm when selected as the target. These TRE values are reasonably small compared to the dimensions of the bladder.

Conclusion

Our validation method shows that the CPD deformable registration technique is a viable method for registering ROI contours, even when lacking distinctive features in the structure.

SP072.4 - Automatic bone and air segmentation during generation of synthetic CT from MR data in the brain

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Adequate differentiation of short-T2 tissue types such as bone from air remains a significant challenge for generating accurate electron density maps. This work describes the integration of ultra-short echo time (UTE) datasets and derivative images into our automated brain synthetic CT (synCT) pipeline to generate synCTs for our MR-only radiation treatment planning (RTP) workflow. MR Data from five brain cancer patients were acquired using Philips’ 1.0T Panorama open MR-SIM. T1-weighted fast field echo, T2-weighted turbo spin echo, FLAIR, and UTE-DIXON (TE = 0.144/3.4/6.9ms) sequences were acquired for all patients. Affine registrations to the UTE magnitude image (UTE1) were performed. A “bone-enhanced” image was generated from DIXON-water, DIXON-fat, and inverted UTE1 datasets. Images were integrated into an automatic routine using k-means clustering with five clusters and morphological operations to segment combined bone and air voxels. A novel method incorporating post-processed UTE phase maps was introduced, enabling automated segmentation of air voxels from bone via a six-kernel Gaussian Mixture Model. A truth table was constructed based on voxel intensity levels in acquired T1, T2, and FLAIR images to assign non-bone/non-air voxels to three classes: CSF, brain tissue, and fat. A voxel-based weighted summation method incorporating T2, FLAIR, UTE1, and “bone-enhanced” images was implemented with synCT voxel values calculated by:

$$\text{synCT}_i = \sum \text{wk}_i \text{r}(i) \text{M}_k$$

where M_k is intensity for voxel i of MR image k, r(i) is the voxel’s assigned class, and wk(i) is a class-dependent weighting factor optimized by minimizing the sum of squares error between simulation CT (simCT) and synCT using a training subset. HU value differences were compared using mean absolute error (MAE). Figure 1 illustrates simCT and synCT images for two patients. Average full-field-of-view MAE over all patients was 164.8±23.4 HU, showing close agreement with expected values. UTE phase-derived air maps were compared to threshold-derived simCT air contours, overlapping with 87.2±6.1% of simCT-based volumes. However, phase-derived air maps were often larger than simCT air contours, leading to higher average HU values for simCT versus synCT in air (-695±66 HU vs. -1024 HU). Another consequence was that the enlarged phase-derived contours yielded lower average values in bone (761±86 HU vs. 841±75 HU). Automatic air and bone segmentation methodology was incorporated into a brain cancer synCT pipeline. Calculated HU values demonstrated good agreement with expected simCT values based on MAE, however further refinement of air masks using the phase-based approach is needed.

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SP072.5 - Effect of Deformable Registration Accuracy on Lung Dose Accumulation

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Objective/Purpose: Deformable image registration (DIR) plays an important role in dose accumulation, such as incorporating breathing motion into the accumulation of the delivered dose based on daily CBCT images. However, it is not yet well understood how the uncertainties associated with DIR methods affect the dose calculations and resulting clinical metrics.

Methods and Materials: In the current study, a biomechanical model based DIR method and a biomechanical-intensity-based hybrid method, which reduced the average registration error by 1.6 mm, were applied to 10 lung cancer patients. Clinically relevant dose parameters were calculated for three dose accumulation scenarios using both algorithms. Dose scenarios included: static, predicted, and accumulated. Static dose refers to the clinical plan on the exhale phase of the 4DCT, which accounts for the breathing motion through the use of an asymmetric Planning Target Volume (PTV) margin, but does not account for the normal tissue motion in and out of the PTV during breathing motion. The predicted dose calculates the delivered dose based on the breathing motion observed on the 4DCT obtained at the time of treatment planning. The accumulated dose calculates the dose delivered based on the
4D CBCT obtained at the start of each treatment fraction. For each dose scenario, the relationship between the dose parameters and a combination of DIR accuracy (Target Registration Error, TRE, and Dice Similarity Coefficient, DSC), tumor volume, and dose heterogeneity of the plan was investigated.

Results: Depending on the dose heterogeneity, measured by Dose Heterogeneity Index (DHI), tumor volume, and DIR accuracy (measured by DSC), in over 30% of the cases differences greater than 1.0 Gy were observed in the minimum dose to 0.5cc (Dmin) of the tumor in the static dose calculation. Such differences were due to the errors in propagating the tumor contours from the reference planning 4D CBCT phase onto a subsequent 4D CBCT phase using each DIR algorithms and calculating the dose on that phase. The differences were more subtle when breathing motion was modeled explicitly (predicted dose) with only one case with over 1.0 Gy Dmin difference. Dmin Differences of up to 2.5 Gy were found in the total accumulated dose due to inter-fraction variations. Such dose uncertainties could potentially become clinically significant. Thus, clinical implications of DIR-based dose accumulation outcomes should be interpreted in the context of the geometric uncertainties associated with the DIR algorithm. More specifically, our results suggest that one might expect larger than 1 Gy differences in a specific Dmin (static, predicted, or accumulated) due to DIR choice in 10-60% of a patient population if two or more of the following criteria are met: 1) DHI of the plan is larger than 20, 2) DIR induced DSC differences in the tumor exceeds 0.08, and 3) tumor volume (or tumor volume difference) is larger than 10 cc (or 5%).

Conclusion: In summary, reductions in average uncertainty in DIR algorithms by 1.6 mm may have a clinically significant impact on the decision-making metrics used in dose planning and dose accumulation assessment.

SP072.6 - Development of a Multi-Modality 4D biomechanical Phantom for Evaluation of Simultaneous Registration/Segmentation Algorithms
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Purpose: Simultaneous registration and segmentation, known as segmentation, has the potential to improve both accuracy and efficiency of both procedures when using multimodal images or longitudinally acquired scans. Currently, no gold standard exists for the evaluation of registration algorithms, in contrast to existing segmentation or registration algorithms, where several systems have been developed. Presented is a phantom and software package that satisfies several criteria: PET/CT/MRI compatibility, realistic geometric deformations, and reliable ground truths for both segmentation and registration, sequential or simultaneous, with a high degree of consistency.

Method and Materials: The phantom consists of a pair of inflatable swine lungs connected to an in-house built programmable respirator (shown in figure 1) via an 8 meter long vinyl tube. This allows metallic components to stay outside the scan room and thus ensure MRI compatibility. The respirator is able to mimic the breathing traces of patients taken using respiratory bellows. The target was constructed in two compartments from vacuum-sealed sea sponges. The inner and outer compartments simulate a tumor and background respectively. Catheters lead into each compartment allowing for injection of radioisotopes. The registration ground truth is determined using a bifurcation-tracking pipeline. The accuracy of the tracking pipeline was evaluated by applying a known virtual deformation to a CT volume of the swine lungs and comparing the known final locations to the ones detected by the pipeline. The segmentation ground truth was acquired by scanning the corresponding BV dataset separately and rigidly registering it to the original scan.

Results: The average bifurcation tracking error was found to be 1.22, 1.26 and 2.26 voxel widths for displacement magnitudes of 2.6, 5.2 and 7.8 cm respectively using a CT scan of a human lung. The tracking error was similarly measured to be 1.36, 1.63 and 2.46 voxel widths for displacements of 1.14, 2.29 and 3.43 cm using the swine lungs. The respirator was able to match breathing traces with a maximum error of 2.2% and an average error of 0.5%.

Conclusion: The 4D biomechanical lung phantom has shown to be a reliable tool for evaluating segmentation algorithms. The bifurcation-tracking pipeline’s accuracy was measured on the order of a single voxel width up to an acceptable displacement. This is crucial in eliminating the unknown uncertainty with which manual selection of fiducial points may introduce into the evaluation of a registration algorithm.

Fig. 1 The computer controlled respirator with its 4 cm range of motion shown.

SP072.7 - Using Magnetic Resonance Image (MRI) alone in Treatment Planning and Treatment Localization
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Purpose: Using MR image directly for dose calculation and patient treatment position localization has been expected. In this study, a method of creating a virtual CT image from a MR image was proposed and evaluated using the corresponding CT image numbers, planning dose distribution, and accuracy of daily CBCT image registration.

Method: A pair of MR image and CT image was collected in same day from each of 10 prostate cancer patients. For each patient, the pair of MR and CT images was pre-registered using the deformable image registration (DIR). Then the corresponding CT images were deformed toward MR to create a CT-MR pair. ROIs on the pair of images, including bone, prostate, bladder, rectum and skin, were delineated and used to create ROI masks. ’Leave-one-out’ test (9 atlas patients, 1 tested patient) was performed. For each test MR image, auto-segmentation and deformable vector field (DFV) were generated based on inter-patient DIR between the test MR image and the 9 atlas MR images. Synthetic CT was then generated using the paired CT and the corresponding DFV (MR, MR) in the atlas.
The voxel intensity in the synthetic CT was determined based on the paired CT images and the corresponding masks based on the intersection of the masks. The evaluation included the comparison of the CT number, the corresponding calculated dose distribution and the corresponding registration to daily CBCT images between the resulting synthetic CT and the paired CT.

**Result:** The mean ± STD of CT number error that calculated on 10 synthetic CT are (2.4 ± 25.23), (-1.18 ± 39.49), (-32.46 ± 81.9) and (8.07 ± 146.94) for prostate, bladder, rectum and bone, respectively. The dose discrepancy calculated using the synthetic CT and the actual CT is small, difference of D99 and D95 of target were < 1%, D40 and D5 of rectum and D50 of bladder were < 1.05%. Using the 10 synthetic CT as the reference planning CT for patient daily CBCT (364 fractions) localization achieved the similar results compared to using the actual CT. The translational vector difference were within 1mm with mean ± STD (0.37 ± 0.23mm), and the rotational discrepancy was within 1 degree in all 3 directions.

**Conclusions:** Synthetic CT created using the atlas of pre-registered CT and MR image pairs can be used to be the planning and localization CT image for dose calculation and daily patient position localization and correction.

**SP073 - Robotics and Virtual Reality in Surgery**

**SP073.1 - Augmented Reality in Image-guided Cardiac Interventions.**

Author(s):

Many inter-cardiac interventions are performed either via open-heart surgery, or using minimally invasive approaches, where instrumentation is introduced into the cardiac chambers via the vascular system or heart wall. While many of the latter procedures are often employed under x-ray guidance, for some of these, x-ray imaging is not appropriate, and ultrasound is the preferred intra-operative imaging modality.

Two such procedures involves the repair of a mitral-valve leaflet, and the replacement of aortic valves. Both employ instruments introduced into the heart via the apex of the heart. For the mitral procedure, the standard of care for this procedure employs a 3D Trans-esophageal echo (TEE) probe as guidance. In spite of the clinical success of this procedure, many problems are encountered during the navigation of the instrument to the site of the therapy. To overcome these difficulties, we have developed a guidance platform that tracks the US probe and instrument, and augments the US images with virtual elements representing the instrument and target, to optimize the navigation process. Results of using this approach on animal studies have demonstrated increased performance in multiple metrics, and a large reduction in the number of times an instrument intruded into potentially unsafe zones in the heart.

The same platform can be employed to guide Aortic valve replacements. Conventionally, aortic valves are replaced, either using an open procedure, or under X-ray fluoroscopy guidance. The former inflicts unnecessary trauma to the patient, while the latter suffers from the problem of high radiations dose, poor target visibility and potential kidney damage as a result of x-ray contrast administration. To overcome these limitations, we have adapted the above platform to achieve an ultrasound-only solution, again augmented with virtual models of instruments and key targets to guide aortic valve replacement procedures. Preliminary results of this approach on cardiac phantoms indicate that this approach may be as effective as the standard fluoroscopy-guided technique, but without the need for radiation and contrast agents.

**SP073.2 - Assistant Laparoscopic Postural: Kinematic Behavior**

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A human laparoscopic assistant can help or hinder the work of the surgeon, so communication between the two must be natural and not cause any cooperation conflict in which the visual or motor perception of the human laparoscopic assistant hampers the optimal vision and concentration of the surgeon. This article shows a new Assistant laparoscopic called PMASS (Postural mechatronics assistant for laparoscopic solo surgery). The objective is to show their dynamic behavior.
SP073.3 - Workspace optimization of a surgical instrument for single port access surgery
Author(s): Bastian Blase, Sebastian Schlegel, Simon Albrecht
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Instruments for laparoscopic single port access surgery have to perform specific movements inside the human abdomen to enable surgeons to perform similar tasks they are familiar with from multi-port minimally invasive surgery. Therefore, these instruments have to move apart before coming together at the surgical site to imitate an anthropomorphic position similar to standard access, thus facilitating handling at the desired target. These movements require additional joints. These joints weaken an instrument’s shaft structure and often lead to reduced strength, whereas parallel structures reduce workspace. Hence, instruments with a segmented planar hybrid parallel-serial mechanism have been developed, combining the advantages of both structures. This mechanism is coupled serially with an end-effector. Within a set of several geometric parameters and boundaries, the favored mechanism is optimized by varying the segments’ lengths for maximizing a so-called area of dexterity comprising all points that can be reached within an angular range of at least 60°. This area can be described in a cylindrical coordinate system in a phase space composed of the radial tool tip position and its inclination. The different movements of the mechanism and the end-effector are superposed and the phase space is analyzed using image evaluation methods. The optimized dexterous workspace by far exceeds a previously defined area of interest that was determined during in-vivo tests. The instruments based on this optimization proved to be agile in several tests like pick-and-place tasks.

SP073.4 - High-Dexterity Telemanipulation Robot for Minimally Invasive Surgery
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A robotic telemanipulation system for single-port laparoscopy (SPL) is presented, introducing several advantages over known systems. Principally, the system offers great flexibility at the surgical site as the instrument arms are segmented and articulate within the abdominal cavity. The instrument arms were thoroughly designed to ensure stability while maintaining a small cross-section, thus keeping patient trauma to a minimum.

Apart from the arms’ solidity, the need for strong actuators is another factor that arises due to the requirement for high manipulation forces during surgery. As, at the same time, available space is extremely limited, extensive research was conducted for finding suitable actuators. Several types of actuators as well as positions within the system were taken into account, prototypes built and tested. Also, as the need arose for some concepts, mechanisms for transporting kinetic energy from the actuators to the joints were examined.

Applying the results of this work, it was possible to build a telemanipulation system consisting of instrument arms, a support base, and a specifically designed user interface. A computer serves to calculate instrument trajectories and respective joint positions from the user input at the interface as well as to facilitate communication between the system's components.

The system exceeds previously defined goals concerning dexterity. Practical tests demonstrated the broad range of movement. At the same time, the extracorporeal components are considerably smaller than their counterparts in telemanipulators on the market, thus improving direct access to the patient during surgery. Furthermore, the complex kinematics of the instrument arms are controlled via an interface with simplified kinematics modelling the instrument’s degrees of freedom (DOF), resulting in intuitive and precise handling.

SP073.5 - Integrated Sensors for a Single-Incision Laparoscopic Instrument
Author(s): Simon Albrecht, Bastian Blase, Sebastian Schlegel
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This paper describes different sensor types for integration into a minimally invasive instrument for laparoscopic robotic surgery. A bionic fiber sensor helps to avoid collisions between the instruments’ arms and the abdomen during manipulation. Position measurement is included by means of magnetic sensors that deliver feedback signals for the drive mechanism. To provide the surgeon with a haptic feedback, two force sensors are studied to be incorporated into a single incision laparoscopic robotic instrument. Their individual characteristics and impact on haptic feedback are investigated, taking into account the individual sensors’ locations.

SP073.6 - Development and Evaluation of an Open-Source 3D Virtual Simulator with Integrated Motion-Tracking as a Teaching Tool for Pedicle Screw Insertion
Author(s): Stewart Mclachlin, Brendan Polley, Mirza Beig, Jeremie Larouche, Cari Whyne
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Pedicle screw insertion techniques are traditionally taught with limited hands-on training, using artificial or cadaveric models, prior to guided supervision within the operating room. As residency programs move to competency-based curricula, more authentic and accessible teaching tools are required to train next generation spine surgeons. Virtual simulation can provide a valuable tool for practicing challenging surgical procedures; however, its potential depends on effective integration into student learning. The objectives of this work were to develop a freely accessible virtual pedicle screw simulator and to improve the clinical authenticity of the simulator through integration of low-cost motion tracking.

The open-source medical imaging and visualization software, 3D Slicer, was used as the development platform for the virtual simulation. 3D Slicer contains many features for quickly rendering and transforming 3D models of the bony spine anatomy from patient-specific CT scans. The virtual simulation needed to include both pre-operative planning and intra-operative pedicle screw
insertion workflows. Pre-operative planning utilizes CT imaging to identify the vertebral levels requiring instrumentation and take anatomic measurements. The intra-operative screw insertion workflow requires identification of the correct entry point and trajectory to create a safe screw tract with a pedicle probe. This requires skill in complex 3D spatial perception and interpreting 2D images into real-world 3D positioning. To address this required skill development, virtual monitoring of the surgeon’s simulated tool was assessed with a low-cost motion tracking sensor in real-time (~$80, LeapMotion, San Francisco). This allowed a screw surrogate to be tracked as the surgeon defined the virtual screw’s insertion point and trajectory on a 3D spine model.

Using a combination of existing and custom-written 3D Slicer Python scripts, an interactive virtual pedicle screw simulator was created. The surgical planning and operative screw insertion were simulated in a six step workflow: (1) identify vertebral levels on CT imaging, (2) choose the surgical region of interest, (3) select screw entry points, (4) take anatomic measurements, (5) define screw trajectory via the LeapMotion, and (6) grade final screw positioning. Initial surgeon feedback of the virtual simulator with integrated motion tracking was positive, with no noticeable lag and high accuracy between the real-world and virtual environments. The software yields high fidelity 3D visualization of the complex geometry and the tracking enabled coordination of motion to small changes in both translational and angular positioning.

The 3D Slicer-based virtual pedicle screw simulation overcomes accessibility issues of previously developed simulators by allowing distribution without the need for expensive commercial software. This will enable trainees to practice instrumentation techniques anywhere they have access to a computer. Further the interactivity provided by the low-cost LeapMotion represents a significant advancement in terms of the simulator’s task authenticity. Future work will evaluate the benefit of this simulation platform with use over the course of resident spine rotations to improve planning and surgical competency and in quantitatively evaluating performance.

SP073.7 - A Robotic System with Ultrasound Imaging for Patient Setup and Monitoring during Fractionated Radiotherapy

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We are developing a cooperatively-controlled robot to assist with the application of ultrasound for patient setup and treatment monitoring of abdominal organs during fractionated radiotherapy. The proposed workflow introduces the robot for both simulation and treatment. During simulation, the operator places the 3D ultrasound (US) probe to visualize the target and the probe pose (position and orientation, in room coordinates) is measured by a ceiling-mounted optical tracker. The robot then holds a model probe at this pose during CT acquisition, and also records the probe contact force. The model probe has the same dimensions as the US probe but does not contain any metal parts that would cause CT artifacts. Treatment planning is performed on this CT image with probe-induced deformation. On each treatment day, the robot assists the operator to place the probe at the same pose and contact force as simulation. This cooperative control mode is enabled by a force sensor mounted between the robot end-effector and probe, which measures forces applied on the probe. Virtual springs guide the operator toward the recorded pose, but the operator can pull against the springs to override the recorded pose and replicate the US image recorded during simulation. This may be necessary to compensate for patient setup errors or anatomical changes. Once the US probe is placed to match the simulation conditions, it can provide real-time monitoring during radiation delivery.

We performed canine experiments using a custom robot that had five active degrees-of-freedom (DOF) and eight passive DOF. In these experiments, three 2.38 mm spherical metal markers were implanted into the kidney of a canine. We followed the proposed workflow for simulation and six fractionated treatments, except that we acquired additional images to measure the markers. Our results showed that placing the US probe at the same pose (in room coordinates) can result in soft-tissue setup errors of up to 35 mm, even after employing conventional setup procedures. The large inter-fraction variation is due primarily to the difficulty in repeatably repositioning the anesthetized canine. In contrast, the virtual springs enabled the operator to override this pose based on US image feedback and reduce the setup error to within 7 mm. Our experiments also revealed ergonomic challenges, especially because the robot had fewer than six active DOF. We are therefore updating the design to use a commercial 6 DOF robot (UR5, Universal Robots, Odense, Denmark), as shown in Fig. 1.
SP074 - Biomedical Monitoring and Bioelectromagnetism

SP074.1 - Towards Dual Respiratory and Cardiac Gated Radiotherapy

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Gating provides a potential solution for managing organ displacement during radiation treatment. In particular, respiratory gating of radiation therapy is an evolving field of study [1,2]. Cardiac gating, meanwhile, remains a largely unexplored area of potential benefit. Electrical impedance measurement has demonstrated its potential application in gating. In the present study, the respiratory and cardiac traces of three healthy human volunteers were recorded by using bioimpedance based simultaneous respiratory and cardiac monitoring circuitry developed in our previous study [3]. Each subject was instructed to maintain a normal breathing rate and hold their breath for a fixed duration. Respiratory motion was also monitored simultaneously using the existing Real-time Position Management™ (RPM) system for validating the impedance trace based on the respiratory motion. Interference caused by the respiratory motion was observed on the recorded cardiac induced bioimpedance change. Comparison of the cardiac traces for both normal breathing and breath holding revealed that the amplitude of the cardiac trace appeared to be modulated by the respiratory pattern. For the signal traces to be potentially applicable for gating purposes, it is desirable that the rendered signal waveform has stable amplitude. The aim of the study is thus to develop a strategy for improving the usability of the cardiac induced bioimpedance trace for radiotherapy gating purposes. A strategy is developed for largely removing the interference in the cardiac signal caused by the respiratory motion based on amplitude demodulation. The following Figure 1 shows a sample bioimpedance trace of recorded respiratory and cardiac motions, together with the amplitude demodulated cardiac trace.

The present study focuses on analyzing the correlation between the cardiac induced and respiratory induced impedance changes recorded and deriving a numerical technique for reducing the fluctuation in the amplitude of the cardiac signal. The technique developed will contribute to the potential application of bioimpedance signal on gating of radiotherapy.

SP074.2 - A mobile terminal to follow-up the evolution of chronic diseases

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This paper presents the firmware design of a low cost and consumption portable device intended to collect (Bluetooth) and transmit (GSM/GPRS) biological signals to a website. This solution forms part of an ambulatory monitoring system for patients with related heart diseases like arrhythmia, hypertension and diabetes, giving a more close interaction between patients and doctors. The hardware is based on the MSP430F5419A microcontroller, the CC2540 Bluetooth Low Energy (both from Texas Instruments), and the SIM908 GSM/GPRS/GPS modem from Simcom. The real time operating system FreeRTOS was used in the firmware. QRS complexes are detected and processed in the ECG wave signal; blood pressure and glucose level are processed as well. A robust communication protocol was implemented and an easy graphical user interface also. A total of 50 different samples were uploaded to the website using developed prototypes in a safety way. This is an interesting solution to have into account in this kind of systems due to its low cost.

SP074.3 - Relationship between the tuning characteristics of stimulus frequency otoacoustic emissions and behavioral tests at moderate levels

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Frequency selectivity, the ability of the auditory system to resolve the frequency components of complex sounds, is typically estimated in humans using a subjective method, the measurement of psychophysical tuning curves (PTCs). Stimulus frequency otoacoustic emission suppression tuning curves (SFOAE STCs) potentially could assess frequency selectivity objectively. We compared PTCs and SFOAE STCs in 24 normal hearing subjects using moderate-level probes with center frequencies near 1, 2, and 4 kHz, showing that both measures of frequency selectivity are similar.

SP074.4 - An Axon Mimic for Medical Electrode Tests

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Tissue’s heterogeneity makes it ineffective as a test bench and calibration standard for biomedical electrodes. There is a need for an axon mimic that can generate a stable, repeatable, programmable, and physiological A-fiber like action potential (AP). The aim of the project is to assess an electronic A-fiber like system for its potential use as a biomedical electrode test bench.

An equivalent 40 nodes of Ranvier were mimicked using resin embedded gold wire (Ø = 20 µm). All nodes share one amplitude con-
control (A) with programmable control for inter-nodal timing (t), duration (n) and propagation rate from a microcontroller running custom software. Statistically, a 20 μm diameter A-fiber has characteristic inter-nodal spacing of 2 mm and propagation speed of about 120 m/s [1] which results in a 16 μs increment time between activation of successive nodes. LabVIEW and DAQ from National Instruments (Version 8.2, National Instruments Corp. Texas USA) are used for acquisition and control. Custom software implements a simplified behavioral model based on Hodgkin and Huxley’s equation [2] with a pulse train (P(t)) propagating along the nodes.

The system was assessed by submerging the nodes in a bath of NaCl 0.9 % solution which acts as the intervening tissue mimic for testing. Data were collected using a pair of standard ECG-electrodes (4831Q, Unomedical a/s, Birkerød, Denmark) with gel removed. The electrode pair was used in a bipolar configuration positioned above the nodes. Fifty repeated measurements (P(t)) = 5, A = 1 V) verified the stability of the system where the time at maximum amplitude was t(pk_max) = 196.4 ± 0.06 ms, maximum amplitude was V(pk_max) = 37.5 ± 1.3 μV, and noise floor was Vnoise = 0.07 ± 0.017 μV.

In conclusion, the system generated a traveling pulse, with programmable amplitudes, durations and times similar to those of a biological AP. The output is stable and repeatable, and most importantly can be coupled to bio-potential electrodes. This platform allows testing and comparisons between surface electrodes and some implantable electrode configurations, as well as general electrode verification, complete systems can also be tested and compared with this stable AP generator.

References

SP074.5 - Evaluation the Accuracy of Oscillometric Blood Pressure Measurement According to the AAMI SP10

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The auscultatory method is regarded as the golden standard in non-invasive arterial blood pressure measurement. The oscillometric method are used widely in most automated blood pressure measurement instruments recently. The limitation of oscillometric method is that both the systolic and the diastolic pressure are estimated using empirical criteria. In fact, there are large variance of the amplitude ratios among population. Therefore, the estimation of the systolic and diastolic blood pressure based on oscillometric technique is not always accurate. In present study, an oscillometric method blood pressure measurement experiment system was established to acquire and analyze the blood pressure measurement data of the subjects with low, medium and high pressure. Eight-five subjects with a wide range of blood pressure were recruited. Each subject was measured three times. The experiment system acquires the cuff pressure and the oscillometric pulse. The manual auscultation measurement was performed on the same-limb simultaneously by two trained observers. The data were analyzed using self-programmed analyzing software based on Matlab. The averages of systolic and diastolic ratios are 0.50 and 0.71 respectively. Both the systolic and diastolic ratios fluctuate in a wide range, especially for the subjects with higher or lower blood pressure. Based on the golden standard, the accuracy of oscillometric method would not be generally accepted for the subjects with a wide range blood pressure.

SP074.6 - PEMF effects on chondrocyte cellularity and gene expression of the rat distal femoral metaphyseal articular cartilage.

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In recent years, interactions between electromagnetic fields and biological systems have increasingly been studied. To date, pulsed electromagnetic fields (PEMF) have a number of well-documented physiological effects on cells and tissues; including the up regulation of gene expression of the transforming growth factor beta super family members, the increase in glycosaminoglycan levels, and anti-inflammatory actions. The purpose of the current study was to determine the effect of PEMF on the rat distal femoral joint cartilage, in terms of chondrocyte gene expression level and cellularity. Twenty female 84 days old Wistar rats, were randomly assigned into two groups: the experimental group received focused PEMF (30 mT/1 Hz/30 min/20 days) on the knee (MS). The control group (Non-MS), was managed similarly, except that PEMF stimulation was simulated. All the animals were euthanized for histological and gene expression evaluation of the knee joint tissues; 6 μm cartilage longitudinal sections were obtained from formalin fixed and paraffin embedded (FFPE) samples, then stained with a hematoxileneosine technique. The sections were analyzed in a light clear field microscope in order to quantify the number of chondrocytes per optical field. To determine the expression levels of collagen type XI alpha 2 (col11a2), (sex determining region Y)-box 6 (Sox6), aggrecan (Acan), runt-related transcription factor 2 (Runx2), and alkaline phosphatase liver/bone/kidney (Alpl), total RNA was isolated from a FFPE RNAeasy Kit. For each sample R1 was reverse transcribed using oligo dT as primer. Real time PCR reactions were performed from 50 ng of cDNA. Statistically significant differences were found in joint cartilage cellularity when MS and Non-MS were compared (101.13 ± 26.61 vs 69.66 ± 15.55 cells per optical field, respectively; p = 0.001). Collagen XI, Sox6 and Aggrecan expression levels were also different in magnetically stimulated tissues relative to control (Differences were evaluated by Student’s t-test and were considered as significant when p < 0.05). On the other hand RUNX2 and ALPL expressions showed no significant differences between groups (Student’s t test, p > 0.05). These results are evidence that in vivo PEMF stimulation increases the number of well differentiated knee joint cartilage cells in healthy young adult rats. This finding indicates an in vivo trophic effect upon cartilage joint tissue. The action mechanisms could be associated to electrical characteristics of cartilage cells and could be related to new matrix production. The low gene expression of RUNX2 and ALPL supports that the chondrocytic response to PEMF do not correspond to a hypertrophic reaction. These results highlight the possible therapeutic future of PEMF in cartilage injuries, and on its ageing.

SP074.7 - Classification of responders versus non-responders to tDCS by analyzing voltage between anode and cathode during treatment session

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Transcranial direct current stimulation (tDCS) has been shown to be beneficial as a potential treatment of several disorders such as depression, addiction and chronic pain. Despite promising results reported in research, there is variability in responsiveness to tDCS among subjects. However, the source of this variability is still...
unknown. Creating a mechanism of determining non-responders (vs. responders) is a crucial step in order to either understand the physiology behind tDCS or increase the effectiveness of treatment. This work proposes a versatile method to predict whether a subject responds to tDCS by analyzing the voltage measured between anode and cathode during a tDCS session. Two groups of subjects are determined as responders and non-responders by assessing the effect of tDCS on their motor potential evoked by transcranial magnetic stimulation (TMS). Voltage measurements are modeled by a double Debye model and two relaxation times are extracted for each measurement. A quadratic classifier is trained to recognize responders and non-responders based on these relaxation times. Our classification results show that there is a significant correlation between relaxation times extracted from voltage and responsiveness to tDCS determined through motor evoked potentials. These results suggest that the relative speed of polarization processes occurring in electrodes and tissue may be associated the amount of current delivered to the brain.

SP074.8 - Matlab toolbox for bioelectric cardiac images analysis

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The heart problems are recognized by the World Health Organization as a major cause of death of human beings. Supported by the concepts of bioelectricity is now possible to better understand the functioning of this organ. In the medical physics research is a priority not to study only new equipment to detect these biosignals, but also new paradigms for processing, allowing the extract improve information of heart activity. We describe isECG (Imaging System for Electrocardiography), a new MATLAB processing toolbox, for bioelectric cardiac image analysis. Using real data (magnetic resonance images and ECG data from 123 bioelectrodes from an anonymous patient) the 3D-realistic heart/thorax geometry, surface ECG-bioelectric potential mapping on torso and myocardium surface potential images were constructed. Specialized routines are available for solution the direct and inverse bioelectric problem, and the results displayed in visualization panels (windows) on the main graphical interface. All ECG bioelectrical potentials signals, are show in new graphical window, and permit it is analysis for an individual ECG signal. Preliminary results demonstrated that isECG is a toolbox that can be used for analysis and visualization of cardiac bioelectric images, and has shown promise for future studies in Bioelectromagnetism.

SP075 - SPECIAL SESSION: Appropriate Technology in Imaging and Radiotherapy - Functionality and Safety Aspects

SP075.1 - Appropriate technology in imaging and radiotherapy - Functionality and Safety aspects

Author(s): Kin-Yin Cheung1, Adriana V. Berumen2, Miriam Mikhail Lette2, Joanna Izewska3
1IOMP, Happy Valley/HONG KONG, 2WHO, Geneva/SWITZERLAND, 3IAEA, Vienna/AUSTRIA

Every country faces resource constraints of some degree insofar as provision of healthcare services, a particularly critical problem in low-resource settings and in view of the rising trend of non-communicable diseases. 70% of cancer-related deaths occur in resource-constrained settings that request access to quality and affordable technologies. In low and middle income (LMI) countries, such medical services for underserved populations are mainly provided by governments. The IAEA/WHO Directory of Radiotherapy Centres (DIRAC) indicates major radiotherapy equipment shortages in these countries. WHO data in the World Health Statistics describe the corresponding census of diagnostic and therapeutic radiation technologies and services. Prioritizing appropriate selection, allocation, use, provision and optimization of cost-effective health technologies and human resources is therefore necessary. Important elements when formulating policy for planning and procurement of healthcare technologies must take into account high cost imaging and radiotherapy equipment, and should be based upon needs assessments and country specific criteria to include compatibility with clinical needs and burden of disease, radiological safety, standard of service and practice, affordability, sustainability, minimum operating requirements, long term functionality in LMI settings in terms of working conditions and infrastructure, and access to maintenance. International guidelines, recommendations, and reports such as produced by the IAEA and WHO can be used in support of planning radiation medicine services. One particular IAEA initiative aims to propose affordable, appropriate and suitable radiotherapy equipment packages and solutions for LMI countries through an IAEA Advisory Group on Increasing Access to Radiotherapy Technologies in Developing Countries (AGaRT), promoting increased access to diagnostic and therapeutic technologies in LMI countries by encouraging the industry to offer complete and integrated solutions that are safe, affordable, highly reliable and effective for low resource settings. WHO has been advising governments for many years in the incorporation of health technologies, including for diagnostic imaging and radiotherapy. For example, the WHO has recently embarked upon a project to list priority medical devices needed for the continuum of clinical management of six highly prevalent cancers, including radiation technologies. WHO is also conducting a Global Initiative on Radiation Safety in Health Care Settings to promote safe and appropriate use of radiation in healthcare. Ten priority actions have been identified in the “Bonn Call for Action” to improve safety and quality in the medical use of radiation for diagnosis and therapy, jointly published by the IAEA and WHO in 2014; engagement of all relevant medical sector stakeholders is warranted to support implementation. The synergies between IOMP, IAEA, WHO and others can enhance the availability of these technologies. Keeping in mind that technology planning criteria are country specific and dynamically change over time as healthcare services and technologies evolve, this joint session provides an excellent forum for global healthcare professionals and experts from international organizations to exchange ideas and experiences, and explore ways of addressing challenges faced during planning and acquisition of appropriate healthcare technologies.
SP076 - Radiobiological Modelling

SP076.1 - Radiation Pneumonitis and Low Dose Radiation Hypersensitivity

Author(s): J. James Gordon1, Karen C. Snyder1, Huailiang Zhong1, Ken Barton1, Zhen Sun1, Indrin J. Chetty1, Maritha Matuszak2, Randall K. Ten Haken1

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Analysis of a University of Michigan (UMich) clinical trial dose-volume histogram (DVH) dataset is summarized, the goal of which was to improve radiation pneumonitis (RP) prediction. A family of dose–damage profiles featuring low-dose radiation hypersensitivity (RHS) achieved higher predictive accuracy than mean lung dose (MLD), motivating a novel RHS normal tissue complication probability (NTCP) model. Results of this model are summarized. If one makes reasonable assumptions regarding the institution-specific DVH mix, the model can reproduce published MLD – RP risk curves obtained in clinical trials at Duke University, Netherlands Cancer Institute (NKI), Washington University (WU) and the University of Milan (UMilan).

SP076.2 - Dose distribution optimization methods based on biological parameters: Impact of the objective function and reoxygenation and proliferation effects

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The non-uniform response of tumors to radiation may compromise radiotherapy treatment outcome when homogeneous dose distributions are used. Responsible for this behavior are mainly the inhomogeneous distributions of oxygen and clonogenic cell density within the tumor. To approach these issues, the delivery of inhomogeneous dose distributions was long ago proposed to increase the efficiency of radiotherapy.

Dose prescription is normally addressed as an optimization problem involving an objective function, OF. Two of the most frequently used OFs aim to: i) maximize the tumor control probability, which is equivalent to minimize the tumor cells survival or ii) seek a uniform density of surviving clonogens.

The published works applying any of these two approaches were implemented using different dose redistribution techniques (sub-volume dose boosting, dose painting by numbers) to tumors with distinct radiosensitivity inhomogeneities. Furthermore, they analyzed the impact of different biological factors or employed mathematical tumors modeling these processes in different ways.

This work studies different methods of dose distribution optimization analyzing the above-mentioned OFs under a common methodology. Effects related to the dose heterogeneity allowed in the distribution and the impact of biological processes like reoxygenation and tumor cell proliferation are also studied. The response of a 2-cm-diameter hypoxic Head-and-Neck virtual tumor to radiotherapy was simulated using a previously published mathematical model [Med Phys. 2015 Jan; 42(1):30]. The model considers the following biological processes: tumor cells proliferation, neo-angiogenesis, diffusion-limited hypoxia, oxygen-dependent cell killing due to radiation, resorption of dead cells, tumor shrinkage and reoxygenation.

A dose painting by numbers approach was chosen to redistribute the dose keeping the average dose delivered to the tumor equal to 2 Gy per fraction.

The impact of the different OFs and dose heterogeneity constraints on treatment outcome was first isolated from other effects. At this stage no tumor cell proliferation was simulated and the tumor oxygenation status was considered to remain constant throughout the treatment. Dose distributions derived for fraction-by-fraction optimizations led to equal treatment outcomes for both OFs. In the dose distributions, the dose modulation was allowed to vary within a 10%, 25%, 35% and a 50% of 2 Gy per fraction. This led to a reduction of 3, 7, 8 and 10, respectively, in the number of fractions needed to achieve tumor control.

Dose distribution optimizations were then performed for a dose heterogeneity limit of 25% of 2 Gy simulating the tumor response considering all the abovementioned biological processes. The effect of changes in the tumor cell proliferation rate was studied for tumor cell doubling-times ranging from 50 to 5 days, including an accelerated repopulation regime arising after two weeks of treatment. The highest therapeutic gain from dose painting was achieved for the simulations with the highest proliferation rate (reduction of 13 fractions compared to the case using uniform dose). When accelerated repopulation is considered, the number of fractions needed to achieve tumor control was lowered from 34, for uniform dose distributions, to 23. The work shows that reoxygenation and tumor cell proliferation play an important role in the simulation of dose-painting.

SP076.3 - Healthy Tissues in The Present of Gold Nano Particles against 103Pd and 125I: Monte Carlo study

Author(s): Mohammad Vahidian, Somayeh Asadi, Mehdi Vaez-Za deh, Mahdieh Marghchouei

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The aim of the present Monte Carlo study is to evaluate the method of variation of energy deposition in healthy tissues in the human eye which is irradiated by brachytherapy sources in comparison with the resultant dose increase in the gold nano particle – loaded choroidal melanoma. The effects of GNPs on healthy tissues are compared between 103Pd and 125I as two ophthalmic brachytherapy sources. To this end, Human eye globe was simulated through the use of MCNP5 code by considering all parts of the eye. Dose distribution in healthy tissues and dosimetry differences in the eye phantom with existing tumor have been taken into account for both mentioned brachytherapy sources. In addition deviations observed in the comparison of simple water phantom and actual simulated eye in present of GNPs are also a matter of interest that has been considered in the present work. Here, both water and eye phantoms were simulated in which the water phantom was the same as the eye phantom with the exception that, water was considered to be the eye composition in all parts of the human eye globe. The previous studies which compared the ophthalmic brachytherapy dosimetry between these two sources reported higher absorbed dose by the tumor for 103Pd versus 125I for an equivalent radiation time. However, the results of this study show that the calculated dose enhancement factor in the tumor for 103Pd is higher than that of for 125I. Also, the ratio of the absorbed dose by healthy tissues in the present of GNPs to the absorbed dose by the tumor for 103Pd is lower than that.
SP076.4 - Monte-Carlo model development for evaluation of current clinical target volume definitions for Glioblastoma using Boron Neutron Capture Therapy

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**Introduction:** Glioblastomas (GBM) are notorious for their extensive diffusion and high fatality rate. Boron Neutron Capture Therapy (BNCT) is a biochemically-targeted type of radiotherapy where thermal neutrons are captured by $^{10}$B, resulting in the emission of high LET α-particles and recoiling $^7$Li atoms. BNCT has the potential to selectively deliver localized dose to tumour cells diffused into normal brain tissue, with minimal normal tissue toxicity. The aim of the current work is to develop a GBM model, taking into account cellular composition of brain with addition of appropriate $^{10}$B concentrations, to determine optimal Clinical Target Volume (CTV) margins for BNCT. It also aims to investigate the effectiveness of GBM cell death (i.e. in the presence of hypoxia and genetic heterogeneity) following BNCT.

**Methods:** A neutron beam model was developed in GEANT4 9.6.p02 and verified against published data. The neutron beam spectrum was obtained from literature for a cyclotron-produced beam. The calculated percentage depth dose curves (PDDs) in water were compared with measured data to verify the neutron beam in terms of total depth dose and boron dose deposition. The GBM model was structured as follows: firstly, Microscopic Extension Probability (MEP) models were developed using MATLAB-2012a, based on clinical studies reporting on GBM clonogenic spread. Typical $^{10}$B concentrations in GBM and normal brain cells were obtained from literature. Each cell was then assigned a $^{10}$B concentration depending on its MEP status. Secondly, a Geant4 microdosimetry model was developed to calculate the dose deposited in individual voxels, each representing a GBM/normal cell; the system was defined as a cubic phantom voxelized to 20 μm side voxels (the average size of glioma cells) and irradiated with an epithermal neutron beam. The material of each voxel was set to brain tissue with addition of appropriate $^{10}$B brain tissue, with minimal normal tissue toxicity. The aim of the study was to selectively deliver localized dose to tumour cells diffused into normal brain tissue, with minimal normal tissue toxicity. The aim of the current work is to develop a GBM model, taking into account cellular composition of brain with addition of appropriate $^{10}$B concentrations, to determine optimal Clinical Target Volume (CTV) margins for BNCT. It also aims to investigate the effectiveness of GBM cell death (i.e. in the presence of hypoxia and genetic heterogeneity) following BNCT.

**Results & Conclusion:** Excellent agreement was achieved between the calculated and measured neutron beam PDDs (within 1%) (Figure 1). The resulting boron depth dose deposition was also in agreement with measured data. Ongoing work is focusing on determination of tumour cell SF following BNCT as a function of various MEP models and $^{10}$B concentrations.

**Figure 1:** Comparison of calculated and measured total PDDs of a neutron beam in water (Insert: the neutron beam spectrum).

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SP076.5 - Exploring RBE Dependence on Proton Track Angular Incidence

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The relative biological effect (RBE) of protons, taken as the ratio of double strand break (dsb) yields for an investigated radiation source to the yields by $^{60}$Co, can be computed by overlaying event-by-event Monte Carlo (MC) particle tracks on a cell nucleus model. Strand breaks (sb) occur when energy depositions (ED) sites coincide with the DNA sugar-phosphate backbone. Dsbs are then modelled as arrangements with at least one sb on each strand within 10 base pairs (bp). Human DNA is tightly packed into higher order structures including chromosomes, chromatin fiber, and nucleosomes (beads on a string configuration). This work compares proton RBE for different angular orientations of nucleosomes relative to incident charged particle tracks within a cell nucleus model.

The MC code LionTrack (Med.Phys.2013;30(4)) was used to generate proton (~1-5 MeV) and $^{60}$Co ED tracks, including all secondary electrons (tracking cutoff of 50 eV). ED sites were subsequently overlaid on a simplified cylindrical cell nucleus (~2 μm radius and half-height) at track-nucleus angles from 0 (normal incidence) to 90 degrees (parallel to nucleus axis). Fractions of ~2 Gy were simulated at each angle for each source. A nucleosome, consisting of a 2-turn, double stranded, and circular arrangement of 99 bp pairs, is replicated in an ordered fashion approximately 3x10$^7$ times in the nucleus and dsb yields are computed for each fraction.

For $^{60}$Co, no angular dependence was detected and the 95% confidence interval on the average angular dsb yield was [2.50 2.65] dsb Gy$^{-1}$ cell$^{-1}$, which was used as the reference to calculate RBE for protons. RBE was larger than one at all proton energies and incidence angles, with two significant trends: As expected, the RBE increased with decreasing proton energy. However, RBE also significantly depends on the track-nucleus angle, due to a preferential track alignment with the nucleosomes at higher angles, but also to a higher probability of traversing the nucleus without hitting any DNA targets. For 1 MeV protons, the spherically weighted average RBE is 7 % higher and 22 % lower than the RBE for 0 and 90 degrees respectively. When simulating RBE, angular dependence of the dsb yields due to the nucleus model chosen should be investi-
gated and a spherically weighted average RBE should be reported.

**SP076.6 - DNA Damage Induced in Glioblastoma Cells by I-131: A Comparison between Experimental Data and Monte Carlo Simulation**

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**Objective:** The passage of ionizing radiation in living cells creates clusters of damaged nucleotides in DNA. In this study, DNA strand breaks induced by the beta particle of iodine-131 (I-131), have been determined experimentally and compared to Monte Carlo simulation results as a theoretical method of determining 131I damage.

**Materials and Methods:** For conducting this experimental study, Glioblastoma (GBM) cells were exposed to 10 mCi I-131, at a dose of 2 Gy, in order create single strand breaks (SSB) and double strand breaks (DSB) in the DNA of irradiated cells. Cells were evaluated quantitatively by the Fast Micromethod assay. The energy spectrum of electrons released in cells were obtained by the macroscopic Monte Carlo code (MCNP4c) and used as an input of the micro Monte Carlo code (MCDS). The percent of damage induced in cells was calculated by Manvity test.

**Results:** A significant reduction (p<0.05) in fluorescence intensity in irradiated cells compared to control cells as determined by the Fast Micromethod assay represented induced SSB and DSB damages in the DNA of irradiated cells. By comparing the experimental and theoretical results, the difference between the percent of SSB per Gy was about 7.4% and DSB was about 1% per Gy.

**Conclusion:** The differences in experimental and theoretical results may be due to the algorithm of applied codes. Since the Fast Micromethod and other experimental techniques do not provide information about the amount of detailed and complex damages of DNA-like base damages, the applied Monte Carlo codes, due to their capability to predict the amount of detailed damages that occur in the DNA of irradiated cells, can be used in in vitro experiments and radiation protection areas.

**SP076.7 - The stochastic extension of the Linear Quadratic model: Taking into account the uncertainty of radiobiological parameters.**

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**Introduction:** We show the way to modify the Linear Quadratic model of cell survival used in Radiation Oncology to accommodate uncertainty in the radiobiological parameters (α, β). The objective is, given the probability distribution functions of α and β, find the probability distribution function of the biological equivalent dose, BED, and the probability of cell survival, p. And furthermore, find how this uncertainty propagates through a fractionation scheme. In this paper we show that this can be done in an explicit way without simulation.

**Materials and Methods:**

The stochastic extension of the Linear Quadratic model consist in promoting α, β, p, BED from single value variables to random variables α, β, p, BED. The delivered dose per fraction, d, is considered as a non-random parameter. For a single fraction, there is an analytical relationship between α, β and BED and p, so we can use the rules of probability to get a formula to obtain the probability distribution functions of p and BED from the corresponding probability distribution functions of α, β. For a fractionation scheme of dose, we have to consider sums of stochastic variables, that involves repeated convolutions of probability functions.

**Results:**

If we define equivalent treatments in the mean, for different fractionation schemes, we can recover the formulas of the usual Linear Quadratic model, substituting α, β by the expected value <α>, <β>. The variance of these treatments can also be shown to be different whenever the variance of α or β is different from zero. For a number of fractions large enough, p can be regarded as a log-normal stochastic variable, due to the central limit theorem.

**Discussion:**

We have described a analytical way to take into account the uncertainty of radiobiological parameters as probability distribution functions into the Linear Quadratic model, without Montecarlo simulation. This higher level of complexity gives in return better information of the effect of this uncertainty on the treatment outcome. Whether these stochastic extensions may explain data variability better than any more sophisticated “non-stochastic” radiobiological model is yet a matter of experiment.
SP077 - Radiation Oncology

SP077.1 - Assessment of CT to CBCT Non-Rigid Image Registration in Prostate Cancer Radiation Therapy
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Medical Physics, CancerCare Manitoba, Winnipeg/CANADA

Purpose: The goal of this project was to investigate the performance of three image registration algorithms implemented in two open source platforms: 3DSlicer and MedInria.

Material and Methods: The study describes CT to CBCT deformable registration by the application of following algorithms: two well known Affine and Fast Symmetric Forces Demons (3DSlicer) as well as Dense Anatomical Block Matching (MedInria) that is based on pyramidal block-matching approach. To the best of author knowledge it is the first study which attempts to investigate the performance of Dense Anatomical Block Matching Algorithm (DABM) for CT to CBCT deformable registration.

Pre-treatment CT (pCT) images of five prostate patients undergoing IMRT were selected for this work. Representative CBCT data sets were acquired in the middle of the radiotherapy treatment to provide the algorithms with realistically challenging registration problem. Deformable registration for each algorithm was followed by the initial Affine alignment of considered images. After registration, structures (GTV, Bladder and Rectum) delineated on pCT were first deformed using obtained vector fields, next propagated to CBCT images and finally compared to the contours delineated on CBCT by experienced Radiation Oncologist. The similarity between deformed CT (dCT) and CBCT images was also analysed.

Accuracy of registration was assessed by the application of the following metrics: Dice Coefficient and Mean Hausdorff Distance for structures comparison as well as voxel-to-voxel absolute intensity difference for dCT-CBCT images comparison. For visualization and structures comparison as well as voxel-to-voxel absolute intensity difference for dCT-CBCT images comparison, a surface map reflecting surface-to-surface distances for the closest surfaces can be created. The differences between considered organs contours as a surface map reflecting surface-to-surface distances for the closest surrounding points. The map of absolute discrepancies in image intensity between dCT and CBCT for selected image slices is also provided.

Results: Early results clearly indicates very promising performance of Dense Anatomical Block Matching method for challenging non-rigid pCT-to-CBCT registration compared to Affine and Demons algorithms which can be seen at the figure 1. This quick quality assessment is expected to be confirmed by more detailed analysis of proposed similarity metrics. Additionally, smooth and unfolding DVF-DABM shows the lack of any unphysical deformations.

SP077.2 - Use of flattening filter free photon beams for off-axis targets in conformal and stereoelectric body radiation therapy
Author(s): Ashley Smith1, Christopher Serago2, Siyong Kim1, Kathleen Hintenlang1, Michael Heckman2, David Hintenlang3
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Dynamic conformal arc therapy (DCAT) and FFF beams are commonly adopted for efficient conformal dose delivery in SBRT. Off-axis geometry (OAG) may be necessary to obtain full gantry rotation without collision, which has been shown to be beneficial for peripheral targets using flattened beams. We investigated dose distributions in OAG using FFF, and the effect of mechanical rotation induced uncertainty.

Sphere targets (2, 4, and 6 cm diameter) were placed at three locations (central axis, 3 cm, and 6 cm off-axis) in a representative patient CT set. DCAT plans were obtained for 6X, 6FFF, 10X, and 10FFF. Homogeneity index (HI), conformity indices (CI), and beam on time (BOT) were calculated. Mechanical rotation induced uncertainty was evaluated using five SBRT patient plans with laterally located tumors. For each, a plan was generated using FFF beams for OAG and CAG. Each was replanned to account for one degree collimator/couch rotation errors during delivery. Prescription isodose coverage, CI, and lung dose were evaluated.

HI and CI values were similar for flattened and unflattened beams; however, 6FFF provided slightly better values than 10FFF in OAG. For all plans HI and CI were acceptable with the maximum difference between flattened and FFF beams being 0.1. FFF beams showed better conformity for low doses and small targets. Variation due to rotational error for isodose coverage, CI, and lung dose was generally smaller for CAG compared to OAG, with some of these comparisons reaching statistical significance. However, variations in dose distributions for either technique were small and not clinically significant.

FFF beams showed acceptable dose distributions in OAG. 10FFF provides more dramatic BOT reduction, but generally provides less favorable dosimetric indices compared to 6FFF in OAG. Mechanical rotation induced uncertainty had an increased effect for OAG compared to CAG; however, variations for either treatment technique were minimal.

SP077.3 - Dosimetric evaluation of the interplay effect for non-gated VMAT treatment of moving targets with high dose rate FFF beams
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1Radiation Oncology, Mayo Clinic, Jacksonville/UNITED STATES OF AMERICA, 2Radiation Oncology, College Of Medicine, Virginia Commonwealth University, Richmond/UNITED STATES OF AMERICA, 3Biomedical Engineering, University of Florida, Gainesville/UNITED STATES OF AMERICA

Purpose: Interplay effects exist between multi-leaf collimator movement and tumor motion when treating moving targets with intensity modulated radiation therapy. Dose deviations caused by the interplay effect can be decreased by reducing the dose rate. It is questionable whether flattening filter free (FFF) high dose rate will increase dose deviations caused by the interplay effect for volumetric modulated arc therapy (VMAT). This work evaluates the interplay effect using a moving phantom to simulate respiratory tumor motion for non-respirato-
ry-gated VMAT treatment using FFF beams, and investigates the impact of dose rate.

METHODS

Two VMAT plans were selected from lung patients treated with 6 MV FFF beams. Dose distributions were measured using a 2D ion chamber array placed on a motor-driven motion platform. Respiratory phase was accounted for by dividing the breathing cycle into 8 equally spaced phases and irradiation was initiated at each of the phases. The 8 starting phases were used to simulate the clinical situation of starting the treatment at a random phase in the patient breathing cycle. All fields were delivered in their treatment geometries with and without phantom motion using 3 dose rates: 1400, 600, and 400 MU/min.

Measured dose was compared to planned dose using gamma analysis (3%/3mm), percent of pixels within 5% of pixel dose, and percent of pixels within 10% of pixel dose. Calculations were done for the 8 initial starting phases and repeated for a random sampling of starting phases for 1000 trials. Target coverage was evaluated by the dose difference for four points at the center of the target. Four points at the periphery of the target were used to evaluate planning target volume margin.

RESULTS

Results for 1000 trials of randomly selected motion phases are reported in Table 1. The delivered dose compared to planned dose in the center of the target region was within 5.0% for the static phantom condition and 7.4% for the moving phantom condition. At the periphery of the target the delivered dose differed from planned dose by -0.9% to 13% for the static condition and -28.8% to 39.7% for the moving condition.

CONCLUSION

Our results indicate the interplay effect had an impact on non-gated VMAT when treating a moving target with FFF, however using high FFF dose rate did not increase dose deviations compared to lower dose rates. The impact of the interplay effect on target coverage is acceptable, as long as sufficient margin is given.

<table>
<thead>
<tr>
<th>Plan</th>
<th>Phantom</th>
<th>Dose Rate (MU/min)</th>
<th>Gamma 3%/3mm</th>
<th>Standard deviation</th>
<th>% of pixels within 5% of dose</th>
<th>Standard deviation</th>
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SP077.4 - In vivo Image Guided Brachytherapy Verification (IGBV) in high dose rate prostate brachytherapy – Initial Clinical Experience

Author(s): Ryan L. Smith1, Annette Haworth2, Jeremy L. Millar1, Michael L. Taylor3, Rick D. Franchi1
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Aim.

High dose rate (HDR) prostate brachytherapy treatment is widely practiced and is a well-established radiotherapy technique. Usually delivered in large dose fractions, poor execution in the delivery of a planned treatment would have significant clinical impact on the patient. The frequency and type of errors that may occur in HDR brachytherapy treatment are mostly unknown as there exist limited options for independent routine monitoring of treatment delivery to identify potential errors and ensure patient safety. We report our initial clinical experience with a novel, non-invasive, source-tracking system based on a flat panel detector (FPD) for treatment verification in HDR prostate brachytherapy: Image Guided Brachytherapy Verification (IGBV).

Materials & Method.

For IGBV, a FPD was mounted in our brachytherapy treatment couch under a customised carbon fibre couch top assembly. Six prostate patients (10 treatment fractions) were included in this clinical study of the IGBV system. At treatment, each patient was aligned on the brachytherapy couch with the target region (prostate) centred on the sensitive imaging area of the FPD. As the HDR treatment proceeded, images of the source position were acquired with the FPD in the form of patient exit radiation. These images were post-processed to determine the position of the source inside the patient and were compared to the treatment plan in order to identify potential errors and verify correct treatment delivery.

Results.

The measured source dwell positions confirmed correct transfer tube connection, afterloader indexer length, source step size and patient/plan selection. The mean linear distance between measured and planned source dwell positions was 2.37 mm (s.d. 0.96mm), after rigid registration with the treatment plan. The average dwell step size across all measured catheters was 2.54 mm (s.d. 0.24mm, n=112). The absolute position of the measured dwell, together with the implanted gold fiducial markers, visible on a pre-treatment radiograph, provided verification of programmed treatment indexer length and therefore delivery to the correct anatomical location. This unique brachytherapy verification process is non-invasive, with the patients virtually unaware of the verification imaging that is occurring during treatment delivery. The total impact on procedure time was less than 15 minutes.

Conclusion.

This novel, non-invasive HDR brachytherapy treatment verification system, IGBV, was implemented clinically, providing confirmation of many treatment parameters by tracking the position of the HDR source as treatment was delivered. An independent treatment monitoring system, such as the one described here, could validate the treatment delivery process in real time, enabling a safety interlock system. The clinical experience with the IGBV system provided confirmation that the treatment was delivered free of potential human related errors. This concept and system will meaningfully improve safety standards by allowing routine treatment verification in HDR brachytherapy across a range of clinical applications.

SP077.5 - Electronic Portal Imaging Device Dosimetry for IMRT: a Review on Commercially Available Solutions

Author(s): Omemh Bawazeer1, Sisira Herath2, Siva Sarasananda-jah1, Pradip Deb3
1School Of Medical Radiation, RMIT University, Melbourne/AUSTRALIA, 2Radiation Oncology, Peter MacCallum Cancer Centre, Melbourne/AUSTRALIA

Much research has been conducted about the utilization of electronic portal imaging devices (EPID) for dose verification during radiotherapy treatment. Currently a number of commercial solutions are available; Portal Dosimetry, EPI Dose, Epiq, Dosimetry Check, and EPIgray software. Results from separate studies on clinical applications of these solutions are published. The objective of this paper is to review the accuracy of these dosimetry solutions when used for intensity modulated radiotherapy technique (IMRT). Although each solution has a different approach to dose verification, most of the IMRT dosimetry verification results are highly satisfactory. However, performance of one solution is less satisfactory when the patient-couch attenuation occurs. Moreover, none of these solutions correct the back scatter effect resulted from supporting arm. In addition, there are no comparative studies currently available about the accuracy of these solutions except one paper that compared Portal Dosimetry and EPI Dose reporting the major differences between these systems. Further studies are needed to compare the accuracy of these commercially available EPID dosimetry solutions.

SP077.6 - The Nano-X Radiotherapy Machine: Lean Innovation Transforming Global Access to Cancer Care

Author(s): Paul Keall1, Enid Eslick1, Peter Lazarakis1, Michael Jackson1, Ilana Feain2
1Radiation Physics Laboratory, University of Sydney, University of Sydney/AUSTRALIA, 2University of New South Wales, Sydney/AUSTRALIA

The Nano-X vision is to level the playing field in global access to radiotherapy. Where cancer patients in low and middle income countries have access to appropriate treatment and care, where the machine is designed from the ground up to deliver an affordable and viable solution for the people that need treatment, where they needs treatment, independently of where highly trained workforces live.

The Nano-X Solution

Nano-X, which will enter the international market by 2020, will launch on a wave of global awareness around this epidemic. Nano-X alleviates major obstacles to global radiotherapy utilization with lean innovation and a compact, affordable system for low and middle-income countries with drastically simplified hardware and workflow. A Nano-X schematic is shown: a full clinical prototype is now under construction and the shielded bunker is complete.
**SP077.7 - Development of an MR and CT compatible non-invasive temperature based optical fiber respiration sensor for use in radiotherapy**

**Author(s):** Ashley Smith¹, Siyong Kim², Christopher Serago¹, Kathleen Hintenlang¹, Robert Pooley³, David Hintenlang⁴

¹Radiation Oncology, Mayo Clinic, Jacksonville/UNITED STATES OF AMERICA, ²Radiation Oncology, College Of Medicine, Virginia Commonwealth University, Richmond/VA/UNITED STATES OF AMERICA, ³Radiology, Mayo Clinic, Jacksonville/UNITED STATES OF AMERICA, ⁴Biomedical Engineering, University of Florida, Gainesville/UNITED STATES OF AMERICA

We have developed a non-invasive temperature based respiration sensor to track the breathing cycle during respiratory gating that is not subject to the limitations of an external marker. The sensor tracks the breathing cycle by measuring the temperature of inspiratory and expiratory air (Figure 1). Because it doesn’t rely on movement of the abdomen it can be used with forced shallow breathing (FSB) or thermoplastic body mask immobilization. The sensor is compatible for use in CT, MR, and linear accelerator environments.

Respiration signals were tested with five volunteers using FSB, and compared to simultaneously recorded signals from an external marker. Temperature readings were also tested in a CT, MR, and linear accelerator environment. The sensor’s effect on image quality was evaluated for CT and MR.

The temperature sensor successfully recorded the breathing cycle for all volunteers, while the external marker had one failure (Figure 2). Fluctuations in temperature sensor signals were similar to background in both a CT and MR environment. There was greater signal fluctuation when the sensor was placed in a high energy linear accelerator field and given a high dose. The fluctuation was acceptable when the sensor was outside the radiation field. It is recommended that the sensor be placed outside the treatment field during treatment. Image quality was not affected by the temperature sensor for CT or MR.

**Conceptual Innovation:** Nano-X will deliver a paradigm shift in radiation oncology by enabling affordable, accessible radiotherapy in resource-limited areas where capital costs and on-site operations are major issues. Nano-X increases patient throughput and decreases on-site staffing using sophisticated algorithms and leveraging telemedicine to enable centralised planning and local treatment with automated decision making. **Methodological Innovation:** Nano-X will treat patients with a fixed vertical beam and a patient rotation couch. This reduces costs enormously by reducing the (i) engineering complexity, (ii) size and radiation shielding requirements of the room (iii) onsite staffing requirements and (iv) time-consuming and inconvenient patient immobilisation procedures and treatment planning. **Technological Innovation:** For Nano-X, tumour motion will be substantial as patients themselves are rotated. The technological innovations in Nano-X are our algorithms for real-time image guidance and dynamic adaptation of the treatment beam to account directly for tumour motion.
We have shown that the temperature based respiration sensor can successfully track breathing cycles even when external markers fail. Performance is maintained in MR and ionizing radiation environments; however it is recommended that it not be used in the direct path of a high energy beam. We have verified that respiratory signals can be obtained without deterioration of CT or MR images. It is anticipated that this device would be highly suitable for respiratory gating in radiation therapy.
SP078 - Brachy Therapy: Part 2

SP078.1 - The Effect of Bladder Preparation on Motion of Organs at Risk in High Dose Rate Gynecological Brachytherapy

Author(s): Parisa Sadeghi1, Robyn Banerjee2, Tien Phan1, Majed Alghamdi2, Amandeep Taggar2, Wendy L. Smith1

1Physics And Astronomy, University of Calgary, Calgary/Canada, 2Radiation Oncology, Tom Baker Cancer Centre, Calgary/AB/Canada

Introduction: High Dose Rate (HDR) brachytherapy is part of the treatment protocol for advanced cervical cancer. The planning process for Magnetic Resonance (MR) guided treatment requires both Computed Tomography (CT) and MR imaging. This combines the high soft tissue contrast of the MR images with the ability of the CT scan to visualize the applicator inside the patient. However, this dual imaging requires multiple patient transfers and increases the overall patient motion. This can lead to changes in both the position and volume of the organs at risk (OARs) in the pelvic region, such as the rectum and bladder.

The purpose of this study is to evaluate the effect of bladder filling (often used to reduce bowel dose) on bladder motion, and quantify the motion of the rectum during HDR brachytherapy of cervical cancer.

Methods: A total of 15 cervical cancer patients were included in this study. Nine patients were treated without introducing bladder filling. Six patients had their bladder contents emptied and re-filled to a specific volume (120 – 200 cc). The change in bladder volume and center of mass (CM) position between the MR and CT imaging sessions, as well as the concordance index (CI) of the contoured bladders on both image sets were calculated using the Eclipse treatment planning system by Varian.

Results and Discussion: It is evident, from the data presented in Table 1 that the prepared bladders display a smaller change in volume compared to the bladders without the filling. In addition, prepared bladders show a mean positional change of 4.2 mm (range: 1.6-8.5 mm), while a positional change of 5.3 mm (range: 1.5-15.4 mm) is observed in the absence of bladder filling. This is interesting because the filling implemented for bowel sparing seems to have the added benefit of reducing bladder mobility. Also the prepared bladders seem to have a higher CI value. The rectum shows an overall positional change of 6.6 ± 4.6 mm over the whole patient population.

Conclusion: Our results clearly display a trend where the bladder preparation leads to a smaller bladder motion, smaller volume change, and higher CI. Although preliminary statistical analysis did not reveal any significant difference between the two bladder preparation protocols, a larger sample size could provide more conclusive results.

<table>
<thead>
<tr>
<th></th>
<th>Bladder (Filled) (Mean ± SD)</th>
<th>Bladder (Not Filled) (Mean ± SD)</th>
<th>Rectum (Mean ± SD)</th>
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</thead>
<tbody>
<tr>
<td>Volume Change (%)</td>
<td>18 ± 14</td>
<td>40 ± 55</td>
<td>17 ± 26</td>
</tr>
<tr>
<td>CM motion (mm)</td>
<td>4.2 ± 2.3</td>
<td>5.3 ± 4.4</td>
<td>6.6 ± 4.6</td>
</tr>
<tr>
<td>CI</td>
<td>0.74 ± 0.06</td>
<td>0.59 ± 0.19</td>
<td>0.51 ± 0.11</td>
</tr>
<tr>
<td>D2cc (cGy)</td>
<td>697 ± 128</td>
<td>632 ± 130</td>
<td>460 ± 87</td>
</tr>
<tr>
<td>D1cc (cGy)</td>
<td>766 ± 143</td>
<td>703 ± 153</td>
<td>507 ± 95</td>
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<tr>
<td>D0.1cc (cGy)</td>
<td>930 ± 170</td>
<td>872 ± 244</td>
<td>629 ± 41</td>
</tr>
</tbody>
</table>

Table 1: Preliminary analysis on motion and deformation of the organs at risk between the two imaging sessions of CT and MRI.

SP078.2 - Retrospective Monte Carlo dose calculations for permanent implant prostate brachytherapy using 125I

Author(s): Paul Soubiran1, Justin Sutherland1, Nelson Miksyz2, Ali-Reza Mehan Haidari3, Rowan Thomson3, E Chooan1, Gad Perry1, Joanna Cygler1

1Radiation Medicine Program, The Ottawa Hospital Cancer Centre, Ottawa/CANADA, 2Physics, Carleton University, Ottawa/ON/CANADA

Clinical dose calculations for low dose-rate (LDR) prostate brachytherapy are currently performed following the protocols defined by the American Association of Physicists in Medicine (AAPM) Task Group no. 43 (TG-43) formalism. Using the TG-43 formalism, absorbed dose is calculated in a homogeneous water environment so the effects of tissue heterogeneities, interseed attenuation, and the finite dimensions of patients are not accounted for. This work retrospectively investigates differences between TG-43 and Monte Carlo (MC) calculated dose distributions for 105 patients treated with LDR prostate brachytherapy at The Ottawa Hospital.

Each of the 105 patients used in this study had a prescribed dose of 145 Gy (Drx) to the prostate through implantation of 125I seeds (Model 6711 RAPID Strand™). Treatment planning and seed implantations were performed in real-time using ultrasound images. MC calculations were performed using the EGSnrc user-code BachyDose. Computational phantoms for each patient were generated from CT images acquired 1 month post-implant by a Philips Brilliance CT scanner – Big Bore. Material compositions were assigned to each voxel within image contours based on CT number: prostate and calcification within prostate contours, air and muscle within rectum contours, urinary bladder within bladder contours, and ICRU 46 soft tissue and bone in the remainder of the phantom. CT number thresholds between tissue assignments were assigned consistently between patients and were determined by manual investigation of CT scans for several patients. The mass density of each voxel was derived from a scanner calibration of Hounsfield Units to density. To avoid misassignment of voxels to calcification and since BrachyDose models full seed geometries, seeds and metallic artifacts were removed from scans prior to tissue assignment by over-riding CT numbers above a threshold in the vicinity of the seeds. Dose to medium was calculated with sufficient histories to achieve a statistical uncertainty of less than 2% in prostate volumes.

Dose distributions calculated with BrachyDose differed considerably from those calculated with TG-43. The patient-averaged minimum dose to 90% of the target volume (D90) was 9.5 Gy lower as calculated by BrachyDose compared to TG-43. The average D99 was 52 Gy less than Drx as calculated by BrachyDose compared to 45 Gy less than Drx as calculated by TG-43. Similarly, the patient-averaged percentage volume that received at least 100% of the prescription dose (V100%) was 4% lower as calculated by BrachyDose compared to TG-43. While doses to organs at risk (OAR) also differed...
between BrachyDose and TG-43 calculated distributions, the differences were smaller. The patient-averaged highest dose received by 1 cc (D1cc) of the rectum was 103 Gy as calculated by BrachyDose and 110 Gy as calculated by TG-43; a 6.5% difference which may be clinically significant. D1cc for the bladder was 86 Gy for BrachyDose versus 88 Gy for TG-43 calculations, which is not clinically significant.

Retrospective MC calculated dose distributions for 105 Ottawa Hospital patients treated with LDR prostate brachytherapy showed a decrease in average dose coverage of target volumes and OARs as compared with TG-43 calculated dose distributions.

SP078.3 - Combining doses for prostate cancer patients receiving external beam radiotherapy and a HDR brachytherapy boost: Dosimetric parameters and dose-surface maps for patients with and without late rectal bleeding

**Author(s):** Calvin R. Moulton1, Michael House1, Victoria Lye2, Colin Tang2, Michele Krawiec2, Tim St Pierre1, David J. Joseph2, James W. Denham3, Martin A. Ebert2

1School Of Physics, The University of Western Australia, Crawley/ WA/AUSTRALIA, 2Radiation Oncology, Sir Charles Gairdner Hospital, Nedlands/WA/AUSTRALIA, 3School Of Medicine And Population Health, The University of Newcastle, Callaghan/NSW/AUSTRALIA

**OBJECTIVE:** Are post-registration rectum dosimetric parameters and rectum dose-surface maps (DSM) different for groups of patients who did or did not have late bleeding?

**Methods:** 91 patients received external beam radiotherapy (EBRT) in 23 fractions of 2 Gy and high-dose-rate (HDR) brachytherapy in 3 fractions of 6.5 Gy. The EBRT CT was registered to the HDR CT with a rigid plus deformable multi-pass method (RD) or a rigid plus scale plus deformable multi-pass (RSD) method in Velocity Advanced Imaging. The unregistered EBRT and registered HDR dose distributions were summed after converting to equieffective doses at 2 Gy/fraction (α/β = 3 and 5.4). The V1Gy to V100Gy (increment=1) and D1% to D100% (increment=1), D1cc, D2cc, D5cc and D10cc were calculated. Rectum DSMs were obtained by virtually unfolding the rectum surface dose slice-by-slice. Patients were classed into toxicity or no toxicity groups if they did or did not have a grade 2 LENT-SOMA rectal bleed from the period 3 months after radiotherapy onwards. The DSMs were spatially analysed by thresholding DSMs from 1 Gy to 100 Gy (increment=1). This analysis included the inferior-superior extent, left-right extent, area, perimeter, compactness, circularity and ellipse fit parameters. Significance (p<0.05) for median comparisons between groups was assessed via two-sided Mann-Whitney U-tests.

**Results:** The dosimetric and DSM results in the figure are for the RSD registration, HDR dose calculated with the Acuros algorithm and an α/β of 3; however, results were similar for alternatives. The V44Gy, V45Gy, V46Gy to V71Gy, D1% to D28%, D1cc, D2cc, D5cc and D10cc were significantly greater for toxicity (N=73) groups. Patients with toxicity had significantly greater left boundaries, greater right boundaries, greater widths and greater perimeters for various DSM isodose contours (e.g. 51-66 and 83 Gy). The ellipse fits at a number of dose thresholds (e.g. 83 Gy) indicated significantly greater lateral extent, greater eccentricity and greater horizontal orientation for bleeders. The lateral centroid components for some dose thresholds (e.g. 83 Gy) were significantly further to the right for bleeders. The proportions of ellipses filled by various thresholded doses (e.g. 50 Gy) were significantly greater for bleeders.

**Conclusion:** Multiple dose-volume parameters, derived from registered plans, correlated with bleeding. The lateral coverage of intermediate and high-dose regions was greater and located further to the right for bleeders. For bleeders, the doses in high-dose regions were greater and more contained within fitted ellipses.

**ACKNOWLEDGEMENTS:** NHMRC (1006447) and University of Western Australia.

SP078.4 - Implementation of Permanent Breast Seed Implants in British Columbia: Innovation and Early Results

**Author(s):** Michelle Hilts1, Deidre Batchelor1, Daniel Morton2, Juanita Crook2

1Medical Physics, BC Cancer Agency - Southern Interior, Kelowna/ CANADA, 2Physics And Astronomy, University of Victoria, Victoria/ CANADA, 3Radiation Oncology, BC Cancer Agency - Southern Interior, Kelowna/CANADA

**Purpose:**

Permanent breast seed implant (PBSI) is an attractive option for women with early stage breast cancer as the procedure is completed in a single outpatient session. In 2012 the BC Cancer Agency became only the second institution worldwide to offer this novel technique pioneered in Toronto. In this work we present technique innovations introduced at BCCA as well as preliminary results from our first 15 patients.

**MATERIALS AND METHODS:**

Modelled after the technique introduced by Pignol et al, we use a template and US guided technique to implant needles pre-loaded with Pd-103 into the breast. CT planning (MIM Symphony) is undertaken to deliver 90Gy to a PTV, seroma+1.25cm cropped to skin and chestwall. A pre-treatment simulation step is included to check template position and transfer key landmarks from the treatment plan onto the skin. In the operating room a portable laser is used to confirm positioning and US is used throughout the procedure to monitor needle placement. Post-implant dosimetry is assessed using CTs obtained on day of implant (day0:reported here) and one month post-implant. Deformable image registration is used to define the post-implant seroma from the pre-implant contour. Implant quality is assessed on an evaluative PTV (PTVeval), seroma+0.5cm. In house software was utilized to measure seed displacements (planned to implanted positions) in 10 cases. Patient satisfaction is also reported.
Results:

Pre-implant volumes ranged from 4.1–20.2cc (median 7.0cc) and 31.4–114.2cc (median 47.4cc) for seroma and PTVs respectively. PTVs were well covered with V100 (mean±SD) of 96.1±2.7% using 77±22 seeds in 17±5 needles. Post-implant PTVal eval dosimetry (day0) for all patients was (mean±SD): 90.4±9.4%, 86.9±10.8% and 64.4±14.9% for V90, V100 and V150 respectively and 87.1±25.3Gy for D90%. The corresponding PTVal eval coverage (mean±SD) for the last 8 implants illustrates rapid convergence to consistently high quality implants: 96.5±2.6%, 93.6±4.6% and 70.9±12.1% for V90, V100 and V150 respectively and 103±16Gy for D90%. Mean seed displacement was 0.9±0.5cm for the 10 patients where seed matching was performed. All patients were very or extremely satisfied with the procedure, citing the single day treatment as a highlight.

Conclusions:

These early results indicate that PBSI is a safe and desirable treatment option for women with low risk breast cancer and technical innovation aimed at increased technique reproducibility has contributed to a rapid learning curve. Our aim, through ongoing technical innovation, is to continue to improve the standardization and reproducibility of PBSI to ultimately enable widespread implementation.

Results: The squared difference criteria for the median dosimetric values were not satisfied for some dosimetric parameters and toxicity criteria. The α/β for the dosimetric parameters, toxicity criteria and TG43/Acuros algorithm options varied from 0.710 to 4.84. The variability was greater across the parameters and toxicity criteria. The α/β (95% CI) for the parameters (toxicity criteria) were 3.98 (0.260-10.1), 0.710 (0.100-6.18), 1.49 (0.090-10.7) and 3.51 (2.45-8.03) for the D1cc (≥1), D2cc (≥1), D5cc (≥2) and D10cc (≥3) options applied with the Acuros algorithm. The mean α/β and mean 95% CI across the parameters, toxicity criteria and TG43/Acuros algorithm options were 2.75 and 0.834–8.94.

Conclusion: The estimated mean α/β was 2.75 for late rectal bleeding. A conclusion on the early/late responding nature of the rectum was not feasible due to variability across parameters and wide confidence intervals. An increased sample size may result in more consistent and precise values across the dosimetric parameters and toxicity criteria.

ACKNOWLEDGEMENTS: NHMRC (1006447) and University of Western Australia.

Figure:Pd-103 in seroma

SP078.5 - Estimation of α/β for late rectal bleeding via minimum dosimetric differences for prostate cancer patients treated with external beam radiotherapy versus a HDR brachytherapy boost after external beam radiotherapy

Author(s): Calyn R. Moulton1, Michael House1, Victoria Lye2, Colin Tang3, Michele Krawiec4, Angel Kennedy5, Tim St Pierre5, David J. Joseph5, James W. Denham2, Martin A. Ebert1

1School Of Physics, The University of Western Australia, Crawley/ WA/AUSTRALIA, 2Radiation Oncology, Sir Charles Gairdner Hospital, Nedlands/WA/AUSTRALIA, 3School Of Medicine And Population Health, The University of Newcastle, Callaghan/NSW/AUSTRALIA

OBJECTIVE: To estimate the α/β for late rectal bleeding via the difference in dosimetric parameters for patients treated with external beam radiotherapy (EBRT) versus a combined treatment of EBRT and high-dose-rate (HDR) brachytherapy.

Methods: In the RADAR trial, 723 patients received 66, 70 or 74 Gy (2 Gy/fraction) of EBRT and 91 patients received 46 Gy (23 fractions) of EBRT and 19.5 Gy (3 fractions) of HDR brachytherapy. HDR dose was calculated with both the Acuros and TG43 algorithms. For combined treatments, the EBRT CT was registered to the HDR CT in Velocity Advanced Imaging. The rectum D1cc, D2cc, D5cc and D10cc were calculated for patients receiving EBRT only and patients receiving combined EBRT/HDR. These parameters were correlated with bleeding for patients receiving combined EBRT/HDR. Patients from the two treatments were classed into toxicity groups if they had at least a certain grade (1, 2, or 3) LENT-SOMA rectal bleed from the period 3 months after radiotherapy onwards. The toxicity numbers for the EBRT only/combined treatment groups were 343/374, 18/183 and 5/66 for grades ≥1, ≥2 and ≥3. The parameters for patients with toxicity after EBRT only versus after combined EBRT/HDR treatments were compared as follows. (1) The medians of dosimetric parameters for the EBRT toxicity group were converted to equieffective doses at 2 Gy/fraction with α/β from 0-11 (increment=0.01). (2) This conversion was also applied to medians of the dosimetric parameters from the unregistered EBRT and registered HDR components for the combined treatment toxicity group. (3) The total median parameters for the combined treatment toxicity group were obtained by summing the converted median dosimetric parameters for the unregistered EBRT and registered HDR components for the combined treatment toxicity group. (4) The α/β with the smallest squared difference between the median converted dosimetric parameters for the two groups was determined and accepted if the squared difference was less than 0.01. (5) Bootstrapped 95% confidence limits (CI) for the α/β were calculated via (1)-(4) after resampling the two groups with replacement (10,000 resamples).

Results: The α/β (95% CI) for the parameters (toxicity criteria) were 3.98 (0.260-10.1), 0.710 (0.100-6.18), 1.49 (0.090-10.7) and 3.51 (2.45-8.03) for the D1cc (≥1), D2cc (≥1), D5cc (≥2) and D10cc (≥3) options applied with the Acuros algorithm. The mean α/β and mean 95% CI across the parameters, toxicity criteria and TG43/Acuros algorithm options were 2.75 and 0.834–8.94.

Conclusion: The estimated mean α/β was 2.75 for late rectal bleeding. A conclusion on the early/late responding nature of the rectum was not feasible due to variability across parameters and wide confidence intervals. An increased sample size may result in more consistent and precise values across the dosimetric parameters and toxicity criteria.

ACKNOWLEDGEMENTS: NHMRC (1006447) and University of Western Australia.

SP078.6 - Failure Mode and Effects Analysis (FMEA) for improving quality assurance for Image-Guided High Dose Rate (HDR) brachytherapy

Author(s): Shada Wadi-Ramahi, Waleed Al-Najjar, Belal Moftah

Biomedical Physics, King Faisal Specialist Hospital and Research Center, Riyadh/SAUDI ARABIA

Purpose:

To evaluate and develop quality assurance (QA) for image-guided high dose rate (HDR) brachytherapy by applying the failure mode and effects analysis (FMEA).

Method:

We started by mapping the major process tree of HDR brachytherapy, and highlighting the image-dependent steps. “Wrong Treatment Site” was identified as being the ultimate end-point that might result from errors in imaging procedures, and fault tree analysis (FTA) for this error was mapped with all the branches leading to it. The use of conventional imaging (2D) with isocentric and non-isocentric machines was also included for completeness. Potential risk for
The FTA, revealed a point during the HDR process (nodes 29 and 30) where QA is lacking. Those are non-image related; however, the error can be stopped from propagating by implementing a pre-treatment image verification procedure, which can be achieved by several methods depending on the user’s capabilities.

Conclusion: We have applied FMEA process to image-guided HDR brachytherapy. The fault tree for “wrong treatment site” error identified areas of potential high risk and exposed areas where QA was lacking in the whole procedure. This helped us in re-prioritizing our QA procedures and guidelines.

Results:
Fourteen major steps were identified: TPS commissioning, source installation and initial QA, patient diagnosis and selection, applicator insertion, primary image set acquisition, secondary image set acquisition, Image transfer and registration, organ delineation, applicator and coordinate system definition, plan optimization and dose calculation, plan transfer to treatment console station, source connectivity to patient, image verification of applicator position before treatment, and finally treatment delivery. Of these steps, six are image dependent and all leads to one error “Wrong treatment site”. The FTA for “wrong treatment site” identified 30 potential failure nodes (2 are machine related, the rest are human related), see attached figure. Out of the 30, eleven are non-image related. Total RPNs ranged from 11 to 254. RPN for image arm ranged from 11 to 254, whereas for non-images RPN ranged from 45 – 192. RPN higher than 100 was considered potential for high risk. The errors were grouped into three major groups (human, procedural or machine). For each set, we took the analysis further by proposing corrective actions, such as development and implementation of departmental guidelines and QA.
Tumor motion due to respiratory motion can lead to dosimetric errors in the delivery of radiotherapy treatments. Respiratory gating can be used to address this issue but requires external markers or motion surrogates to monitor the breathing motion. However, these are not always well correlated to the true position of the tumor. We present a feasibility study of respiratory gated radiotherapy using a real-time positron emission tracking system.

The tracking system, called PeTrack, uses implanted low activity positron emission markers and position sensitive gamma ray detectors to track breathing motion in real-time. A LabVIEW interface is developed to synchronize gating between the signal from PeTrack and the NRC Elekta Precise linac. Prototype PeTrack detectors were mounted on an aluminum frame surrounding a dynamic anthropomorphic thorax phantom (Figure 1). Dose was delivered to the phantom in 500 monitor unit increments with a 3x3 cm$^2$ photon beam and with 6 and 10 MV nominal beam energies. Radiochromic films were inserted in the phantom to measure spatial dose distributions. The phantom lung insert was translated in the inferior/superior direction with sinusoidal and real patient breathing motion (±10 mm amplitude). The motion was tracked using a small $^{22}$Na fiducial marker (0.43 MBq activity) embedded in the lung insert. The beam was turned off when the marker was outside of a 5-mm one dimensional gating window.

Clear improvement of the dose distribution is observed between gated and non-gated delivery (Figure 2). Monitoring of the beam on/off times show synchronization with the location of the marker within the latency of the system.
A new real-time IGRT system, kilovoltage intrafraction monitoring (KIM), is undergoing clinical evaluation through a first-in-world prospective clinical trial for prostate cancer patients. KIM uses kV fluoroscopy to monitor, in real-time, the 3D position of radio-opaque markers implanted into the prostate target. The real-time target position is used to guide the treatment: if the prostate moves outside the tolerance (motion exceeding 3mm for 5 seconds) the beam is paused and the patient is repositioned. The goal of this study is to investigate the localisation accuracy and dosimetric impact of the KIM system, in planned 30-patient gated prostate cancer radiotherapy trial.

To date, three patients have completed their 40-fraction treatments. Simultaneous intra-fraction kV and MV images from the 116 fractions were used offline to measure the accuracy of the KIM real-time measurements. The measured triangulated kV-MV marker positions were considered to be ground truth, and were compared to the KIM measurements. For the dosimetry, dose delivered during each fraction with KIM was measured using a motion-synchronized isocenter shift dose reconstruction method. In the fractions with a gating event, dose reconstruction was also carried out for a simulated treatment scenario with no KIM gating correction representing the current standard of care. Target and normal tissue dose volume statistics were compared for the planned treatment delivery, delivery with KIM gating and delivery with no KIM correction (see figure 1). KIM has a finite gating threshold and therefore, in the presence of motion, it will deviate from the planned treatment.

The mean error ± standard deviation of KIM in the LR, SI and AP directions was 0.14±0.50, 0.38±0.27, and -0.46±0.45 mm respectively. In total, 14 fractions had successful KIM gating corrections. Prostate motion with KIM corrections and simulated with no KIM corrections were 1.9±1.2 mm and 3.8±1.4 mm respectively. Mean (range) differences between the planned and KIM corrected doses and the planned and no KIM correction doses were respectively: PTV D95% -1.4 (-3.4, 0.7) & -3.1 (-10.9, -0.7); CTV D100% -0.8 (-2.8, 0.7) & -0.1 (-7.0, 1.9); rectum V65% -3.5 (-9.4, 5.7) & -4.9 (-11.2,18.7); and bladder V65% 1.58 (-0.9, 5.8) & 2.8 (-10.0, 10.4).

In conclusion, the results demonstrated that both the accuracy and precision of KIM system are sub-millimetre, and KIM gating improves the agreement between the planned and delivered treatments for prostate radiotherapy. The KIM technology has wide-scale applicability as it is implemented on a standard linear accelerator with little modification.

Purpose: Irregular breathing can influence the outcome of four-dimensional computed tomography imaging for causing artifacts. Audio-visual biofeedback systems associated with patient-specific guiding waveform are known to reduce respiratory irregularities. In Japan, abdomen and chest motion self-control devices (Abches), representing simpler visual coaching techniques without guiding waveform are used instead; however, no studies have compared these two systems to date. Here, we evaluate the effectiveness of respiratory coaching to reduce respiratory irregularities by comparing two respiratory management systems.

Methods: We collected data from eleven healthy volunteers. Bar and wave models were used as audio-visual biofeedback systems. Abches consisted of a respiratory indicator indicating the end of each expiration and inspiration motion (Fig. 1). Respiratory variations were quantified as root mean squared error (RMSE) of displacement and period of breathing cycles.

Results: All coaching techniques improved respiratory variation, compared to free-breathing. A typical case study showing improvements regarding respiratory irregularity is summarized in Fig. 2. Displacement RMSEs were 1.43±0.84, 1.22±1.13, 1.21±0.86, and 0.98±0.47 mm for free-breathing, Abches, bar model, and wave model, respectively. Free-breathing and wave model differed significantly. Period RMSEs were 0.48±0.47 mm for free-breathing, Abches, bar model, and wave model, respectively. Free-breathing and wave model differed significantly. Period RMSEs were 0.48±0.47 mm for free-breathing, Abches, bar model, and wave model, respectively. For variation in both displacement and period, wave model was superior to free-breathing, bar model, and Abches. The average reduction in displacement and period RMSE compared with wave model were 27% and 47%, respectively.

Conclusions: This study was to evaluate the efficacy of audio-visual biofeedback to reduce respiratory irregularity compared with Abches. Our results showed that audio-visual biofeedback combined with a wave model can potentially provide clinical benefits in respiratory management, although all techniques could reduce respiratory irregularities.
difference between the predicted position and the modeled position calculated after 115 ms had elapsed. We computed model correlation errors using the difference between the correlation model’s position estimate and the internal fiducial position from x-ray imaging. To estimate overall uncertainty, we quadratically summed the correlation, prediction and end-to-end targeting error (±0.5 mm) in each direction. We also tested the linear correlation between target amplitude and tracking errors for each direction.

Results showed that the cranio-caudal direction exhibited the greatest correlation and prediction errors, but total radial error was less than 5 mm (Table 1). Significant weak correlations (r = 0.08 – 0.19, p<0.0001) existed between target amplitude and correlation errors in all directions except left-right; whereas, strong correlations existed with prediction errors (r = 0.55 – 0.67, p<0.0001) for all directions.

Based on the overall 3D radial position errors, results suggest that for 95% of the beam delivery time the target centroid will be within 4.6 mm of the planned target volume. These results along with consideration for internal fiducial migration, target rotation and liver deformation may help guide planning target volume expansion.


Table 1. Tracking errors for Cyberknife liver treatments. LR = left-right, AP = anterior-posterior, CC = cranial-caudal.

<table>
<thead>
<tr>
<th>Error</th>
<th>Direction</th>
<th>Mean (mm)</th>
<th>Std Dev. (mm)</th>
<th>95th percentile (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation</td>
<td>LR</td>
<td>0.71</td>
<td>1.01</td>
<td>2.15</td>
</tr>
<tr>
<td></td>
<td>AP</td>
<td>0.64</td>
<td>0.86</td>
<td>1.80</td>
</tr>
<tr>
<td></td>
<td>CC</td>
<td>1.20</td>
<td>1.68</td>
<td>3.50</td>
</tr>
<tr>
<td></td>
<td>Radial</td>
<td>1.74</td>
<td>1.26</td>
<td>4.19</td>
</tr>
<tr>
<td>Prediction</td>
<td>LR</td>
<td>0.15</td>
<td>0.09</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>AP</td>
<td>0.09</td>
<td>0.07</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>CC</td>
<td>0.17</td>
<td>0.10</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>Radial</td>
<td>0.26</td>
<td>0.14</td>
<td>0.51</td>
</tr>
<tr>
<td>Total</td>
<td>LR</td>
<td>1.24</td>
<td>N/A</td>
<td>2.39</td>
</tr>
<tr>
<td></td>
<td>AP</td>
<td>1.19</td>
<td>N/A</td>
<td>2.07</td>
</tr>
<tr>
<td></td>
<td>CC</td>
<td>1.57</td>
<td>N/A</td>
<td>3.66</td>
</tr>
<tr>
<td></td>
<td>Radial</td>
<td>2.47</td>
<td>N/A</td>
<td>4.56</td>
</tr>
</tbody>
</table>

SP079.4 - Tracking Accuracy for Robotic Radiosurgery in the Liver

Author(s): Jeff D. Winter¹, Raimond Wong², Anand Swaminath², Tom Chow¹
¹Medical Physics, Juravinski Cancer Center, Hamilton/CANADA
²Oncology, McMaster University, Hamilton/CANADA

Cyberknife® robotic radiosurgical treatment of liver employs an online motion management system to track and compensate for target motion during free-breathing. Lesion tracking on the Cyberknife is achieved using a room-mounted orthogonal x-ray system to localize internal fiducial markers as well as an optical camera system to measure the position of the patient’s abdomen during breathing. The system establishes a correlation model linking internal target position to an external optically-tracked surrogate to enable near-real-time robotic adjustments of the linear accelerator. However, inherent system delays (115 ms) require a prediction algorithm to estimate the future position. Throughout treatment, periodic x-ray images are collected to verify and update this internal-external correlation model.

In this study, our aim was to quantify key uncertainties in the targeting of liver lesions on the Cyberknife system. We analyzed the logged Cyberknife tracking information for a total of 28 patient treated over 124 fractions and isolated treatment images collected immediately prior to beam delivery. To assess target amplitude and absolute prediction errors, we isolated 20 s time intervals surrounding each treatment x-ray image. We computed target amplitudes using peak/valley detection and prediction errors using the absolute

SP079.5 - Deep Inspiration breath hold lung SBRT- Can Flattening Filter Free beam based VMAT combined with gated CBCT facilitate precise treatment delivery with sufficient dosimetric accuracy?

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¹Radiation Oncology, yashoda hospital. Hyderabad/INDIA, ²Radiation Oncology, All India Institute of Medical Sciences, New Delhi/INDIA, ³Research And Development Centre, Bharathiar University, Coimbatore/INDIA

Objective(s):The combination of VMAT technique using high dose rate FFF beams along with the computer controlled deep inspiration breath hold technique provides opportunity to further reduce treatment margins in lung SBRT over free breathing (FB) approaches. The aim of this study was to investigate the potential benefits of VMAT based DIBH SBRT over FB SBRT. This was performed by conducting a dosimetric comparison of VMAT technique with IMRT
technique using both DIBH & FB approaches.

**Materials/Methods:** Ten lung SBRT patients treated using 6MV FFF-VMAT based DIBH technique were retrospectively selected for this study. Treatment planning were performed in both DIBH & FB patient data set using IMRT & VMAT techniques. Treated patients dose prescription of 60 Gy in 5 fractions was used as standard dose prescription for the techniques. Plan evaluation was performed with RTOG0813 treatment planning criteria. Paired t test was used for statistical analysis. The dosimetric accuracy of the gated VMAT was assessed using a global gamma index (3% dose difference, 3mm DTA (Distance to agreement)) and measured with 2D detector attached to a solid cube phantom. Actual patients number of breath hold cycles and total delivery time with breath hold phases of 20/25s and recovery phases of 25 seconds were also incorporated during QA procedures.

Results: Irrespective of the techniques, DIBH approach could very well satisfy the RTOG0813 treatment planning criteria for the studied patients. As shown in table mean average Dose conformity of 1.03 + 0.012 for VMAT-DIBH was significantly better as compared with IMRT-FB, VMAT FB & IMRT-DIBH techniques (p<0.03). Mean average Lung V20Gy volume was 4.84+ 2.4, 5.22+ 2.5, 10.07+ 2.3, and 10.27+ 2.04% for VMAT-DIBH, IMRT-DIBH, VMAT-BH, and IMRT-BH respectively. In terms of Heart V15cc and Esophagus V5cc maximum dose, VMAT-DIBH plans exhibit the lowest as compared with the other techniques. Both the IMRT & VMAT-DIBH plans could be accurately delivered despite undergoing multiple beam on/off cycles, with mean QA pass rate over 95% (IMRT-DIBH VS VMAT-DIBH = Mean 96.42+1.2 vs 97.8 + 1.1).Treated DIBH patients gated CBCT analysis showed that average mean setup error was 2.8mm (range 1.5 - 4.2mm) in latero-lateral, 3.4mm (range 2.2 - 4.8mm) in antero-posterior, 3.2mm (range 2.4 - 5.6mm) in craniocaudal directions.

Table-1

<table>
<thead>
<tr>
<th>RT0G-0811 treatment planning parameters Mean Average</th>
<th>IMRT-FB</th>
<th>IMRT-BH</th>
<th>VMAT-FB</th>
<th>VMAT-BH</th>
<th>RT0G limit for none deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTV - CI</td>
<td>1.098±0.055</td>
<td>1.068±0.043</td>
<td>1.062±0.038</td>
<td>1.031±0.13</td>
<td>&lt;1.2</td>
</tr>
<tr>
<td>P value</td>
<td>0.109</td>
<td>0.083</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lung V20Gy (%)</td>
<td>10.27±5.12</td>
<td>5.22±2.5</td>
<td>10.07±2.3</td>
<td>4.86±2.4</td>
<td>&lt;15%</td>
</tr>
<tr>
<td>P value</td>
<td>0.9901</td>
<td>0.6001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart V15cc (%)</td>
<td>30.1±9.35</td>
<td>19.27±6.88</td>
<td>32.11±9.17</td>
<td>19.19±6.4</td>
<td>-</td>
</tr>
<tr>
<td>P value</td>
<td>0.01</td>
<td>0.002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esophagus V5cc (%)</td>
<td>1157±1034</td>
<td>1011±677</td>
<td>1071±903</td>
<td>947±779</td>
<td>&lt;3100</td>
</tr>
<tr>
<td>P value</td>
<td>0.6182</td>
<td>0.8688</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Results:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results from this study showed that with proper patient coaching FFF beam based DIBH lung SBRT combined with gated CBCT facilitate precise treatment delivery with sufficient clinical dosimetric accuracy.
ABSTRACTS | IUPESM 2015 WORLD CONGRESS ON MEDICAL PHYSICS & BIOMEDICAL ENGINEERING

SP079.6 - Feasibility of markerless tumor tracking by sequential dual-energy fluoroscopy on a clinical tumor tracking system

Author(s): Jennifer Dhont, Kenneth Poels, Dirk Verellen, Koen Tournel, Thierry Gevaert, Femke Steenbeke, Mark De Riddler Radiotherapy, Universitair Ziekenhuis Brussel, Brussels/BELGIUM

The purpose was to evaluate the feasibility of markerless tumor tracking through the implementation of dual-energy imaging into the current clinical dynamic tracking workflow of the Vero SBRT system. An innovative approach of fast sequential fluoroscopy sequences was implemented omitting the pre-requisite of fast-switching kV-generators.

Two sequential 20s (11Hz) fluoroscopy sequences were acquired at the start of one fraction for 7 patients treated with DT on the Vero system. Sequences were acquired using 2 on-board kV imaging systems located at ±45° from the MV beam axis, at respectively 60kVp (3.2mAs) and 120kVp (2.0mAs). Table 1 shows the kV imager positions that were selected based on marker visibility. Prior to evaluation, the implanted fiducial was removed on all images to be evaluated, to not bias the results. Offline, a normalized cross-correlation algorithm was applied to anatomically match the high (HE) and low-energy (LE) images. Per breathing phase (inhale, exhale, maximum inhale and maximum exhale), the five best matching HE-LE couples were extracted for DE subtraction. A contrast analysis according to gross tumor volume (GTV) was conducted between the DE and HE images based on contrast to noise ratio (CNR). Improved tumor visibility was quantified using an improvement ratio (IR=CNRDE/CNRHE).

DE subtraction through sequential fluoroscopy was incorporated on the Vero system with only minor adjustments to the imaging settings. Removing the implanted fiducial was successful on all images. HE-LE sequence matching was effective for 12 of 14 imaging angles, correlation coefficients per imaging angle can be found in Table 1.

Table 1 Mean correlation coefficient per imager (Im) between high- (HE) and low-energy (LE) images, contrast-to-noise ratio (CNR) across tumor-volume for HE and dual-energy (DE) images, and relative improvement ratio (IR=CNRDE/CNRHE)

<table>
<thead>
<tr>
<th>Correlation coefficient</th>
<th>CNR ± SD</th>
<th>IR</th>
</tr>
</thead>
<tbody>
<tr>
<td>HE</td>
<td>DE</td>
<td></td>
</tr>
<tr>
<td>patient 1</td>
<td>0.954 ± 0.011</td>
<td>0.53 ± 0.15</td>
</tr>
<tr>
<td>Im.1 125°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>patient 1</td>
<td>0.936 ± 0.009</td>
<td>0.23 ± 0.08</td>
</tr>
<tr>
<td>Im.2 35°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>patient 2</td>
<td>0.991 ± 0.001</td>
<td>0.17 ± 0.02</td>
</tr>
<tr>
<td>Im.1 315°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>patient 2</td>
<td>0.980 ± 0.002</td>
<td>0.51 ± 0.21</td>
</tr>
<tr>
<td>Im.2 225°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>patient 3</td>
<td>0.976 ± 0.031</td>
<td>0.49 ± 0.14</td>
</tr>
<tr>
<td>Im.1 45°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>patient 3</td>
<td>0.784 ± 0.028</td>
<td>1.07 ± 0.28</td>
</tr>
<tr>
<td>Im.2 315°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>patient 4</td>
<td>0.969 ± 0.005</td>
<td>0.22 ± 0.08</td>
</tr>
<tr>
<td>Im.1 348°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>patient 4</td>
<td>0.859 ± 0.032</td>
<td>0.85 ± 0.24</td>
</tr>
<tr>
<td>Im.2 78°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>patient 5</td>
<td>0.988 ± 0.014</td>
<td>0.30 ± 0.13</td>
</tr>
<tr>
<td>Im.1 250°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>patient 5</td>
<td>0.983 ± 0.017</td>
<td>0.03 ± 0.02</td>
</tr>
<tr>
<td>Im.2 160°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>patient 6</td>
<td>0.652 ± 0.019</td>
<td>0.11 ± 0.08</td>
</tr>
<tr>
<td>Im.1 320°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>patient 6</td>
<td>0.975 ± 0.029</td>
<td>0.47 ± 0.05</td>
</tr>
<tr>
<td>Im.2 230°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>patient 7</td>
<td>0.884 ± 0.024</td>
<td>0.36 ± 0.19</td>
</tr>
<tr>
<td>Im.1 65°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>patient 7</td>
<td>0.985 ± 0.004</td>
<td>0.12 ± 0.02</td>
</tr>
<tr>
<td>Im.2 75°</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overlying bony anatomy was removed on all DE images; Figure 2 shows an example. CNR per patient and per imaging angle can be found in Table 1. With the exception of two imaging angles, the DE images showed no significantly improved tumor visibility compared to HE images. Qualitatively, it was observed that for these imaging angles that showed no significantly improved CNR, the tumor tissue could not be reliably visualized on neither HE nor DE images due to a total or partial overlap with other soft tissue.

Dual-energy imaging by sequential fluoroscopy was shown feasible by implementing an additional fluoroscopy sequence into the DT workflow of the Vero system. However, for most imaging angles, DE images did not provide improved tumor visibility over single-energy images, most likely due to an overlap of the tumor with other soft-tissue. Optimizing imager settings and angles is likely to improve the efficacy of dual-energy imaging.

(a) (b) (c) (d)

Fig. 1 A low-energy (a) and high-energy (b) image acquired at 160°, with the corresponding DE subtraction image without (c) and with (d) GTV and PTV contour, from a patient with a metastatic lesion in the right lower lobe.
SP080 - Other Radiation Oncology: Part 2

SP080.1 - Estimation of the second cancer risk from adjuvant radiation therapy for stage I seminoma of the testis

Author(s): Michalis Mazonakis¹, Theocharris Beriss¹, Charalambos Varveris², John Damilakis¹

¹Department Of Medical Physics, University of Crete, Heraklion/GREECE, ²Department Of Radiotherapy, University of Crete, Heraklion/GREECE

Purpose: To estimate the second cancer risk associated with the adjuvant radiation therapy for stage I seminoma of the testis.

Methods: The study population consisted of eleven patients with stage I testicular seminoma who underwent postoperative radiation therapy with a 6 MV photon beam. Three-dimensional conformal radiotherapy plans based on CT scans were generated for all patients. Two parallel-opposed anteroposterior and posteranterior fields were used to deliver 20 Gy to the para-aortic lymph node region. The organ equivalent dose (OED) to stomach, colon, liver, and pancreas, which were partly included within the treatment volume, was determined using differential dose-volume-histograms and a plateau dose-response model. Furthermore, a previously validated Monte Carlo model of a linear accelerator producing 6 MV X-rays was employed to calculate the radiation dose at sites excluded from the primarily irradiated area. Para-aortic irradiation to 20 Gy with standard treatment field sizes was simulated on a computational humanoid phantom representing an average adult man. Monte Carlo calculations were performed to determine the average radiation dose (Dav) received by each of the following out-of-field organs: brain, salivary glands, oral mucosa, thyroid, lung, esophagus, urinary bladder and prostate. The Dav and OED values together with organ-specific risk coefficients were used to estimate the excess absolute risk (EAR) of cancer induction at the age of 70 years due to radiotherapy of a typical 35-year-old patient.

Results: Monte Carlo simulations showed that the out-of-field organ dose from para-aortic irradiation varied from 0.004 Gy to 0.37 Gy. The mean OED value for stomach, colon, liver, and pancreas, as derived by the patient study, was equal to 2.50 Gy, 1.88 Gy, 1.43 Gy and 5.60 Gy, respectively. The organ-specific EAR for developing second cancer at sites outside the treatment volume was (0.002-0.9) per 10000 persons per year. The corresponding risk range for the partially in-field organs was (2.5-10.6) per 10000 persons per year. The highest EAR value was found for stomach cancer.

Conclusions: The risk of out-field cancer after adjuvant radiotherapy for stage I seminoma of the testis is low. However, the above treatment may lead to an increased probability for carcinogenesis at sites exposed to primary radiation. This elevated risk should be taken into account during the follow-up of testicular cancer survivors.

SP080.2 - 3D Slicer Gel Dosimetry Analysis: Validation of the Calibration Process

Author(s): Kevin M. Alexander¹, Csaba Pinter², Jennifer Andrea², Gabor Fichtinger², L John Schreiner³

¹Department Of Physics, Engineering Physics And Astronomy, Queen’s University, Kingston/ON/CANADA, ²School Of Computing, Queen’s University, Kingston/ON/CANADA, ³Department Of Medical Physics, Cancer Centre of Southeastern Ontario, Kingston/ON/CANADA

Advanced three-dimensional conformal radiation therapy techniques have rapidly developed in recent years. The techniques generate dose distributions with steep dose gradients to cover the tumor and spare healthy tissue, and these deliveries need validation. Three-dimensional dosimetry tools, such as gel dosimeters, have been shown to be promising tools for measurement and verification of radiation dose deliveries, particularly during commissioning of new treatment techniques.

Gel dosimetry consists of three-dimensional chemical systems that quantify the effects of radiation-induced chemical changes in a gelatin matrix which can be imaged using various systems, such as the Vista optical CT scanner (Modus Medical Devices, London, Canada). By its very 3D nature, gel dosimeters require extensive post-irradiation data processing. In our clinic, gel dosimeter analysis was traditionally performed using Matlab coupled with the Computational Environment for Radiotherapy Research and would take several hours to process and analyze data. To reduce analysis time and to produce a more robust analysis system, a gel dosimeter analysis workflow was developed using a custom extension in 3D Slicer (an open source and customizable computational tool used for image analysis and visualization). Gel dosimeter analysis using the extension now takes 5-10 minutes.

A major component of gel dosimetry analysis is the calibration relating the optical response of irradiated gel to dose. Here, we present a calibration method using measured depth dose data from well-characterized electron beams compared to optical depth dose data in an imaged gel. Four 1L jars from two batches of Fricke gel dosimeter were made and irradiated with 6x6 cm² beams using three different beam energies. To validate the robustness of the calibration component of the 3D Slicer extension, the calibration gel jars were analyzed five times and the mean sensitivity of each of the gels was determined. Consistency of measurements for a single user examining the four gel irradiations was shown to have high reproducibility, with a relative standard deviation of 0.1%. To examine the effect of inter-user variability of the gel calibration process, the analysis was performed by three different users. The mean sensitivities determined by the three users had a maximum relative standard deviation of 0.6%.

Overall, the calibration step of the 3D Slicer Gel Dosimetry Extension makes gel dosimeter analysis more consistent and about 20 times faster than previous dose readout approaches.

Calibration Process

SP080.3 - 3D Slicer Gel Dosimetry Analysis: Validation of the Calibration Process

Author(s): Kevin M. Alexander¹, Csaba Pinter², Jennifer Andrea², Gabor Fichtinger², L John Schreiner³

¹Department Of Physics, Engineering Physics And Astronomy, Queen’s University, Kingston/ON/CANADA, ²School Of Computing, Queen’s University, Kingston/ON/CANADA, ³Department Of Medical Physics, Cancer Centre of Southeastern Ontario, Kingston/ON/CANADA

Advanced three-dimensional conformal radiation therapy tech-
SP080.3 - Whole body interactive 3D visualisation of both the benefits and risks of radiotherapy for common cancers: a tool to guide decision making

Author(s): David Edmunds, Ellen Donovan
Joint Department Of Physics, The Royal Marsden Hospital, Sutton/UNITED KINGDOM

Purpose

More people who have had a common cancer are surviving. Radiotherapy is contributing to this success but it has long-term consequences. There is a complex relationship between the benefits of radiotherapy and the risks of adverse effects (e.g. cardiac damage or second cancer induction). These vary with many factors including disease stage, age at exposure to radiotherapy and radiation dose. The modern era of radiotherapy planning and delivery methods results in a wide variety of delivered dose to organs outside the treated region. Standard treatment planning systems calculate and display dose within the region of a planning scan. There is no tool describing doses beyond this region, or providing information on the benefits and risks of the radiotherapy based on plan specific doses and patient characteristics such as age.

We have developed the aRRESt (Radiotherapy Risk Evaluation System) program, which provides an interactive 3D visualisation of cardiac risks and second cancer risk estimates for radiosensitive organs throughout the body.

Method

A cross-platform graphical user interface (GUI) was developed using the C++ programming language, with 3D visualization and interaction provided by the Visualization Tool Kit (VTK) module. The GUI provides an indication of the lifetime risk of second cancer induction [1], and of major coronary event risk [2] for any treatment plan input. Dose cube and outlined regions of interest (ROI) are extracted from DICOM files exported from a commercial treatment planning system. Mean organ doses are used to estimate the lifetime/cardiac risks.

Figure 1

An image from the 3D interactive visualisation tool, which can be switched between dose and the risk of an adverse effect from radiotherapy for a selectable organ. The display shown is from a CT scan of an anthropomorphic phantom, extracted from the Pinnacle treatment planning system.

Conclusion

The aRRESt program provides a quick and convenient method of visualising the benefit-risk relationship for different radiotherapy treatment deliveries and patient characteristics. Currently based on a generic body model, the ultimate aim is to use patient specific information. The tool will be used in combination with the standard treatment plan to assist decision making on a per-patient basis.

References


SP080.4 - A Software App for Radiotherapy with In-situ Dose-painting using high Z nanoparticles

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The purpose of this work is to develop a user friendly and free-to-download application software that can be employed for modeling Radiotherapy with In-situ Dose-painting (RAID) using high-Z nanoparticles (HZNPs). The RAID APP is software program written in Matlab (Mathworks, Natick, MA, USA) based on deterministic code developed to simulate the space-time intra-tumor HZNPs biodistribution within the tumor, and the corresponding dose enhancement in response to low dose rate (LDR) brachytherapy of I-125, Pd-102, Cs-131 and kilovoltage x-rays such as 50 keV and 100 keV. Through the graphical user interface (GUI) of the RAID APP, the user will be directed to different features to compute various parameters related to the dose enhancement and the biodistribution of NPs within high risk tumor sub-volumes. The software was developed as a tool for research purposes with potential for subsequent development to guide dose-painting treatment planning using radiosensitizers such as gold (Au) and platinum (Pt).

SP080.5 - Performing radiation therapy research using the open-source SlicerRT toolkit

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Purpose: Radiation therapy (RT) is a common treatment option for a wide variety of cancer types. Although we have seen significant improvements in this technique over the past years, performing research in RT is limited to using either expensive, closed, proprietary applications or heterogeneous sets of open-source software packages with limited scope, reliability, and user support. Our SlicerRT toolkit aspires to overcome these limitations by providing an extensive set of RT research tools leveraging the advanced visualization and image analysis features of its base platform 3D Slicer (see http://slicer.org).

Methods: The SlicerRT toolkit (see http://slicer.org) comprises of a set of 3D Slicer extensions: SlicerRT core [1], Matlab Bridge, Multi-dimensional Data, and Gel Dosimetry. The SlicerRT core extension contains 26 modules, many of which provide common RT tools used in most RT research scenarios. Numerous core modules
employ the advanced algorithms provided by the Plastimatch library [2]. Matlab Bridge provides a convenient way for connecting the researchers’ existing MATLAB algorithms to the SlicerRT ecosystem. Multi-dimensional Data offers a feature set for handling multi-dimensional datasets, such as longitudinal or 4D data. Finally, Gel Dosimetry [3] facilitates gel dosimetry analysis workflows through a streamlined, workflow-based end-user application. The toolkit is an open-source resource that is developed and maintained according to the highest standards in the industry, including flexible, maintainable architecture, automated testing, and the use of a software collaboration suite that enables accurate tracking of our efforts and plans.

Results: Four 3D Slicer extensions have been implemented, each of which can be downloaded from the 3D Slicer Extension Manager. Using these open-source software tools makes it possible to conduct cutting edge RT research without parallel development efforts. Essential RT tools are provided by SlicerRT core, augmented with the extensions Matlab Bridge and Multi-dimensional Data, supporting special use cases. Gel Dosimetry acts as a proof of concept for quick prototyping of advanced applications accommodating complex workflows. The user base of the toolkit is constantly expanding, with 30+ groups having adopted it so far. SlicerRT acts as a medium into which researchers can integrate their methods into, and which they can use to perform comparative validation, develop novel RT techniques, or transition advanced methods into routine clinical practice.

Future work: As SlicerRT has matured to contain most of the planned functions, our focus has shifted from feature development to usability and stability. Thus we propose to perform a complete overhaul of the current Contours mechanism to be more complete and more flexible. To enhance user experience, we plan to significantly improve our user documentation to make it as straightforward and helpful as possible. Also, although we have performed validation on core algorithms, it only covers a subset of the tools SlicerRT provides. It is also among our goals to validate the rest of the algorithms.

Acknowledgement: This work was in part funded by Cancer Care Ontario through Applied Cancer Research Unit and Research Chair in Cancer Imaging grants, and the Ontario Consortium for Adaptive Invention in Radiation Oncology (OCAIRO).

SP081 - Validation and Verification of Therapy Dose Delivery: Part 1

SP081.1 - Validation of Eclipse Treatment planning system Commissioning using Octavius 4D

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The accuracy of dose calculation in a treatment planning system mainly depends on the algorithm used for calculation, the beam data configured and the beam modelling in the treatment planning system. The Eclipse planning system uses the Analytical Anisotropic Algorithm (AAA) and the Acuros XB (AXB) for dose calculation and these have been extensively verified for its accuracy. The commissioning and quality assurance of a treatment planning system has been studied comprehensively ever since the computerised treatment planning system came in to use. Generally the validation of a TPS is limited to verification of point doses and dose profiles. The availability of the Octavius 4D enables a full 3D dose comparison.

Purpose: The purpose of this study was to validate the commissioning of Eclipse treatment system for photon beams of Clinac IX unit with Octavius 4D system that enables volumetric comparison of dose distribution.

Methods: Beam data configuration was performed on an Eclipse planning system (Version 13.0) for a Clinac IX dual energy linear accelerator with 6MV and 10 MV photon beams and six electron energies viz 6 MeV, 9MeV, 12 MeV, 15 MeV, 18 MeV and 22 MeV. The calculations for the validation were carried out with Analytical Anisotropic Algorithm (AAA) version 13 implemented in Eclipse planning system. Absolute point dose verifications were performed with 1D water phantom and 0.6 cc ion chamber supplied by PTW. The 729 detector array of the Octavius 4D system was used independently for 2D planar dose verification. The rotational unit of the Octavius 4D system with the inclinator and the 729 detector array was used for dose verification in 3D. Profile comparisons, 2D and 3D gamma analysis were performed to validate the Eclipse system for photon beam dose calculation.

Results: Good agreement was observed between the measured absolute point doses and the AAA calculated doses in water phantom. The agreement was within 2% and less than 1% at most points in the central axis. The 2D comparison of dose distributions pass rate for 3%/3mm gamma index criteria were 95% are above and the failed points were mostly in the penumbral region. The gamma analysis for 3D dose comparison also had pass rate of 96%-99% with 3%/3mm criteria for both 3D CRT and IMRT verifications.

Conclusions: The calculations performed by the Eclipse Treatment Planning system with the configured beam data and the Analytical Anisotropic Algorithm were accurate. The Octavius 4D system with the 729 detector array is a useful tool for comprehensive validation of the Treatment planning system for photon beams.
Evaluation of Electron Beam Algorithm of Prowess Panther Planning System for Customized cutouts of Different Sizes

Abstract: In this comparative study electron beam dose calculation algorithm used in prowess TPS is evaluated. This is done by comparing PDDs and OPFs (Output Factors) of different cutout sizes with minimum field size dimension of 2 cm for electron energies of 6 MeV, 9 MeV, 12 MeV, 15MeV, 21 MeV. Cutouts are designed in TPS and then fabricated in mould room using lipowitz. The measurement of PDDs and OPFs are carried out by using CC01 and Omnipro-Accept software in 3D water phantom and Dose 1 electrometer. The OPFs are measured at D max of each energy and cutout size. The calculated PDDs and OPFs from Prowess Panther are compared. OPFs and PDDs comparison were made for both SSD 100 cm and SSD 110 cm. The R20 – R90 region of PDD is selected for comparison with an increment of 10 points. Data analysis is carried out by calculating mean difference and standard deviation for PDDs and percentage difference for OPFs between measured and treatment planning calculations.

The values of mean difference between calculated and measured PDDs at 100cm SSD are less than 2mm for 2cm diameter circle up to 12 MeV. Higher than 12 MeV the values of mean difference are greater than 3 mm. Similar results are obtained with squares and rectangles of different sizes like 2cm square and 9x2 rectangle and the mean difference is less than 2mm for 6MeV, it increases with increase in energy. For cutout sizes having large dimensions from 3cm the agreement is within 2mm irrespective of cutout shape size and applicator size. Overall trend shows that with increase in energy mean difference increases although increase is more prominent for 2cm circle at 21MeV as compared to squares and rectangles at same energy. For extended SSD 110cm, the mean difference of depth doses follow the same trend as in case of standard SSD 100cm. In case of higher energies the calculated results are lower in upper part of the curve from R90 to R60 while in lower part the calculated values are higher. Calculated and Measured OPFs are also compared. OPFs are in good agreement for fields greater than 4 cm. But for fields smaller then 4cm disagreement is more than acceptable limits. The Planning algorithm over estimate dose in case of small field sizes as compared to measured results.

Prowess panther accuracy depends on field size and energy and slightly depends on field shaping. Accuracy of prowess panther does not agree well for field size which has any dimension as small as 4 cm, especially for low energies. Additional correction factors must be applied on MUs calculated from Prowess panther for field sizes smaller than 4cm.

Conclusion

The effectiveness of the MU calculation method was verified at SAGA-HIMAT. We are trying to put to practical use as soon as possible. Then the more efficient operation of the treatment beam would be possible.
Derived RBE\textsubscript{10} values based on the Microdosimetric Kinetic Model and SOI bridge microdosimetric spectra is presented in Fig. 2. The RBE\textsubscript{10} values match very well with those obtained from the TEPC measurements. Due to the high spatial resolution of the microdosimeter, more detailed RBE\textsubscript{10} measurements were obtained at the end of the SOBP compared to the TEPC. It should be noted that the bridge microdosimeter measurements were done in a PMMA phantom while the TEPC measurements were carried out in water.

This work presented the first RBE\textsubscript{10} derivation in a $^{12}$C ion therapeutic beam using a high spatial resolution SOI microdosimeter and demonstrated a simple and fast method for Quality Assurance in charge particle therapy using silicon microdosimeter.
SP081.5 - Characterization of a ZnSe(Te) inorganic scintillator for scintillation dosimetry applications

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Purpose: The purpose of this work is to characterize a ZnSe(Te) inorganic scintillator for future application in scintillation dosimetry. This study will determine the usability of this scintillator within a multipoint scintillation detector system.

Methods: Different lengths of a ZnSe(Te) scintillator (MolTech GmbH) ranging from 0.5 to 3.0 mm were tested and optically coupled to a 15 m optical fiber (ESKA GH-4001). The photodetectors used in this study are a spectrometer (QE65Pro, Ocean Optics) and a photomultiplier tube (H10721, Hamamatsu). The detector was irradiated using an orthovoltage device (Xstrahl 200) at 120, 180 and 220 kVp, and a linear accelerator (Varian Clinac iX) at 6 and 23 MV for photons beams and at 6, 12 and 18 MeV for electrons beams. The energy, particle type, dose and dose rate dependencies were examined. Also, the attenuation within the scintillator was measured and its emission spectrum was characterized under various irradiation conditions.

Results: The scintillator demonstrates energy and particle type dependence for both the light production and spectral shape. The ZnSe(Te) measured spectrum ranges from 550 to 800 nm for beam energies listed above. For electron beams and MV photon beams, a component at 690 nm is added and the peak at 771 nm is shown to increase with energy (fig. 1). For a given energy, linear dose dependence is observed for all beams tested (R²>0.996). Moreover, the scintillator exhibits no dose rate dependence for MV photon beams tested. However, at 120 kVp, a dose rate dependence obeying a power function (R²=0.998) is observed (fig. 2).

Figure 1: Spectra for different energy beams

Figure 2: Dose rate dependence for 120kVp, 6MV and 23MV

Conclusion: The ZnSe(Te) inorganic scintillator has been characterized for dosimetry applications. When using this scintillator, one must takes into account the dose rate, energy and particle type dependences. Despite these dependencies, this scintillator with a spectrum of higher wavelength remains a good candidate for multi-point applications.

SP081.6 - Determination of correction factors for the use of ionization chambers in the presence of magnetic fields

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Various groups in Europe, North America and Australia are currently developing magnetic resonance imaging (MRI) guided radiotherapy technology by integrating an MRI scanner to a linac (MRI-linac). MRI-guided radiotherapy will provide exquisite images of soft-tissue with high temporal resolution to allow tracking tumor and organ motions in real-time. One of the challenges to implement MRI-linac technology in clinical practice is to calibrate the radiation output under the presence of a strong magnetic field (B-field). The addition of the permanent B-field from the MRI affects the response of ionization chambers (ICs) (Meijssing et al. 2009, Phys. Med. Biol. 54 2993-3002; Smit et al. 2013, Phys. Med. Biol. 58 5945-57; Reynolds et al. 2013, Med. Phys. 40 042102). In this work we show preliminary results of Monte Carlo (MC) calculations of beam quality correction factors under the presence of a B-field for various ICs. We used the Geant4 toolkit throughout this work. First we established the best set of parameters for the Geant4 condensed history algorithm so that the code passes the Fano test within 0.5% (Poon et al. 2005, Phys. Med. Biol. 50 681-94). Then, we used well-established methods from the literature (Muir and Rogers 2010, Med. Phys. 37 5939-50) to calculate kQ values for several ICs in a SL25 6 MV beam without (kQ) and with (kQB=1.5T) the presence of a 1.5 T B-field. The maximum percentage difference between our kQ values and TG-51 (McEwen et al. 2014, Med. Phys. 41 041501) results for a set of seven chambers was 1.4%, demonstrating that our MC model is adequate (Table 1). Our results in Table 1 show that kQB=1.5T values strongly depend on IC model/geometry and material composition of the ICs, i.e., for identical geometry but different collector and wall materials, kQB=1.5T values were different. For the set of ICs
investigated we observed corrections of up to 4.4% for the Exradin A19 chamber. Among the investigated chambers, the PTW 30011 presented the smallest correction factor (1.2%). Our future work will use a realistic energy spectrum of an MRI-linac unit (Atlantic, Elekta Inc.) to calculate $k_{QB}=1.5T$ values for selected ICs. Future work is also needed to validate calculated $k_{QB}=1.5T$ values against experimental data.

Table 1: $k_Q$ values calculated using Geant4 with and without the presence of a 1.5 T B-field. The B-field was perpendicular to the beam and perpendicular to the axis of the cylindrical ICs.

<table>
<thead>
<tr>
<th>Chamber</th>
<th>Vol. (cm³)</th>
<th>Collector</th>
<th>Shell</th>
<th>Guard</th>
<th>$k_Q$ (TG-51)</th>
<th>$k_Q$ (This work)</th>
<th>$k_Q^{B=1.5T}$</th>
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<tr>
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<td>Al</td>
<td>Graphite</td>
<td>N/A</td>
<td>0.992±0.008</td>
<td>0.985±0.005</td>
<td>0.959±0.005</td>
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<tr>
<td>PTW 30010</td>
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<td>Al</td>
<td>PMMA</td>
<td>Graphite</td>
<td>0.992±0.008</td>
<td>1.006±0.005</td>
<td>0.980±0.006</td>
</tr>
<tr>
<td>PTW 30011</td>
<td>0.6</td>
<td>Graphite</td>
<td>Graphite</td>
<td>Graphite</td>
<td>0.992±0.008</td>
<td>1.001±0.005</td>
<td>0.988±0.006</td>
</tr>
<tr>
<td>PTW 30012</td>
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<td>Al</td>
<td>Graphite</td>
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<td>0.994±0.008</td>
<td>1.005±0.005</td>
<td>0.978±0.006</td>
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<tr>
<td>Exradin A1</td>
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<td>C552</td>
<td>C552</td>
<td>C552</td>
<td>0.991±0.008</td>
<td>0.986±0.014</td>
<td>0.959±0.015</td>
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<tr>
<td>Exradin A1SL</td>
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<td>C552</td>
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<td>Exradin A19</td>
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<td>0.991±0.008</td>
<td>1.003±0.005</td>
<td>0.956±0.006</td>
</tr>
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SP082 - Nonlinear Dynamic Analysis

SP082.1 - Aging Process: Central Pressure Waveform Loss of Complexity

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Introduction: Aging is defined as the age-related decline in physiological function where arterial stiffening and hypertension constitute related disorders in the cardiovascular system. Age can be considered as one of the most powerful determinants of cardiovascular risk, usually viewed as a chronological, unmodifiable and even untreatable factor. Arterial mechanical properties of the small vessels are known to be altered with advancing age (dilatation and stiffening), leading to a rise in pulse pressure (PP). In this sense, central pulse pressure (cPP) has been more closely related to cardiovascular events than peripheral pulse pressure (pPP). From the point of view of chaos theory, multiscale and nonlinear complexity (structure and interactions of individual subsystems) appears to degrade with aging and disease. In our previous studies, waveform complexity of arterial pressure (AP) was related to stiffness variations as well as to the presence of wave reflection. Additionally, age related changes were also analyzed in cPP waveform. Objective: The aim of the present study was to evaluate changes in the waveform complexity of cPP as a result of the aging process. Material and Methods: Continuous, noninvasive blood pressure measurements were analyzed in 16 healthy subjects (8 young, 20-29 yr and 8 aged, 50-69 yr). Individuals with cardiovascular disease risk factors were excluded from the experiment. A generalized transfer function was used to obtain the cPP waveform from the pPP (measured by applanation tonometry) using a customized software (SphygmoCor, AtCor Medical, Sydney, Australia). Time series waveform complexity was assessed by means of fractal dimension (FD) calculation, based on the method provided by Higuchi. Statistical analysis was carried out using an unpaired Student’s t-test. A value of p<0.05 was considered statistically significant. Results: A significant decrease in FD values was obtained in cPP waveform for aged subjects (1.09±0.02 to 1.04±0.01), concomitant to a cPP increase. Conclusion: Considering previous studies, the loss of complexity has been hypothesized to be an indicator of the transition from normal aging to frailty. In the present work, loss of waveform complexity was observed as a consequence of the aging process in cPP. Arterial structural changes were reflected in FD variations, independently of the AP calibration, due to the space filling property and the fine structure of the waveform were analyzed. Further studies are necessary in order to determine if changes in waveform complexity can be utilized as a complementary factor of vascular aging.

SP082.2 - Changes in COP scaling behaviour in quiet stance after mTBI

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The analysis of centre of pressure (COP) timeseries is well suited to the evaluation of balance control. Balance control is often interpreted as a physiological control system with coordinating sensory inputs and muscle outputs. COP variables can provide clues about the controlling mechanisms affecting balance. Mild traumatic brain injury (mTBI) often results in functional impairments including balance impairments that seem to suggest altered signalling within the brain. It was hypothesized that the altered mechanisms affecting balance after mTBI might be reflected in altered scaling properties of COP. University football players (n=74) were tested at the beginning of the season as a baseline and were retested if they sustained an mTBI during the season (n=6, tested an average of 15.7±7.2 days after injury). Players who did not sustain an mTBI were also retested at the end of the season for comparison (n=17). Each participant was asked to stand quietly with eyes closed for 90 seconds on a portable force platform. Scaling behaviour was determined by (1) classifying the timeseries using the beta estimate, (2) identifying how many scaling regions exist, and (3) calculating scaling estimates for each region. Data for mTBI and uninjured groups were compared to their own respective baselines. Results demonstrated that while typical scaling behaviour of COP timeseries were always the same—short-term persistence (H1>0.5) and long-term anti-persistence (H2<0.5)—the group who had sustained mTBIs demonstrated a significant change (between baseline and post-mTBI) toward less random short-term values in the mediolateral direction whereas the uninjured players did not (see Figure 1). While the overall ability to maintain balance is not altered, demonstrated by the unchanging long-term scaling behaviour and by the fact that no players were falling over, some subtle changes to how the COP is being controlled in balance do occur after an mTBI. This method of measuring changes to balance may be useful in determining whether or not players are being returned-to-play when still impaired in ways that may lead to re-injury.

SP082.3 - Tracking algorithm of spiral wave core in a cardiac tissue using Hilbert transform and phase variance analysis

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Arrhythmia is a common and increasing disease, especially in developed countries. There are several treatment approaches toward arrhythmia such as anti-arrhythmic drug, radio frequency ablation and electrical stimulation. To investigate about mechanism of arrhythmia and improve efficacy of these treatments, optical mapping system has been used in many previous works. Optical mapping is an useful measurement system of cardiac excitation. This mapping system is mainly composed of isolated heart dyed with voltage sensitive dye, high brightness excitation light, and high speed camera. Because emitted spectrum of voltage sensitive dye changes with a change of transmembrane potential of each cardiac cell, we can measure the activation potential at each points and it’s propagation as the change of fluorescence spectrum. Using this system, propagation of excitation in cardiac tissue can be measured in high speed (more than1000 fps) and in high resolution (less than 0.05 mm / pixel).
Spiral wave propagation of excitation in a cardiac tissue (spiral reentry) is known to play a key role to cause and sustain dangerous arrhythmia, such as tachycardia and fibrillation both in ventricular and atrium. It has been reported that stability of the center of spiral wave (spiral core) is related to the sustainability of spiral reentry. Thus detection and tracking of spiral core in optical mapping images is important to analyze spiral reentry. Bray et al. proposed phase analysis of spiral reentry using Hilbert transform. In this method, core of spiral is mathematically defined as “phase singularity point” around which the contour integration of phase value is 2π or -2π. However, applying this definition to detect the spiral core in optical mapping images is difficult because there are huge amount of surrounding counters in an image. In this work, we present novel detection algorithm of the core of spiral reentry in optical mapping images. Using angular dispersion of phase values in a bounding box, we detected high dispersion point as the core of spiral. We will report the accuracy of the detection and the computational cost of this algorithm.

**SP082.4 - Mapping the Fractal Dimension of Arterial Pressure**

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**Institution:** Buenes Aires Regional Faculty, National Technological University, Ciudad Autónoma de Buenos Aires/ARGENTINA, Faculty Of Engineering And Exact And Natural Sciences, Favaloro University, Ciudad Autónoma de Buenos Aires/ARGENTINA, School Of Advanced Studies In Engineering Sciences, National Technological University, Ciudad Autónoma de Buenos Aires/ARGENTINA

**Introduction:** The cardiovascular system is constituted by a complex network of vessels, where highly uniform hierarchical branching structures, that cover a wide range of diameter scales, are regulated by the anatomy and local flow requirements. In recent years, homeodynamic and holistic concepts such as fractal and nonlinear analyses were proposed to be helpful to study the complexity of physiological functions. In the systemic circulation, arteries bifurcate many times before they become capillaries where the scaling factor of vessel length, diameter and angle between two children branches is established at each level of recurrence. For these reason, this type of vascular system can be described using a fractal scaling principle. In this sense, it was observed than the basic pattern of blood distribution is also fractal, imposed both by the anatomy of the vascular tree and the local regulation of vascular tone. In our previous studies, arterial pressure time series (AP) waveform complexity changes were evaluated by means of a fractal dimension (FD) measure. To our knowledge, a holistic analysis of FD variations throughout the arterial network has not been previously reported. **Objective:** The aim of the present study was evaluate the variation of arterial pressure waveform complexity considering its anatomical location in the branching structure. **Material and Methods:** Continuous, AP measurements were obtained in the following sites: left ventricle and descending thoracic aorta (five male mongrel dogs, instrumented with solid-state implantable pressure sensors, Konigsberg Inc., Passadena, USA) and carotid and femoral arteries (five male middle-aged subjects, without cardiovascular risks factors, evaluated by applanation tonometry, Millar Inc., Houston, USA). Due to experimental limitations, invasive (in humans) measuring methodologies were performed. Assessment of FD in AP time series waveforms was developed by applying Higuchi’s method. Topological dimension was not considered in FD relative changes (ΔFD) calculation. Statistical analysis was carried out using the paired Student’s t-test. A value of p<0.05 was considered statistically significant. **Results:** A significant increase in ΔFD was observed at the thoracic aorta (higher complexity) in respect to ventricular pressure FD values (+233.06±75.34%). On the other hand, femoral artery AP manifested a decrease in ΔFD (lower complexity) in comparison to the carotid site (-56.51±13.62%). **Conclusion:** A holistic evaluation of AP waveform complexity in the arterial network was performed, where its FD changes were related to the vascular site. While the ventricular pressure time series was observed to be “fractalized” at the aortic level (due to the waveform is more exposed to the multiple wave reflections), AP showed a loss of complexity at distant sites from the cardiac muscle, manifesting an ‘unwrinkling’ phenomenon.

**SP082.5 - Moving deterred fluctuation analysis for inspecting time evolution of scale invariant structures in biomedical signals**

**Author(s):** Hamidreza Saghir, Tom Chau, Azadeh Kushki

**Institution:** Ibbme, University of Toronto, Toronto/Canada

Detrended fluctuation analysis (DFA) is commonly used for characterizing the fractal structure of biomedical signals. One of the underlying assumptions of DFA is that the fractal structure is consistent [AK1] in time and can be characterized by a single scaling exponent. However, the scale invariant structures of multifractal signals are modulated in time and lead to the existence of a spectrum of scaling exponents. Conventionally, Multifractal analysis has been used to study the statistical distribution of a range of scaling exponents. However, these methodologies do not provide any information about the time evolution of scaling exponents.

This article introduces a new methodology based on DFA, called moving deterred fluctuation analysis (MDFA) for examining the evolving scale-invariant structure of a signal in time through phase-couplings between temporal scales. Instead of using non-overlapping time intervals as in conventional DFA, MDFA computes the root mean square of the detrended residuals in a moving window at each time point. This approach allows to analyze the coupling between different time scales and to identify the evolution of the scaling properties of the signal. The results show that MDFA allows to detect the presence of scale-invariant structures in biomedical signals and to monitor the evolution of their scaling properties over time.

We used MDFA to inspect time evolution of scaling exponents in ECG signals during a movie-watching task in group of 33 participants (n=33, age: 12.5 +/- 2.9 years, full-scale IQ: 112.9 +/- 14.1, 19 male[AK2]). The results show that the modularity of the local scaling structure was significantly influenced by condition (i.e. relaxed, stroop practice, anxious, p<0.04). This modulation was not significantly different for a white noise series of the same length. MDFA returns an average scaling exponent of 0.5 [AK3] for white noise which is consistent with the results of other methods. These results suggest that MDFA is a useful tool for inspecting the time evolution of scale-invariant structures in multi-fractal signals and should be further investigated.
figure 1. Example of MDFA for one participant (left) compared to white noise (right). Top panel demonstrates the time modulation of scaling exponents. Middle panel shows the evolution of root mean square residuals across time and scales. Bottom panel shows the probability distribution of scaling exponents in anxious (stroop) and relaxed (baseline) conditions. (practice is a transitory state in which the participant practices the task a few times before starting the stroop task)
"When can I drive?" is a question frequently asked of orthopedic surgeons following injury and surgery of the lower limb. Surgeons are left to make a difficult decision, as there are no specific guidelines on when patients should be cleared to drive, and there are significant discrepancies between mean recovery times for different procedures in the literature. Although there is no clear consensus between law enforcement, insurers, road authorities and the medical community, the decision as to whether an orthopedic patient can adequately brake an automobile following surgery is generally defaulted to the surgeon. Surgeons are faced with the dilemma of managing their duty to the patient, to the public, and the medicolegal risks involved with giving patients advice on when they can get back on the road. Studies suggest that a simulator may be useful in assessing braking capacity following surgery of the lower limb; however, they are currently not widely used by surgeons. Significant recurring issues exist with current or proposed simulators: (1) they generally cannot be used to assess trauma patients due to the need for baseline testing preoperatively, (2) limited data is available to demonstrate their ability to evaluate a patient's braking performance, (3) braking forces are not translated into stopping distances or indeed not considered at all, (4) and the devices are often not practical in an outpatient setting. In order to drive safely, one must be capable of stopping a vehicle in an emergency. Braking capacity depends on a host of patient variables including visual acuity, neurological function, musculoskeletal function, and the influence of drugs among others. Our intention is to develop a method to evaluate performance of the lower limb, specifically. This work presents the design of a simulation device that will provide surgeons with an objective assessment of their patient's braking performance in an outpatient clinic. This simulator will compare calculated total stopping distances after the appearance of an emergency stimulus with the total stopping distance recommended for specific driving speeds in the literature. Alternatively, this maximum stopping distances will be inferred using recommended brake reaction times and forces to provide a benchmark for the assessment of braking performance.

Objective. The main objective of this research is to compare the impedance parameters between knees with and without meniscal injury in female athletes.

Materials and methods.

a) Volunteers. In this study participated 6 sportswomen (Age: 19.5±0.8 years, BMI: 20.4±3 kg/m²). Previously, all volunteers were assessed for meniscal problems comparing right and left knees by a sports medical professional staff. All volunteers had physical condition according to the parameters of the American College of Sports Medicine. Body composition were measured to all volunteers.

b) Procedure. The bio impedance parameters where assessed with a BIOPAC System (MP150), which injects an electrical current of 1 mA at different frequencies (12.5 kHz, 25 kHz, 50 kHz, 100 kHz).

In order to monitor the knee condition by bio-impedance, four electrodes were placed in each knee. All volunteers were asked to fully extend each leg in periods of 5 seconds to perform the test at 30 seconds.

c) Signal processing. All the data were analyzed using the Matlab software. The impedance data were analyzed and compared at different impedance frequencies. Subsequently, these results were correlated with the clinical findings made to all the volunteers.

d) Statistical analysis. The comparison of impedance parameters between knees with and without meniscal injuries were made using a t-test for independent groups.

Results. All the volunteers had meniscal injury in the right knee; however there were not statistical differences when we compare the length of the lower pelvic limb the mean and standard deviation (X±SD), were: 91.9±7.4 vs. 91.8±7.0, for right and left limbs (t=0.02, p=0.98). The mean and standard deviation of the bio impedance parameters were as follows: 48.9±10.7 vs. 71.5±19.1. When we compare with a t-test we found significant differences between knees.
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with and without injury (t=−3.58, p=0.002), see figure 1.

![Figure 1. Differences in the mean and SD of impedance parameters of right and left knee with and without meniscal injuries, t=-3.58, p=0.002.](image)

**Conclusions.** In this study we demonstrated that the impedance technique could be a good option in order to monitor the knee condition.

**SP083.4 - Development and evaluation of a mechanical stance controlled orthotic knee joint with stance flexion utilizing a timing based control strategy flexion**

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Medical conditions such as spinal cord injury, spina bifida poliomyelitis and others can result in severe loss of lower limb muscle function and lead to impairments in mobility. For patients who have the potential to walk, orthotic treatments including knee-ankle-foot-orthosis are commonly used to address problems with knee instability. Recent advancements have led to the development of more sophisticated orthotic knees that restrict knee flexion during stance-phase while allowing articulation during the swing-phase. These stance-control orthotic knee joints stabilize the knee joint during the stance-phase of gait without restricting swing-phase flexion, thus achieving a more normal gait for individuals with quadriceps muscle weakness. However, there are inherent challenges in ensuring safe weight-bearing capabilities while allowing for maximum knee flexion during swing-phase over a range of walking speeds. **The work here presents a new type of stance control strategy and stance controller design employing a mechanical timing system, which was modelled using empirical data and functionally tested in a gait laboratory.**

Pilot clinical testing was performed on a prototype stance-control orthotic knee joint incorporating a novel timing system for controlling knee lock during swing- and stance-phase. Our timing-based control strategy was developed using empirical models of gait cycles at normal and fast walking speeds. Clinical feasibility of this approach was tested on a poliomyelitis patient using spatiotemporal, kinematic, and kinetic gait data captured using a standard motion capture system and floor-mounted force plates. Walking trials were performed with the orthotic in its unlocked functional mode, as well as in a locked mode to represent traditional knee-ankle-foot-orthoses.

The results of these tests showed that our prototype design provided reliable knee stability while facilitating swing-phase flexion, for more normal knee joint kinematics in both the swing and stance phases. In particular 44 degrees of swing-phase flexion and 15 degrees of stance-phase flexion were achieved, compared to 5 degrees stance-flexion in the locked conditions. Our empirical stance-control model indicates that the timer can range from 0.572 to 0.963 seconds while allowing for successful operation for both normal and fast walking speeds. During clinical evaluation, all trials were completed with the subject being able to consistently unlock the knee during walking without incidence of instability when the knee would not unlock.

**The stance control mechanism was effective for gait initiation, steady state walking and gait termination, however further testing is needed in-situ to assess other mobility conditions.** Critical to the reliability and robustness of the proposed strategy, was the requirement of the chosen triggering conditions to be sufficiently independent of variations in walking speed. Our analysis shows that a large enough window exists for which a single timer duration would ensure the timely locking of the knee joint, to ensure both swing-phase initiation and proper locking throughout stance-phase. In addition to providing stance control and stance flexion, the knee joint design was significantly decreased size and weight from current stance-controlled orthotics.
SP084 - New Designing Ideas

SP084.1 - Soprano - Nasogastric Tube Insertion Guide

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Nasogastric Tubes (NGTs) are used for feeding and administering oral medication in patients with either impaired swallowing mechanisms or obstruction in the upper aero digestive tract that prevents oral feeding. They are inserted through the nose into the stomach and represent an important means of long-term feeding especially in patients with neurological diseases (e.g. strokes). In the US alone, 1.2 million NGTs are inserted yearly. NGT placement entails a significant risk of malpositioning that may result in death from aspiration of liquids into the lungs and expose healthcare institutions to significant medicolegal liability risks. Yet, current methods of confirming correct placement are not foolproof. Moreover ensuring proper placement consumes significant resources- e.g. Chest x-rays for confirmation, hospitalization for costly alternative endoscopic and radiological guided placement methods.

Our device, Soprano is coined on the concept of frugal engineering. With a simple, elegant and innovative solution, we addressed a clinical problem that demands immediate attention and possibly save numerous lives and millions of dollars. Our basic specifications were easy steerability and an accurate and reliable feedback mechanism to identify the correct placement of NGT in the esophagus. (1) Our device is a semi-rigid guide that has a specific elliptical cross-sectional profile that acts as a funnel through which the NGT can be passed through easily into the esophagus and thereby all the way into the stomach. (2) The guide has been specifically designed with an inherent curvature conforming to the anatomy of the nasopharynx area that enables easy steering. (3) Additionally, the guide provides an accurate audio feedback that works on the basis of our inherent inhalation and exhalation cycles. This produces an audio feedback should the guide be wrongly inserted into the trachea. However, no sound is produced if the guide is correctly inserted in the esophagus. Further research into human physiology and sound frequency produced within the esophagus would allow us to further improve Soprano to accurately detect the frequency of sound produced when correctly placed in the esophagus, giving a positive signal instead of the current negative confirmation. (4) The NGT can then be passed through the guide and the guide later removed via a special slit and having a perforated guide. Soprano promises to be a simple, cost and time-effective solution that for both patients and healthcare professionals alike.

SP084.2 - High Output Impedance Current-Conveyor Oscillator for Electrical Bioimpedance Applications

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The objective of this work is to investigate the use of a current conveyor oscillator with current output for tissue excitation in a wide frequency range. It was implemented using a sinusoidal oscillator that provides an output current in a wide frequency range with a maximum amplitude of 650 μApp. It uses a second generation class AB current conveyor developed with CMOS AMS-0.35 μm technology and is configured in a Wien bridge structure. It has a low power oscillator supplied by ±1.5 V with a consumption of approximately 400 μW. The simulation results showed a frequency sweep between 1.04 to 1,230 kHz by using an integrated bank of capacitors. The maximum total harmonic distortion was 1.8% in the frequency range. The output impedance was bigger than 46 MΩ at lower frequencies but 2.4 MΩ at 1 MHz. The development of a low power current source without using an external voltage generator might be very attractive for measuring cell impedance at the electrode site and for designing battery powered bioimpedance systems.

SP084.3 - Healthcare Device for People Affected by Dementia

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Dementia may be defined as a progressive disorder that affect cognitive abilities in a level enough to cause disability to face everyday life [1]. Around 44 million of people worldwide suffer Dementia and it is expected that this number will reach until 75 million to 2030. Almost 60% of them live in countries without high incomes and have a weak public health service. Although the term Dementia refers to a group of illness that can produce similar symptoms, the Alzheimer’s disease is the main of them in terms of patients affected. The symptoms can be devastating because of they include a total memory loss and the lack of recognize familiar objects, remember and perform basic activities. In addition, changes in personality and the necessity of professional assistance affect not only the patients but also their families and friends [2, 3].

At least 25% of the hospitalized patients in clinical services have dementia, and many of these admissions could be prevented if their relatives provide a better support at home [4]. Although this condition implies a save of significant health resources, there are risks related to an inadequate healthcare of patients affected by Dementia outside of a hospital. In this way, the first problem to solve is their technical support.

Technical support can be defined as one device that aims to monitor, assist, prevent, or alleviate a disability without losses in the quality of life of the patients that require it. As a response of this necessity, it has developed a device to allow the technical support of the patients with Dementia, without direct vigilance from their caregivers. The device is a bracelet that reminds the users about his or her daily activities through easy recognition signals. A tracking system that uses sensors in limited areas provides information about the patient’s location. In addition, a record system allow regulation of medicines, activities and other relevant information about patients in real time. This device provide autonomy and independence when the Dementia is in its early or middle stage.

The main features of this device are their low cost, easy construction and simple functioning compared to other options available in the market. These differences allow to extend its use in countries with emerging economies without significant investments. In addition, its use could help to relieve the saturation of health services and save resources in different medical assistance levels.


It is a technical difficulty to acquire large field image under the complexity and cost restrictions of diagnostic and instant field research purpose. The goal of developing our wide field-of-view imaging system is to achieve tolerable resolution to detect fluorescently-labeled micro-sized particles or cells in the entire image field without the field curvature effect, while maintaining a cost-effective procedure and simple design. In order to obtain a large field image with a simple lens-based optical imaging system, we designed a curved sample chamber. We conducted a systematic study including optical simulations and experiments with a curved sample substrate to ensure a simple and practical design of the proposed system, aimed for a clearer and wider large field of view on a flat plane image sensor. In order to apply our system to point-of-care CD4 test, which can monitor HIV/AIDS disease progression by counting absolute number of CD4 T-cells in a known volume of the blood, the curved sample chambers were manufactured by an injection molding technique. The curved sample chamber reduces the field curvature and image distortion at acceptable level for the CD4 test without using a sophisticated optical elements. The optimal design has a field-of-view of 13 mm and a magnification factor of 0.54. The designed system enables us to image the objects at a spatial resolution > 8 µm and it can be also used for dynamic measurements, such as microscale flow dynamics and micro-organism behavior, by time-lapse imaging and particle tracking methods. Potential applications include a point-of-care medical diagnosis as well as a rapid environment monitoring in field study.
New technological capabilities (such as multi-core processors with hypervisors) are enabling medical devices to execute a much wider range of functions than has been historically possible. Next generation medical devices will be able to support or perform a wide range of process control functions and business functions that augment their value beyond the core clinical functions. “Intelligent” medical devices will be able to identify themselves on the network, support heightened security safeguards, do periodic self-tests and status reports, support remote diagnosis and repairs, issue predictive failure alerts, perform essential functions autonomously offline, enforce safety “guardrail” precautions against user error, and interface automatically with service and asset management processes to enable real-time updates, configuration management, and performance monitoring.

Four major stages of interoperability maturity are proposed, with specific functions assigned to each stage and sub-stage. (1) Network Transaction management, (2) Peripherals management, (3a) Availability and Change Mgt, (3b) Reliability, Risk Mgt, (3c) Configuration Mgt, (3d) System Lifecycle Mgt, (4) Integrated Clinical Environment (ICE, ASTM 2761). Key functions are identified that will enable more rigorous standardization of data and process models.
SP085 - Women in Medical Physics

SP085.1 - Women in medical physics: Current status Results from IOMP survey
Author(s): Virginia Tsapakis
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Introduction: The gender composition of medical physicist (MP) workforce around the world is principally unidentified. Acknowledging this issue, IOMP decided to perform a survey to investigate the percentage of women MPs in different countries as compared to total MPs. It was expected that the survey would provide information on gender imbalance, if it existed, and provide a basis for establishment of a subcommittee. Moreover, the results of the survey could provide an opportunity for countries as well as IOMP, for a more in-depth analysis and deliberate on further actions.

Materials and Methods: An online questionnaire was created, prepared as a Google Forms survey asking the country, the total number of MPs, the number of women MPs and finally the gender of the person providing the data. The questionnaire was sent to all 6 regional member organizations of IOMP and a major country, the USA. The regional organizations were asked to distribute it among national member organizations (NMOs) and even to non-IOMP member countries.

Results: Sixty-six countries responded to the survey. The results cover more than 3/4 of the MP manpower in the world. The total number of MPs was 17024, of which 28 % were women (4807). The median values of percentages of women were 21 % in the USA, 35 % in Asia, 33 % in Africa and 24 % in Latin America. It was noted that a substantial number of European countries were far away from the target that the European Commission has set, that is 40 %. On the other hand, there were countries in other regions of the world such as the Middle East and Asia, in which women MPs outnumbered men MP. Interestingly enough, there were countries where only women MPs existed and all these were developing countries.

Conclusion: This is the first international survey ever that investigated the gender situation on MPs around the world. Due to these very interesting findings, IOMP decided to perform a more in-depth study in the very near future.

SP085.2 - Is there a ‘Leaky Pipeline’ for Women in Clinical Medical Physics in Canada?
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We examined the role of women in clinical medical physics in Canada through a representative career path. Gender data for centers affiliated with the Commission on Accreditation of Medical Physics Education Programs (CAMPEP)-accredited residencies and graduate programs were found through departmental websites and informal surveys. Historical certification data was obtained from the Canadian Organization of Medical Physicists (COMP).

Canadian medical physicists receive certification of competence through Canadian College of Physicists in Medicine (CCPM) examinations. Members (MCCPM) must have a minimum level of work experience and fellows (FCCPM) must have additional work experience and significant contributions in the field. A cross-sectional view of the proportion of women at each career stage is shown in Figure 1.

We hypothesized that the paucity of women with FCCPM certification could be due to the natural time delay between career stages. Figure 2 shows the historic trends of the number of CCPM members in total (members and fellows) and fellows separated by gender.
fewer women in leadership positions. This may change in time as the increasing number of women entering the field advance through their careers.

**SP085.3 - Women in Medical field in Brazil: gender equality?**

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The women participation in the Brazilian workforce has increased greatly since 1970; however, it is still lower than men in many specialized professions. In 2013, for a population around 200 million people, the female birth rate was 49.3%. Despite that, at the age of vocational training (20 to 25 years old) this percentage reverses to 50.4%, reaching 53.8% for women older than 60 years, retirement age. In order to verify the presence of women in the medical field a study was carried out including physicians, nurses and medical physicists based on the Brazilian Health System and professionals associations records. The results showed that for physicians there is already gender equality among professionals, presenting an increase from 37% to 52% in ten years for female professionals. For nursing, approximately 80% are women, showing the predominance of this gender due mainly to the characteristics of “caretakers” of this profession. For medical physics area, the scenario is not the same. The country has a reasonable number of certified medical physicists (MP) in radiotherapy, 273, considering that there are 275 linear accelerators, 68 cobalt equipment, 86 high dose rate (HDR) and 61 low dose rate (LDR) brachytherapy devices in use. However, only 36% of these professionals are women. In nuclear medicine, there are in total only thirty certified MPs while only 30% of them are female with the appropriated skill to attend the demand that currently comprises 814 SPECTs, 110 PETs devices and more than 3000 therapy procedures. Diagnostic radiology presents an even more critical situation, with sixty nine certified MPs for a large number of devices, around 3648 CTs, 22052 X-rays, 4250 mammography units, among others practices, where only 36% are women. In conclusion it can be observed that the women representation in scientific and technical workforce is growing fast in the last decade. However, for medical physics field, the women representative in the medical physics area is not expressive and has not been increasing at the same rate of the others medical professionals. Significant efforts should be made on professional formation, emphasizing the female MP education.

**SP085.4 - Women Biomedical Engineers as Consultants in Clinical Engineering Field in Latin American Countries: Case of Study**

**Author(s):** Gabriela Jimenez Moyao, Carmen Rendon Isguerra, Sandra Galan, Claudia D.C. Cárdenas Alanis, Erendira Jimenez, Maria Fernanda Zumpano Romero, Stefany Penafort Flores, Paola Salgado Rodriguez, Pamela Lopez Uroz  
Escala Biomedica, Mexico City/MEXICO

The Consultancy in the engineering field has been a common practice since many years ago; the Biomedical Engineering is not an exception; the multidisciplinary of the career gives the biomedical engineers a wider perspective in the clinical practice, infrastructure planning, management, logistics and engineering fields and the analytical results of this convergence promotes the problem solving and high accuracy advices. Women Biomedical Engineers in the consultancy field are a growing hired staff in Mexico and a specific case of study is a clinical engineering consultancy company in Mexico City with projects mostly in Mexico and Latin America, whose staff is mainly formed by women.

The objective of this article is to define the consultancy model inside and outside the company describing how the women inside the company have been educated based on an inspirational leadership, mostly since the school by the company’s founder experience about the clinical engineering field and the motivation to follow values such as truth and justice and also to develop skills such as leadership, effective communication, strategic thinking, innovation and creativity and a systematic improving of their technical knowledge in order to be creative in the problem solving in the consultancy field.

Furthermore, outside the company, describing the challenges women have faced during the consultancy work in the different work fields with different stakeholders such as Hospital Staff, Planning Hospitals Teams, Medical Equipment Vendors, how it has been faced and the solutions and the contribution of these experiences to positioning the company and the women staff members in a competitive mostly men labour field.

In the article there is reference to the interviewed women and also there are mentioned significant testimonies that confirm the hypothesis about the huge impact of the women consultancy work in the clinical engineering field within work teams in the healthcare sector. As a conclusion the experiences described suggest that the women biomedical engineers with leadership skills and good technical knowledge are valuable for the improvement of the healthcare sector and the impact is huge when the knowledge is share inside different organizations through the consultancy efforts.
For the indirect effects of radiation, our results show that both hydroxyl radicals and hydrated electrons are responsible for the enhanced formation of damage in modified DNA. In the presence of Pt-adducts, hydroxyl radicals mainly contribute to the formation of single-strand break, while hydrated electrons are the main species responsible for the DSB formation.

In conclusion, Pt-drug modification is an extremely efficient means of enhancing the formation of DNA DSBs by both LEEs and hydrated electrons created by ionizing radiation.

### DNA damage yield (10⁻⁸/Gy/bp) for electron-irradiation of unmodified and Pt-modified DNA.

<table>
<thead>
<tr>
<th>Electrons</th>
<th>DSB-Formation</th>
<th>SSB-Formation</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Pure-DNA</td>
<td>Cisplatin+DNA</td>
</tr>
<tr>
<td>0.5-eV</td>
<td>---</td>
<td>4.4 ± 1.5</td>
</tr>
<tr>
<td>10-eV</td>
<td>1.2±0.2</td>
<td>3.0 ± 0.2</td>
</tr>
<tr>
<td>10-keV</td>
<td>0.7±0.1</td>
<td>0.9 ± 0.1</td>
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The aim of this work is to investigate the effects of different sizes and concentrations of gold nanoparticles (GNPs) on the cell viability in both lymphoma and choroidal melanoma cells. To this end, GNPs were synthesized following the Fern’s method in three sizes of 20, 40 and 60 nm. Both Melanoma and Lymphoma cells were grown in 6 (24-well) plates so that the first three plates containing Melanoma cells and the last three plates containing Lymphoma cells. In all six plates, the first five wells were coated with five different concentrations of GNPs and the sixth of them was assigned as control. For both Melanoma and Lymphoma cells, one plate was injected by GNPs with the diameter of 20 nm in five different concentrations of 200, 150, 100, 50 and 25 µg and two plates were injected by GNPs with the concentrations of 600, 400, 200, 100 and 50 in which the nanoparticles have a diameter of 40 nm in one of them and 60 nm in another. MTT method was used to assay the cell viability after incubating the cells for 48 hours at 37°C. Compared to the control, in all six plates the results show that both melanoma and lymphoma cells grown were decreased in the present of nanoparticles. However, there was difference on cell grown between Melanoma-GNPs and Lymphoma-GNPs exposures in vitro. For instance, at the concentration of 200 µg the present GNPs in Lymphoma cells showed strong decrease of cell viability, while, the viability decrease in melanoma cells was not very considerable. Choose of the size and concentration of GNPs to achieve the best results in ophthalmic brachytherapy are depend on the tumor. Considering the sensitive tissue which the eye is involved in, the dose to normal tissues in comparison with the resultant dose increase in the tumor is of utmost importance in investigation of GNPs effects on ophthalmic brachytherapy dosimetry which require In-Vivo study. Also, further in vitro cytotoxicity tests are required before high-concentration GNPs can be used for choroidal melanoma treatment.

The main focus of the present study is to investigate dose enhancement effects in presence of gold nanoparticles (AuNPs) in proton delivery site of the ocular melanoma by the use of fixed pencil beam method associated with the Harvard ocular nozzle in a series of Monte Carlo simulations. Moreover, this paper also aims to present a comparison of the obtained results between the actual eye model, consisting of all sections of the eye and realistic compositions in the presence of AuNPs, and in the exact same organ, albeit in a preclinical experiment of the mentioned material. Previous Monte-Carlo simulations have strained to acquire the same results obtained through latest experiments that have considered dose enhancement effects of proton treatments with existence of AuNPs, but to no avail; thus, multiple simulation codes such as MCNP, GEANT4, and FLUKA have been taken into account to insure the least possible deviation from in vivo findings. Rigorous libraries and models have been used, and all physical processes involved have been accounted for; furthermore, for the sake of accuracy, the production of the most probable secondary particles due to interactions with matter has also been examined. Contribution to dose enhancement effects are due to stopping losses, coulomb interactions, and elastic and non-elastic collisions of proton itself, as well as from secondary particles that are produced in mentioned processes. The attempt of such paper is to shed light on the endless possibilities of escalating the efficiency of medical endeavors through interdisciplinary methods which combine various aspects of science and technology to attain desired results.

The objective of this work is to develop a method that allows generating a calibration curve for the DNA DSB focus assay in-vitro after internal irradiation with radionuclides. The samples should be exposed to radionuclides used in radionuclide therapy, nowadays also called molecular radiotherapy (MRT), simulating absorbed doses and dose-rates that are similar to the ones that have been observed in patients.

Therefore, we studied the induction of radiation-induced co-localized γ-H2AX and 53BP1 foci in lymphocytes as surrogate markers for the DNA DSB focus assay in-vitro absorbed doses to the blood for the two most frequently used radionuclides in MRT (I-131 and Lu-177).

Methods: We investigated blood samples of 3 healthy blood-donors. 9 experiments were carried out (2 experiments with I-131 and 1 with Lu-177 for each volunteer). For each experiment we withdrew approximately 28ml of blood at different time-points. One sample without radioactivity was used to determine the individual background focus rate. Radionuclides of known activities were diluted with NaCl and mixed with whole blood (3.5ml) to result in radioactive blood samples with different nuclide concentrations to deliver absorbed dose rates between 5mGy/h and 100mGy/h. Each vial was incubated for 1h at 37°C on a roller-mixer to uniformly blend the samples during the exposure. Thereafter, white blood cells were recovered by density centrifugation and washed in PBS followed by fixation in 70% ethanol. Samples were subjected to two-colour immunofluorescence staining and the average frequencies of the DNA DSB focus assay will provide additional information for in-vivo absorbed doses to the blood per nuclear disintegrations occurring in 1ml of blood were calculated for both isotopes using the radiotherapy transport code MCNPx2.71.

Results: Overall 55 blood samples were evaluated in a dose range between 6mGy and 95mGy. Only minor nuclide-specific, intra- and inter-subject deviations were observed. We obtained a linear relationship between the number of DSB-marking γ-H2AX and 53BP1 foci/nucleus and the absorbed dose to the blood (R²=0.92) which agrees well with published values for external irradiation.

Conclusions: This in-vitro calibration method for the DNA double strand break focus assay will provide additional information for in-vivo measurements in patients after molecular radiotherapy and will further improve the absorbed dose to the blood calculation method.
SP087 - Educational and Professional Activities: Part 2

PRESIDENTS CALL

SP087.1 - The potential role of IFMBE in improving the state of medical equipment in developing countries

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In developing countries medical equipment is often non-functional. Well known reasons for that are donations of already broken equipment and lack of spare parts and consumables. It is to be expected that current state of the art medical equipment is even less suitable for donation, given the way they are designed to function under conditions that are hard to find in rural areas in low resource countries. The key to start solving these problems lies in improving technical education at all levels in these countries. This paper explores how the IFMBE can work together with several other institutions (WHO, local professional organizations, non-profit organizations, Ministries of Health and Education,...) to train and sustain a competent technical workforce that can do maintenance, repair, and design of biomedical equipment using locally available materials and knowledge.

SP087.2 - Biomedical Engineering Education through Outreach Programs in Hospitals

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Health expenditure is a measure of the share of activity related to health care, both preventive and curative. Industrialized Countries spend around 10% of Gross Domestic Product (GDP) [1] with a high 17.9% for the USA. Middle income Countries, such as Uruguay, have lower figures, but growing as does the dissemination of medical actions in larger portions of the population. More hospitals are build and more equipment are installed every year. Traditional Engineering Education is slow at developing Biomedical Engineering (BME) Programs, because initial demand is scarce and because existing Electrical or Mechanical Engineers usually take over specific functions after some training by equipment providers. Uruguay has a 120 years old University but is only starting to train BME graduates. Job offers greatly exceed qualified staff available, which led us to suggest urgent training programs based on an Outreach Program in Hospitals (OPH), therefore at low cost.

OPH based BME training is build upon existing Electrical Engineering and Systems Engineering Programs, using courses of maths, physics, chemistry, software development, electrical engineering and management. Six optional courses are added, from electronic design to medical image processing and management (DICOM, PACS), electrical safety standards, medical terminology, physiology and anatomy.

A full year design project of a biomedical equipment is assigned to groups of three students, to both foster collaborative attitude and to obtain a functional solution to a clinical instrumentation problem.

Students are then assigned in their fourth University year to a full time six months intern-ship in a Secondary Level Hospitals, where
BME is non-existent. This is done within a University Outreach Program. As the only technological reference persons in the Hospital Director’s office, BME students face a variety of maintenance, purchasing, staff training, safety measures enforcement, documentation and installation/removal of equipment. Every student is assigned a remote instructor who acts as a reference available on call or otherwise. The instructors are University teachers in capital city Montevideo, while students are in remote (100 Km to 600 Km) hospitals, where a basic “intern-ship” salary is paid, in addition to feeding/lodging on premises.

Results of this low budget, OPH based BME program are promising with first graduations expected June 2015. The main results are (1) self confidence and sense of responsibility acquired by student (2) its low cost and (3) the interest of BME firms for future employment.

From the Hospital Point of view, equipment documentation, staff safety instruction and maintenance purveyors relations are the benefits so far.

This model of integrated, easily implemented BME Program based on University Outreach has the potential to be considered in other settings in Latin America, the Caribbean and elsewhere, where quick BME staffing requirements must be met at low cost, helping to reduce Health Expenditure.


SP087.3 - Clinical Engineer: a health professional to recognize
Author(s):

Background:
In latter years, Clinical Engineer’s figure is taking on more and more importance in health technology management, due to his technical knowledge and capacity to interact with different fields professionals. Unfortunately, this situation does not reflect reality; in many low and medium income countries this figure does not exist and in many high income countries Clinical Engineer is not recognized as health professional, but very often compared as biomedical technician. Internationally Clinical Engineers, as subset of Biomedical Engineers, belong to Unit Group 2149 “Engineering Professionals Not Elsewhere Classified” under the International Standard Classification of Occupations produced by the International Labour Organization.

Objective:
Clinical Engineers community is strictly collaborating with World Health Organization (WHO), in particular with Adriana Velazquez Berumen, Senior Adviser on Medical Devices, to recognize Clinical and Biomedical Engineer’s figure worldwide.
The main aim is to stress the importance of Clinical Engineer in healthcare facilities. This work will be a chapter of Human Resources for Medical Devices, part of WHO Medical device technical series.

Methods:
The approach used in this work analyses the main activities carried out by Clinical Engineer, in order to give awareness of all activities involving this figure. Therefore the analysis focuses on Clinical Engineer’s role at national level, in particular within the Ministries of Health of different Countries. This analysis was possible through several statements by professionals who work at national level. Finally the analysis gives attention to Clinical Engineering’s diffusion worldwide in the six WHO regions (African Region, Region of Americas, Eastern Mediterranean Region, European Region, South-East Asia Region, Western Pacific Region) through data from Clinical Engineering Societies around the world.

Conclusions:
Clinical Engineer is without doubt a professional who needs to be recognized worldwide with more support. He is a fundamental resource in health technologies management and contributes both to healthcare organization and patient health.

SP087.4 - “Rehabilitation Engineering: Designing for Ability” - A summer outreach course for attracting talented high school students to the rehabilitation engineering field
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1Institute Of Biomaterials And Biomedical Engineering, University of Toronto, Toronto/CANADA, 2Department Of Mechanical And Industrial Engineering, University of Toronto, Toronto/CANADA, 3Handy-Metrics Corporation, Toronto/CANADA, 4Central Neighborhood House, Toronto/CANADA, 5Toronto Rehabilitation Institute - University Health Network, Toronto/CANADA, 6Rehabilitation Sciences Institute, University of Toronto, Toronto/CANADA, 7Department Of Occupational Sciences And Occupational Therapy, University of Toronto, Toronto/CANADA, 8Department Of Physical Therapy, University of Toronto, Toronto/CANADA

Motivation:
We need to inspire talented students to pursue rehabilitation engineering, and develop the technologies that will help our aging population overcome disabilities and live fulfilling lives for as long as possible. Our team experiences a perennial challenge of attracting top-quality students to important yet often unglamorous facets of this field (e.g. supporting independent toileting for people with mobility challenges), partly because prospective students may not recognize these challenges, or see how they can be addressed through science and engineering. In response, we developed a week-long course in rehabilitation engineering for high-school students through the University of Toronto’s “Da Vinci Engineering Enrichment Program”, which we have led every summer since 2012.

Course structure:
The course was designed provide students with memorable interactive experiences in a range of rehabilitation engineering applications. To discover accessibility challenges, students completed a “Built Environment Obstacle Course”, where they navigated UofT while simulating mobility and vision deficits, then assessed how built environment features affected their experience. Students participated in hands-on demonstrations in Toronto Rehab’s Challenging Environment Assessment Laboratories and Neural Engineering Lab to understand how engineering technologies are being applied to problems such as preserving hand dexterity in cold weather, and allowing people who are ‘locked-in’ to control their own environments. Guest speakers included engineers, clinicians and an entrepreneur who could communicate authentically to the students about the challenges, importance and rewards of developing and commercializing technologies to improve the lives of people with disabilities. The week culminated with a “Home-Care Design Challenge”, focused on solving problems related to aging-in-place. These design problems were selected from real client case studies presented by a home-care field educator.

Student feedback:
Students reported significant improvements in their understanding of key learning objectives (Figure 1). Students appreciated the Toronto Rehab visits, the diverse topics, the design challenges, and the instructional team’s ability to make the content understandable, interactive, and relevant.
Africa sees very few such programmes being offered. The Biomedi-
fication degrees in Biomedical Engineering or closely related subjects,
Whereas many universities in the developed countries are now of-
tation Division, Uganda Industrial Research Institute, Kampala/
placements for the students. The students are given clear objectives
SinoAfrica Uganda, Joint Medical Stores have continuously offered
Internship posts have been secured in all government hospitals
pitals as well as companies where they were otherwise unknown.
The awareness of the Biomedical Engineers and students in hos-
grade for their performance. This was brought about to improve
is an integrated part of the training where the students are actually
The degree has been designed in such a way that student internship
is seen to be the first of its kind in Sub-Saharan Africa. It has been
running for less than three years with some other institutions in the
country offering Diplomas.

The degree has been designed in such a way that student internship
is an integrated part of the training where the students are actually
graded for their performance. This was brought about to improve
the awareness of the Biomedical Engineers and students in hos-
pitals as well as companies where they were otherwise unknown.
Internship posts have been secured in all government hospitals
and many private hospitals and companies. Companies Such as
SinoAfrica Uganda, Joint Medical Stores have continuously offered
placements for the students. The students are given clear objectives
with specific outcomes from each placement. They get a place-
ment supervisor as well as an academic supervisor to monitor their
progress.

The Uganda Industrial Research Institute (UIRI) has gone a step
further in supporting the degree programme. They not only provide
placements for the students but also over dedicated training such as
embedded systems and programming that students can take to
improve their knowledge and skills.

The awareness of the Biomedical Engineers and students in hos-

Expected outcomes: All of the participating students gained an
awareness of the problems faced by older adults and the societal
importance of finding solutions. Those who pursue engineering will
better understand their potential roles in rehabilitation engineering
and the importance of including stakeholder perspectives. Con-
versely, those who pursue other medical disciplines will appreciate
the importance of engineering in medicine and the potential for col-
laboration with engineers to advance their work.

The process for developing the proposed curriculum was performed
by structuring the types of knowledge needed for risk management
on HIT obtained through the exploration and study of the environ-
ment in which these technologies are embedded. The exploration of
the literature and specific standards to manage IT risks pointed out
several incidents involving the use of HIT. It was also investigated
the types of risks associated with the use of HIT, the professional
characteristics of IT professionals and the necessary requirements
to apply the standards for risk management on the healthcare sys-
tem. This investigation has shown the kind of knowledge required
by the CE professionals. The proposal curriculum to train clinical
engineers for managing HIT are shown at Table 1.

<table>
<thead>
<tr>
<th>Nº</th>
<th>Module</th>
<th>Workload (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction on health information systems</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>Medical IT-network</td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>Usability, ergonomics and accessibility</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>Technology project management</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>Safety and risks of IT-network</td>
<td>70</td>
</tr>
<tr>
<td>6</td>
<td>Risk management</td>
<td>30</td>
</tr>
<tr>
<td>7</td>
<td>New technology in healthcare</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>Multidisciplinary and hospital infrastructure</td>
<td>30</td>
</tr>
</tbody>
</table>

The proposal here intended not only to upgrade the expertise of the
clinical engineering professionals, but also aims to improve the inte-
SP087.7 - A Successful High School Science Mentorship Program: Students on the Beamlines at the Canadian Light Source

Author(s): Tracy Walker¹, Tomasz W. Wysokinski¹, Mark A. Webb¹, Ning Zhu¹, George Belev¹, Cécilia Barrette-Leduc², Katarina Stefanovic², Lylia Xiao², Sara Marrè², Shu Yi Zhai², Yu Xin Zhuang², Marie-Eve Brassard², Denise Miller³

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Canada’s only synchrotron is an extremely brilliant source of X-ray and infrared light for research in a multitude of disciplines. We also have a unique program that engages high school students in authentic science research experiences. The Students on the Beamlines (SotB) [1] program connects high school students from across Canada with scientists at the Canadian Light Source (CLS) for mentorship through an authentic science research experience. “Authentic” indicates that we facilitate a research project that is as close to what professional scientists do as a high school student is capable. These are not demonstration experiments. Students must design a project that builds on previous work (through literature review) and ask a scientific question that requires synchrotron techniques to address. The results of their experiment are expected to potentially produce novel information that is of interest to the scientific community. It is this negotiation between the goals of producing ‘good science’ and creating an ‘educational and learning experience’ that is part of what makes this program unique. Key to the program is that the students function as primary investigators. Their mentors facilitate, direct and advise the students, but the project belongs to them and they make the decisions.

The case study presented is one from Pensionnat Saint-Nom-de-Marie, a girls’ school in Montreal, Canada. Honey bees in Canada are suffering significant winter death due to infestations of the Nosema fungus. It is known that the infestation deforms the digestive system of infected bees. Students used the Biomedical Imaging & Therapy (BMIT) beamline at CLS to collect x-ray projection and CT images of healthy and infected bees clearly showing the bees’ digestive system.

More than 500 students have participated in SotB so far and report that the experience has had a profound impact on their view of research, careers in science and of scientists. Teachers are eager to involve their students because the program fits with current educational initiatives encouraging student engagement through the use of inquiry methods in the science classroom. Several other synchrotron research facilities are emulating the program. The point of this presentation is to share our experience so the concept of student participation in mentored authentic science research can spread. In our case, using a synchrotron is the context and a hook to attract student participation. Any research context would work similarly.

SP088 - Computer Aided Diagnosis

SP088.1 - Automatic Analysis of Plantar Foot Thermal Images in at-Risk Type II Diabetes by Using an Infrared Camera

**Author(s):** Luis Vilchahuan*, Rachid Harba*, Raphael Canals*, Martha Zequera*, Carlos Wilches*, M.T. Arista*, L. Torres*, H. Arbanil1
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Temperature of the plantar foot surface is an important feature in type II diabetes as abnormal temperature variations can be an early sign of foot diseases. In this paper, automatic way to analyze these temperature variations is presented by using an infrared camera. A robust acquisition protocol is proposed and an image processing software is developed. Three types of analysis are performed. First, the mean plantar foot temperature of both feet results from a segmentation procedure based on the Chan and Vese active contour method. Second, the point-to-point absolute mean difference between the 2 feet is assessed by using a rigid registration method. Third, significant hyperthermia regions such that the point-to-point absolute difference is greater than 2.2°C are highlighted. All these measures are fully automatic and do not need manual intervention. 32 type II diabetic subjects in a pre-ulcerative state were recruited in the Dos de Mayo hospital (HNDM) in Lima, Peru. These persons were classified in two risk groups of developing an ulcer based on a medical exam: a medium risk group, and a high risk group. Results show that the mean temperature of the plantar foot surface is higher of 1°C in the high risk group compared to the medium risk group. The mean point-to-point absolute difference shows identical values in the 2 groups. Finally, 9 subjects out of the 82 ones show significant hyperthermia of one foot compared to the other (6 in the medium risk group and 3 in the high risk group). It is expected that the new opportunity to automatically analyze foot temperature in hospitals or in diabetic health centers will help in reducing foot ulcer occurrence for type II diabetic persons.

SP088.2 - Computer Assisted Diagnosis of Sclerotic Bone Lesions from Dual Energy CT

**Author(s):** Duc Fehr1, Charles R. Schmitzlein1, Sinchun Hwang2, Joseph O. Deasy1, Harini Veeraraghavan2
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**Purpose:** To develop a computer assisted diagnosis (CAD) tool for the detection of sclerotic bone lesions in the pelvic region from dual energy computed tomography (DECT). Automatically identifying every single bone metastatic lesions from CT images is difficult owing to (a) large number of such lesions, and (b) very low contrast between the lesions and the marrow or bone.

**Method:** We developed a CAD tool that automatically detects sclerotic bone metastases from DECT images from the pelvic region. Our method consists of two stages. In the first stage, the bone and marrow regions are automatically segmented through a voxel-wise classification of the DECT image represented as a composition of multiple materials by using support vector machine classifier, followed by morphological smoothing. The appropriate material composition is determined through a learning using SVM that selects the best material composition for segmenting the bone and marrow from the rest of the image. In the second stage, the contrast inside the bone and marrow regions are enhanced through bi-histogram equalization followed by mean shift clustering. Mean shift clustering groups voxels with similar intensities into single clusters. Finally, the segmented regions extracted from the mean shift clusters are scored by the their shape. The following parameters including area, eccentricity, solidity, major axis, minor axis, perimeter, and the medial axis are used as constraints on the shape. Shape filtering prefers isolated regions that are solid, with small elongation and smaller size rather than highly elongated shapes (such as the bones). The shape filtering outputs potential sclerotic bone lesion regions, which can then be validated by a radiologist.

**Results:** We compared the candidate regions generated by our method with the ground truth regions manually identified by a radiologist. Our results agreed with the radiologist marked regions despite the presence of confounding metal artifacts and the low contrast between healthy bone and the lesions.

**Conclusions:** We developed a CAD tool that automatically detects sclerotic bone lesions in the pelvic areas from dual energy CT. The detected lesions using our approach highly similar to the radiologist identified regions despite the presence of confounding structures with similar intensities including the sclerotic lesions, healthy bone and metal artifacts.

SP088.3 - Mutual Information Based Template Matching Method for the Computer Aided Diagnosis of Alzheimer Disease

**Author(s):** Esra Polat, Albert Guvenis
Institute Of Biomedical Engineering, Bogazici University, Istanbul/TURKEY

**Background**
Early and reliable detection of Alzheimer Disease (AD) from Positron Emission Tomography images using computerized methods is a desirable objective for the effective management of that disease. Several characteristics of the computer aided diagnostic system (CAD) are important for improving this process: (1) Taking advantage of the growing number of images in databases (2) Ability to search a database for similar cases (3) Robustness with respect to data acquisition and processing factors (4) Full automation. In particular the third and fourth requirements are important in view of the fact that many CAD systems require user intervention.
Purpose

Our goal was to develop a fully automated CAD system for detecting AD that can meet these requirements.

Method and Materials

We have used the Alzheimer’s disease Neuroimaging Initiative (ADNI) database for this study. Images for each patient were co-registered in order to correct for patient motion and had voxel sizes of 160 x 160 x 96. Voxel size was 1.5x1.5x1.5 in mm. There was 397 PET images including 259 normal and 138 AD patients.

A similarity measure based on mutual information (MI) was used to determine the closest matches for a new case. A K-Nearest Neighbor algorithm based distance measure was used to decide if a new image was from a healthy or AD patient. A leave one out evaluation method was implemented. Evaluation results were computed using ROC analysis. All development was carried out in a Matlab environment.

Results

Initial ROC analysis resulted an area under the curve (AUC) equal to 0.744±0.025 for this dataset. Much higher AUC values are expected for the nonlinearly registered images across patients. This is work in progress.

Conclusions

First results show that it is possible to discriminate between AD and healthy individuals by using template matching and mutual information as a similarity metric. Further studies are underway in order to improve these results by introducing nonlinear registration methods and by adjusting the image size and grey scale parameters used in the process. Robustness, adaptation ability to growing databases without having to retrain the system and case based reasoning possibilities will be some advantages of the new CAD system.

Figure 1 ROC Curve for the first database of images
also had imaging prior to fracture. An expert Radiation Therapist manually contoured the residual bone within the fractured vertebral body. A system based on Clarion Technology Inc’s “Spinemapper” application that automatically identifies vertebral levels and segments vertebral bodies, previously applied in unfractured vertebral bodies was extended to automatically contour the volume of each fractured vertebral body. The automatic method produced volumes highly correlated ($R^2=0.994$) with, but approximately 9% less than the expert contoured volumes. Using a curve fit to the volumes of adjacent “normal” vertebrae, the percentage change in volume in the fractured vertebra was estimated. Based on such curve fits, the estimated percentage volume loss ranged from 5% to 40% in the patient group studied. For the three subjects where both pre- and post-fracture CTs were available, the post-fracture assessment of predicted percentage volume loss matched the measured value based on pre- and post fracture data within 10%. This study demonstrates the viability and precision of this method to automate the analysis of fractured vertebral body volume and height reduction. These factors can then be incorporated into the scoring and management of patients with vertebral fractures.

Fractured Vertebral Body Volumes: Automatic vs Manual Segmentation

**SP089 - Tissue Modelling**

**SP089.1 - The protective effect of the eyelid on ocular injuries in blunt trauma**

*Author(s):* Xiaoyu Liu$^1$, Lizhen Wang$^2$, Jing Ji$^2$, Yubo Fan$^3$

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The instinctive blink reflex makes the eyelid close when a foreign body is approaching the eye. This study aimed to investigate the protective effect of eyelid on ocular injuries in blunt trauma. A finite element model of the eyelid model was created and was incorporated into a validated eye model. The process of a projectile impacting on a naked eye and an eyelid-covered eye were reproduced in dynamic simulation. Dynamic responses on the cornea and retina were performed to evaluate the risk of damage to the tissues. The simulation indicated that the eyelid significantly protected the cornea against damage from blunt impact, especially for a small-size projectile. This is because the eyelid distributes the local stress concentration to the whole ocular surface. However, the eyelid failed to provide the retina with an effective protection against damage in blunt trauma. This is because the retinal damage is a typical contre-coup injury, which is the result of shockwave propagation in the eyeball. In conclusion, the eyelid has different protective effects on ocular injuries caused by different injury mechanisms for eye closure.

**SP089.2 - A Tale of Two Tendons: The Tradeoff between Strength and Fatigue Resistance**

*Author(s):* Samuel P. Veres, Tyler W. Herod, Neil C. Chambers

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Two predominant, functional classes of tendons exist: energy storing tendons and positional tendons. Energy storing tendons operate under much greater in vivo stresses than positional tendons, and are more prone to injury. Using a bovine forelimb model, we assessed the ultrastructural differences between superficial digital flexor (SDF, energy storing) and common digital extensor (CDE, positional) tendons. Scanning electron microscopy was used to study the ultrastructures of 4 SDF/CDE tendon pairs from 4 different animals at magnifications up to 90,000X. SDF tendons were found to have significantly smaller diameter collagen fibrils than CDE tendons (77.3±26.6 vs. 134.9±51.7 nm; $p<0.0001$). The collagen fibrils in SDF tendons were often bundled together by a dense network of filamentous webbing that ran predominantly perpendicular to fibrils’ longitudinal axis. Similar webbing was not observed in the CDE tendons. Hydrothermal isometric tension analysis of intermolecular collagen crosslinking, conducted using 7 SDF/CDE pairs from 7 different animals, showed that the energy storing SDF tendons had significantly more crosslinking (denaturation temperature: 65.2±1.1 vs. 62.9±1.1°C; $p = 0.0003$), and significantly more thermally stable crosslinking (portion of samples that survived the temperature ramp to 90°C: 85.7% vs. 0%; $p = 0.0006$) than the paired, positional CDE tendons. Thermal assessment using differential scanning calorimetry confirmed SDF and CDE tendons to have markedly different collagen crosslinking. Samples from paired SDF and CDE tendons had significantly different onset temperature (64.2±0.7 vs. 63.1±1.0°C; $p=0.0035$), endotherm full-width-at-half-maximum...
INTRODUCTION

Insoles and customized footwear are used to alter the plantar pressure (PP) distribution during gait. However, so far, it is not possible to predict the effect of these interventions on PP. This would undoubtedly enhance the customization process. The aim of this study is to evaluate a newly developed contact model, which allows to calculate dynamically the PP within a multibody gait simulation framework.

METHODS

Standard gait analysis was performed on 10 healthy subjects (mean age 62.2±4.6 years, mean BMI 24.6±2.2 kg/m²). The experimental setup included a 6 cameras BTS stereophotogrammetric system (60Hz), synchronized with 2 Bertec force plates (960Hz) and 2 PP systems (Imagortesi, 150Hz).

The PP simulation is performed during a moment-driven forward analysis using the experimental 3D kinematics and ground reaction forces in combination with a scaled generic musculoskeletal model as input in OpenSim. A scattered bed of spring-damper systems [1] was used as contact surface attached to the calcaneus of the model, which was obtained from a CT-scan of a healthy subject.

An optimization procedure optimized the contact parameters and geometry position based on the experimental ground reaction force. The performance of the contact model is evaluated by comparing the simulated and measured peak pressure curves (fig. 1).

RESULTS

A good agreement between simulated and measured peak pressure was found for all regions (see Fig. 1). In the first part of stance (30-60%) the overlap was nearly maximal, while around 80% of the gait cycle the overlap was lower. The hindfoot contact is prolonged during the simulation compared to the measurements.

DISCUSSION

The newly developed contact model showed a good performance in predicting the peak PP over time. With respect to finite element contact simulation, this contact model allows a continuous simulation of PP at a limited time. Due to its characteristics this contact model has potential to be used in the design of insoles and customized footwear.

REFERENCES


Figure 1: The plots show the measured (gray) and simulated (red) peak pressure curves for the 4 regions: whole foot, forefoot, midfoot and hindfoot, subdivided using anatomical marking [2]. The curves are averaged over the 10 subjects, with its nominal 95% bootstrap prediction bands [3]. The overlap between the bands is indicated by the colored bar, with blue representing no overlap and red maximal overlap.

SP089.4 - 3D numerical investigation of the effects of altered mechanical loading during skeletal growth

Author(s): Kamel Madi1, Peter D. Lee1, Katherine A. Staines2, Andrew A. Pitsillides3, Andrew J. Bodey1, Brian K. Bay1

1Manchester X-ray Imaging Facility, University of Manchester, Didcot, oox/UNITED KINGDOM, 2The Royal Veterinary College, London/UNITED KINGDOM, 3I13-2 Branchline, Diamond Light Source, Didcot/UNITED KINGDOM, 4School Of Mechanical, Industrial & Manufacturing Engineering, Oregon State University, Corvalis/OR/UNITED STATES OF AMERICA

Purpose

Abnormal growth plate closure during endochondral ossification and subsequent deformity resulting from altered mechanical loading has key implications in the progression of joint deformities such as...
varus and valgus. Despite several studies investigating changes in bone growth in response to mechanical loading [1], there is a lack of 4D data (3D with time) quantifying the relationships between the closure of the growth plate and the local micro-mechanical environment that the cells in the epiphyseal growth plate may experience. We aimed to combine X-ray computed tomography and computational modelling to investigate whether there is a correlation between the 3D high resolution images of growth plate cartilage topology, the octahedral shear stress (believed to promote endochondral ossification [2]) and the spatial localisation of the bridges.

Methods

Synchrotron-based micro-CT imaging of joints from a mouse strain (Str/ort) with natural susceptibility to OA and age-matched CBA (control) mice was performed at different stages of the disease on the Diamond-Manchester Branchline I13-2 (effective pixel size: 1.1 μm). Novel image processing methods were developed to map the location/density of the bridges onto the joint surface and to characterise the 3D topology of the growth plate cartilage. In parallel, 3D volumetric meshes of the entire tibia including the growth plate cartilage were generated from the tomographic images and finite element computations were carried out to simulate static compressive tests (sustained loading).

Results

Compared to control mice, the growth plate cartilage of late-OA joints is thicker with higher local curvature (Fig. 1), suggesting different remodelling and local stress state. Our first micro-FE computations in a late-OA joint revealed that the bridges seem to act as stress concentrators and are hence more likely to fracture under loading and/or to redistribute stresses within these particular vicinities of the growth plate cartilage.

![Fig. 1 Distribution of the local mean curvature in the growth plate cartilage of adult mice.](image)

Conclusions

Our data reveal changes in the internal 3D topology of the growth plate cartilage in a model of spontaneous mouse osteoarthritis that could be linked for the first time to the micro-mechanical environment experienced by the growth plate during skeletal growth. Further investigation at earlier disease stages will reflect how these different topologies impact the stress and strain distributions and whether this may correlate with growth rate, greater bridge cluster-
SP090 - QA Measurements for Therapy Dosimetry

SP090.1 - Response Characteristics of a Large-Area Ion Chamber with Various Radiotherapy Beams

Author(s): Makan Farrokhkhil1, Andrew J. Jung2, Yinkun Wang3, Bern Norrlinger4, Robert K. Heaton4, Mohammad K. Islam4
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Introduction: Previously described Integral Quality Monitoring (IQM) system, utilizes a large area gradient ion chamber mounted on the collimator to measure the “dose-area-product” of field segments. The gradient in spatial response is created by a slope in separation between electrode plates. The system verifies the dose delivery by comparing the measured and predicted signals in real-time. Since the signal of the ion chamber is comprised of the beam fluence through the open aperture as well as the attenuated beams through collimating structures, it creates a new dosimetric paradigm in Radiation Therapy. This presentation describes several dosimetric performances of the IQM detector including the response variation with various field sizes, beam energies, dose rates, and spatial sensitivity of treatment fields in several Linear Accelerator (Linac) platforms.

Method: Dosimetric measurements were performed in Elekta Synergy (60 leaf-MLC/i2) and Infinity (160 leaf-Agility), as well as Varian iX and TrueBeam (160 leaf- Millennium) Linacs. The beam energies across these platforms were 6, 10, 18 MV, 6 MV Flattening Filter Free (FFF) and 10 MV FFF. All the beams deliver 1 cGy/ MU for a 10 × 10 cm² field at dmax-depth, with the source to detector distance of 100 cm. The chamber was mounted on the accessory tray of Elekta and the upper wedge tray of Varian Linac.

Results: The chamber signals, expressed in IQM Count, for a 10 × 10 cm² field with 6 MV beams were 1946 and 2259 Counts/MU for TrueBeam and Infinity respectively. The difference in counts can be attributed primarily to: (i) differences in the source to chamber distance (ii) differences in MLC and jaw transmission factors and the back-up jaw configuration. The field size factors for 6 MV beams, normalized to a 10 × 10 cm² field, ranged from 0.008 to 4.352 for TrueBeam and 0.023 to 3.941 for Infinity for fields ranging from 1 × 1 cm² and 20 × 20 cm² respectively. The relative energy response varies widely with field size, machine model, and beam filtration. A maximum difference in response for 10 MV, 18 MV, 6 MV FFF and 10 MV FFF beams, relative to 6 MV beams in corresponding Linac were found be 20.6, 23.4, 23.9, and 39.4% for field sizes ranging from 1 × 1 cm² to 20 × 20 cm². When a 3 × 3 cm² field was shifted by 3.0 cm in the direction of increasing gradient, signal difference of up to 12 % and 10 % were observed for TrueBeam’s 10 and 6 MV beams respectively. For a 10 VM FFF beams however, no measurable difference in signal was observed for the same shift, due to the combined effect of chamber gradient and off-axis profile.

Conclusion: Since the IQM Chamber intercepts the entire projected area defined by the primary jaws, the signal is comprised of the open beam and the attenuated beam through the MLC and jaws. A significant difference in some key dosimetric response is therefore expected across various beam energy, filtration and Linac models.

SP090.2 - Very small circular fields output factors: Comparison of MC calculations, EBT3 film and micro-diamond measurements

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The purpose of this work was to obtain output factors (OFs) of 6MV beam collimated by customized circular cones of 1.3 and 3.5 mm diameter at isocenter. We also compared OFs from these cones with OFs from BrainLab™ of 10, 12.5, 15 and 40 mm cones.

OFs were measured using GafChromic EBT3 films and micro-diamond detector. Detectors were placed isocentrically in a water phantom at 1.5 cm depth. Two sets of EBT3 measurements were extracted from different image resolutions as shown in Table 1. Micro-diamond detector was also used to measure cone OFs with detector axis orthogonal to the incident beam. BEAMnrc/DOXYZnrc codes were used to calculate OFs and dose profiles in water with 1x1x1 mm³ voxels for the 10-40 mm cones and 0.1x0.1x0.1 mm³ voxels for the 1.3 and 3.5 mm cones, respectively.

Results for OFs (relative to 40 mm diameter cone) are shown in Table 1. Differences of 15.4% and 15.9% were found for cone 1.3 and 3.5, respectively. Maximum differences of up to 4.0%, 2.9% and 1.9% were found for cones 10, 12.5 and 15 mm, respectively. Scanning resolution of the films was critical for the two smallest fields and the differences between two EBT3 OF’s measurement set were 6.7% and 14.3% for cone 3.5 and 1.3, respectively.

In conclusion, differences in output factor were within 4% for cones with 10 mm diameter and greater. However, larger differences were observed for the 3.5 and 1.3 mm field sizes. Scanning resolution has significant effect on the output factor of the smallest cones in this work.

Table 1. Output factors measured and calculated for a range of circular cones. Statistical uncertainty of MC calculations was within ±2.5%.

<table>
<thead>
<tr>
<th>Cone diameter (mm)</th>
<th>1.3†</th>
<th>3.5†</th>
<th>10</th>
<th>12.5</th>
<th>15</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamond</td>
<td>-</td>
<td>0.687</td>
<td>0.878</td>
<td>0.931</td>
<td>0.960</td>
<td>1.000</td>
</tr>
<tr>
<td>EBT3 (1.8 mm pixel size)</td>
<td>0.132</td>
<td>0.586</td>
<td>0.909</td>
<td>0.953</td>
<td>0.961</td>
<td>1.000</td>
</tr>
<tr>
<td>EBT3 (0.13 mm pixel size)</td>
<td>0.154</td>
<td>0.628</td>
<td>0.910</td>
<td>0.958</td>
<td>0.965</td>
<td>1.000</td>
</tr>
<tr>
<td>MC (0.1 mm voxels)</td>
<td>0.137</td>
<td>0.605</td>
<td>0.874</td>
<td>0.931</td>
<td>0.978</td>
<td>1.000</td>
</tr>
<tr>
<td>% Diff =</td>
<td>OFmax−OFmin</td>
<td>/</td>
<td>OFmax+OFmin</td>
<td>/2</td>
<td>15.4</td>
<td>15.9</td>
</tr>
</tbody>
</table>

† In-house customized collimators with indicated nominal field size at isocenter.

SP090.3 - Investigation of pass rate variability in ArcCheck measurements

Author(s): Harald Keller1, Albert Chen2, Daniel Létourneau2
1Radiation Oncology, University of Toronto, Toronto/ON/CANADA, 2Radiation Medicine Program, Princess Margaret Cancer Centre, Toronto/ON/CANADA

Spine SBRT (stereotactic body radiation therapy) is an emergent radiation therapy treatment technique for bone metastasis in the spine. Such treatments are nowadays delivered using volumetric modulated arc therapy (VMAT). The ArcCheck detector (Sun Nuclear Corporation, Melbourne, FL) is part of the patient-specific QC process to routinely evaluate the ability to accurately deliver VMAT plans. It was found that the results of such ArcCheck measurements
for spine SBRT plans can vary widely from patient to patient, more so than for other treatment sites. The purpose of this work was to investigate potential sources of this variability in order to streamline the QC process for spine SBRT patients.

A set of 144 spine SBRT treatment plans published between July 2012 and May 2014 was available. All plans used a single 360 degree arc with isocenter in the spine. The vast majority of treatment plans were delivered on a single linac (Elekta Beam Modulator (TM)).

Absolute dose pass rates (ADPR) are the percentage of values (detectors) in a measured dose map (cylindrical surface within the ArcCheck phantom) that have passed a set of criteria, usually a 3% dose-difference and 2 mm distance-to-agreement criterion with respect to the calculated dose map obtained from the planning system (Pinnacle, Philips). The number of detectors participating in the comparison is set by a dose threshold (TH).

For this work, the pass rates and their variability were studied for several parameters associated with the measurement and analysis of the dose map: the TH threshold, sensitivity of the results to ArcCheck phantom (dose map) shifts, global and local gradients in the measured dose maps and the degree of beam modulation as assessed by the number of monitor units per delivered dose (MU/cGy) of the arc. For efficient analysis, an emulation of the pass rate algorithm was implemented in Matlab and validated against the commercial software (SNC patient, Sun Nuclear).

The ArcCheck results for the spine SBRT plan set showed a mean ADPR of 86% with a wide range between 60% and 98%. ADPR was largely constant for most patients as a function of TH, except for TH below 10% where most pass rates dropped significantly and increased variability within the set. As expected, ADPR decreased with applied dose map shift for most instances, but ADPR was not correlated to the degree of ADPR sensitivity to these dose map shifts. The within-set ADPR variability was almost independent of “flatness” of the dose map (quantified as the sum of the gradient taken over the dose map). Only for very flat dose maps with small gradients the ADPR was consistently above the set mean (around 90%). Degree of beam modulation had some correlation with ADPR (correlation coefficient 0.608) where higher/lower beam modulation resulted in lower/higher pass rates, respectively.

In summary, there is no known single parameter that is driving the variability of the ADPR. Multivariate analysis should be performed and parameters that influence the computation of the dose map need to be incorporated as well.

SP090.4 - Characterization and image quality evaluation for a clinical 2.5 MV in-line portal imaging beam

Author(s): Jeniffer Owen1, Jose E. Villarreal-Barajas2, Rao Khan3, James Grafe3

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Characterization and image quality evaluation for a clinical 2.5 MV in-line portal imaging beam

Recently, a 2.5 MV inline portal imaging beam has been made available on Varian TrueBeam™ Linacs. The aim of this work is to present our initial investigations of the 2.5 MV beam characterization and imaging quality assessment.

The 2.5 MV beam output was calibrated following the AAPM TG-51 procedure. The beam output has been stable over four months to within 1%. The PDD was measured with a CC13 chamber, a Markus chamber, and Gafchromic EBT3. The resulting depth of maximum dose, dmax, and PDD at 10 cm depth (%dd(10)) was measured to be 5.7 mm (51.7%), 6.1 mm (51.9%), and 5.1 mm (51.9%) for a 10x10 cm² field size at 100 cm SSD for the CC13, Markus and EBT3 film, respectively (Figure 1). The beam quality is slightly lower than that of a 60Co beam; however we estimated a kQ value of 1.00 for output calibration purposes. Additionally, the measured HVL was 9.8 mm Cu (14.8 mm Cu for 60Co), corresponding to an effective energy of approximately 550 keV. The relative entrance dose as measured with EBT3 films was 63%, compared to 23% for a 6 MV beam.

The image quality was assessed with the Standard Imaging Phantom QC-3. The estimated MTF for the MV-imaging system shows that 2.5 MV has better spatial resolution than the 6 MV beam (Figure 2). The 2.5 MV exhibited nearly three times higher surface dose than the 6 MV, however, for a separation of 20 cm, the 2.5 MV mid-separation dose is 78% of the 6 MV dose and the exit is only 58% of the 6 MV dose. Future work will focus on the clinical implementation and development of quality control protocols for this novel imaging beam modality.

Figure 1. Percentage-depth dose plots of the 2.5 MV imaging beam measured with EBT3 Gafchromic film, a CC13 ion chamber, and a Markus ion chamber for a 10x10 cm² field at 100 SSD. The entrance dose was measured using EBT3 film placed perpendicularly to the beam on a solid water phantom.

Figure 2. Normalized Modulation Transfer Functions (MTF) of both 2.5 MV and 6 MV portal imaging beams, calculated from the Standard Imaging QC3 phantom. The Low Dose mode delivers 1 MU for the 2.5 MV beam and 1.5 MU for the 6 MV beam and the High Resolution mode delivers 1.5 MU and 3 MU for 2.5 MV and 6 MV, respectively. The plots are normalized to the 2.5 MV Low Dose MTF for the 2.5 MV Low Dose and 6 MV Low Dose curves, and to the 2.5 MV High Resolution MTF for the 2.5 MV and 6 MV High Resolution curves.

SP090.5 - Usefulness of the commercialized EPID based dMLC QA tool for Elekta Agility MLC

Author(s): Samiu Cho1, Woonhoon Choi1, Ho Lee1, Kwangwoo Park1, Jungil Lee1, Jeongmin Yoon1, Eungman Lee1, Suk Lee1, Sang Hoon Lee2, Juree Kim2, Jinho Choi2, Sangwook Lim2, Ki Chang Keum3

1Radiation Oncology, Yonsei University, Seoul/KOREA, 3Radiation Oncology, Korea University, Seoul/KOREA

The dynamic intensity modulated radiation therapy(dIMRT) and volumetric modulated arc therapy (VMAT) requires accurate leaf position, leaf speed, gantry position and gantry speed while modulating the dose rate. The Elekta Agility linear accelerator(Elekta AB, Stockholm, Sweden) could be to meet these characteristic with
als (air, bone and homogeneously with RW3) and different square field sizes (FS) were irradiated to evaluate the isocenter dose in the homogeneous phantom. The global accuracy was assessed by comparing OFs and PDDs evaluated with TPS with that reconstructed by DC.

Then, DC was run pre-treatment and in-vivo for 15 patients: 1) 7 IMRT prostate cases, 2) 3 abdominal VMAT cases, 3) 5 head VMAT cases. Gamma analysis (3%, 3mm) was used to compare measured with calculated dose distribution.

Isocenter dose was equal within 1.75% for pre-treatment and in –treatment measures and for all FS. Due to the use of a pencil beam algorithm, high OF and PDD differences (up to 64.2% and 110%, respectively) were found in the air filled phantom at small FS.

In patients, gamma passing rates evaluated on the whole treatment volume were above 98% and 94% for pre-treatment and in vivo prostate cases respectively; above 92% for both pre-treatment and in vivo abdominal VMAT patients, and above 89% and 73% for head VMAT patients.

In conclusion, DC is capable of successfully reconstruct the dose distribution in the patient from the EPID measured exit fluences, even if a more accurate algorithm is needed when low density regions are involved.

Figure1 Validated EPID images for dMLC QA

The acquisition of images and analysis of results took about 25 min. We performed dMLC QA using same dynamic delivery MLC file for 3 month in the 4 Agility linac MLC and averaged result parameters. These parameter values were established as our reference and tolerance level. We could figure out Agility MLC changing trend using ARTISCAN report tools after the parameters were validated. The EPID based dMLC QA program not only improve the QA procedures by reduce the time consuming process, but also guaranties the dosimetric accuracy of dIMRT and VMAT by verification of MLC/gantry position and speed.

Acknowledgements: This work was supported by the Radiation Safety Research Programs (1305033) through the Nuclear Safety and Security Commission.
Radio-immunotherapy is one such approach where cancer cells are targeted by vectors labelled with a radioisotope. In a specific case of targeted alpha-therapy (TAT), a tumour-specific antibody/protein is radiolabelled with an alpha-emitting radionuclide, termed a radioimmun conjugate (RIC). This radioimmunoconjugate attaches preferentially to tumour-specific antigens, and releases high-linear energy transfer (LET) α-particles of a few MeV kinetic energy. Alpha radiation has the shortest range and highest energy transfer (and correspondingly high radiobiological effectiveness), resulting in localized but significant ionization damage (e.g. to DNA). Alpha-emitting radioisotopes can be used to kill isolated cells, small cell clusters and to regress tumours [2]. The high-LET α-radiation produces increased rates of DNA double-strand breaks. The LET is ~100keV/μm, giving a higher probability of causing DSBs; ratio SSB/DSB≈20 compared with 60 for low-LET radiation.

Over the past 20 years the development of RICs has enabled TAT to progress from in vitro studies, through to pre-clinical in vivo experiments and clinical trials. The dose to normal tissues provides a limitation to the injected dose and to that received by the tumour. However, TAT can achieve cancer regression within the maximum tolerated dose (MTD) for normal tissues provides a limitation to the injected dose and to that received by the tumour.

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This lecture gives an overview of clinical results in an endeavor to recommend whether and how TAT and High-Z NPs can be integrated into the therapeutic armamentarium for cancer.


However, for solid tumours the promise of TAT is greatly extended by the development of tumour antivascul ar alpha-therapy (TAVAT); i.e. killing of tumour capillary endothelial cells that results in disrupting of tumour capillary networks and shrinking tumours [5].

High-Z Nanoparticle Radiosensitization

High-Z nanoparticles (NPs) have been a topic of interest in medical research since 1950s. It has, however, only been in the last 20 years that the practical use of NPs for imaging and radiotherapy has been demonstrated [6]. It has been shown that the presence of gold (or other high-Z material) nanoparticles improves the cell-killing effect of radiation in vitro and with in vivo mouse models. High-Z nanoparticles are being used in human trials for sensitization of tumour in radiation therapy, yet the mechanisms of enhancement are still being investigated [7, 8].

In a specific case of gold, NPs generally have an individual diameter between 1nm-1μm and are suspended in an aqueous solution. The high atomic number of gold relative to tissue means that when gold is introduced into a tumour, it acts as a contrast agent for imaging and it amplifies the biological damage in the case of external beam therapy. Cell death after radiotherapy occurs due to DNA damage induced by Reactive Oxygen Species (ROS). The ROS are generated from interactions of the incident radiation with atoms, emissions and scattering from those atoms, and subsequent interaction with oxygen based molecules. This process relies on emission of photo-electrons and Auger electrons, Compton Scattering, and Pair production.

Increasing localized dose deposition can improve therapeutic outcome, but needs to be done so that healthy tissues are not compromised by spurious dose deposition that nanoparticles may cause. It is very difficult to quantitatively analyse a statistically relevant number of individual cells for both nanoparticle content and biological markers. X-ray-Fluorescence (XRF) microscopy can be used to correlate nanoparticle content of individual cells with biological consequence to identify specific mechanisms of radiosensitization. This information is critical for understanding implications of such technologies as they move into human trials. XRF microscopy has only recently been able to rapidly image large area samples, and is uniquely available at the Australian Synchrotron [9]. This is a notable advance in the technique and is unique in the world. It can be used to quantify the mass of gold in each cell and hence deduce the number of nanoparticles. Subsequently, number of DNA breaks and Au content can be correlated to investigate the role of variables.

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SP091.2 - Enhanced uptake of gold nanoparticles coated with polyethylene glycol
Author(s): Charmaine Cruje, Devika B. Chithrani
Department Of Physics, Ryerson University, Toronto/ON/CANADA

Polyethylene glycol (PEG) has promoted the prospective cancer treatment applications of gold nanoparticles (GNPs). In vivo stealth of GNPs coated with PEG (PEG-GNPs) takes advantage of the enhanced permeability and retention effect in tumor environments, making them suitable for targeted treatment. Because PEG minimizes gold surface exposure, PEG-GNP interaction with ligands that mediate cancer cell uptake is lower than uncoated GNPs. Hence, the cellular uptake of PEG-GNPs is significantly lower than uncoated GNPs in vitro. As intracellular localization of GNPs maximizes its therapeutic enhancement, there is a need to improve the uptake of PEG-GNPs. To enhance uptake, a peptide sequence containing an integrin receptor binding site, or RGD, was conjugated with PEG-GNPs of varying core sizes. Spherical GNPs of diameters 14, 50 and 70 nm and a PEG chain length of 2 and 5 kDa were used to determine a preferred core size and chain length for uptake in vitro and in HeLa and MDA-MB-231 cells. Results show that enhanced cancer cell uptake may be achieved with the peptide sequence used for all sizes of PEG-GNPs in HeLa cells. For MDA-MB-231 cells, higher cancer cell entry was observed less significantly and only for a size of 14 nm. Hence, improved cancer cell entry of PEG-GNPs into HeLa cells may be achieved with the use of an RGD peptide, while a different peptide sequence would have to be used for MDA-MB-231 cells.

SP091.3 - Nuclear targeting of gold nanoparticles for improved therapeutics
Author(s): Celina J. Yang, Devika B. Chithrani
Biomedical Physics, Ryerson University, Toronto/CANADA

The combining of nanotechnology and medicine is gaining more and more interest in the field of biomedical sciences. Gold nanoparticles (GNPs) have been extensively used in cancer research due to their ability to act as an anti-cancer drug carrier for chemotherapy and as a dose enhancer in radiotherapy. Most GNP research in the past involved a system where GNPs were in the cytoplasm of the cell as unmodified GNPs enter the cell through a receptor mediated endocytosis. However, it is predicted that therapy response can be further enhanced if GNPs can be effectively targeted into the nucleus. Nuclear targeting requires a modification to the GNPs to escape the regular endo-lyso pathway and target to the nucleus. An effective strategy for designing a GNP-peptide complex for targeting the nucleus will be presented. Two different sequences of peptides where conjugated onto GNPs. The role of one peptide enhanced the uptake into the cell, while the other induced nuclear delivery. With nuclear targeting, there is a possibility in producing additional low-energy secondary electrons in response to irradiation within the nucleus. This can cause more damage to the DNA. This research will establish a more successful NP-based platform for combining treatment modalities that can lead to a more effective approach in the treatment of cancer.

SP092 - Neural Signal Processing: Part 1

SP092.1 - Delta-Modulated High Frequency Oscillations Linked to Pathological Brain in Female Mecp2-Deficient Mice
Author(s): Sinisa Colic1, Min Lang2, Rob Wither3, Liang Zhang4, James H. Eubanks5, Berj L. Bardakjian6
1Electrical And Computer Engineering, University of Toronto, Toronto/CANADA, 2Department Of Physiology, University of Toronto, Toronto/CANADA, 3Department Of Neurology, University of Toronto, Toronto/ON/CANADA, 4Department Of Surgery, University of Toronto, Toronto/CANADA, 5Institute Of Biomaterials And Biomedical Engineering, University of Toronto, Toronto/ON/CANADA

Mutations in the X-linked gene encoding methyl CpG-binding protein 2 (MeCP2) have been linked to a neurodevelopmental disorder known as Rett syndrome. Rett syndrome is predominantly found in females, occurring 1 in 10,000 live births. Among other impairments the clinical manifestation of Rett syndrome typically involves epileptic seizures, providing a unique genetic model of epilepsy. Me Cp2-deficient mouse models recapitulating many of the deficits of Rett syndrome have been developed to examine the seizure-like activity from intracellular electroencephalogram (iEEG) recordings. The majority of the studies to date have focused their analyses on the low frequency oscillations (LFOs) associated with the epileptiform discharge rhythm occurring in the 6 – 10 Hz frequency range. However, some more recent studies on Mecp2-deficient mice have revealed the existence of high frequency oscillations (HFOs) in the frequency range 80 – 600 Hz and shown that these HFOs interact with the phase of the LFOs. HFOs are an important clinical biomarker for seizure-onset zone, often used by clinicians to determine resection areas in patients with intractable epilepsy. Furthermore, recent clinical studies are suggesting that by examining the LFO-HFO interactions it may be possible to achieve a more accurate identification of the epileptogenic zone which would potentially lead to more successful resection outcomes. In this study the coupling of HFOs to the phase of the LFOs was examined in female Mecp2-deficient mice before and after mecp2 gene reactivation therapy. Our analyses show that the modulations could be subdivided into two distinct categories, coupling between the phase of the delta LFO (3 – 6 Hz) with the amplitude of the fast ripple HFO (400 – 600 Hz) and coupling between the phase of the theta LFO (6 – 10 Hz) with the amplitude of the fast ripple HFO (400 – 600 Hz). Examining the differences in modulation before and after mecp2 gene reactivation revealed that the delta with fast ripple modulation was abolished, whereas the theta with fast ripple modulation diminished. This matches the findings of a recent clinical study showing that the modulation of the delta with the fast ripple was an indicator for epileptogenic onset zone, and when that region was resected it would lead to successful surgical outcome. As the mecp2 gene is reactivated the animals show significant improvements suggesting that an interplay exists between the delta LFOs and the fast ripple HFOs leading to a pathological brain. Understanding this interaction could potentially be used as a biomarker for accurately identifying pathological seizure activity and potentially lead to better treatment outcomes.

Acknowledgement This work was supported by grants from the Natural Sciences and Engineering Research Council of Canada and from the Canadian Institutes of Health Research.
SPO92.2 - Contrast between Spectral and Connectivity Features for Electroencephalography based Authentication

Author(s): Chunjung Han1, Sangkyong K. Kim1, Heenam N. Yoon1, Wonkyu K. Lee1, Cheoolsoo S. Park1, Kokeun K. Kim1, Kwang Suk Park1
1Interdisciplinary Program Of Bioengineering, Seoul National University, Seoul/KOREA, 2Department Of Computer Engineering, Kwangwoon University, Seoul/KOREA, 3Center for Cognition and Sociality, Institute for Basic Science, Seoul/KOREA, 4Department Of Biomedical Engineering, The College Of Medicine, Seoul National University, Seoul/KOREA

Biometrics using electroencephalography (EEG) have received attention as a strong security method and has been investigated by many researchers. Studies applied spectral and connectivity features to identify individuals. However, comparison of spectral and connectivity features are not yet conducted in the aspect of stability. In this paper, we present contrast between spectral and connectivity features for EEG based authentication with signals measured in different days. Spectral features are represented as power spectrum density (PSD) over 2-40Hz with 1Hz resolution provided from each channel. Connectivity features are presented as coherence (COH) of two channels combined, frequency range of 2-40Hz with 1Hz resolution. Total of 20 subjects participated and measured 32 channels of EEG for 10 seconds in eyes-closed resting state in three different days. We evaluated false authentication rate (FAR), false rejection rate (FRR) and half total error rate (HTER) as performance of authentication system designed: by using data measured in first day as train data (600 trials) and others as test data (1,173 trials). The similarity of data is measured using correlation modified Euclidean distance. During the decision making process, two values of threshold were set. The results were achieved with minimum of 10.45% HTER when using PSD, and 17.45% of HTER when using COH. It is well known that PSD features are relatively stable over time thus we post-analyzed coherence characteristics of EEG measured over three different days to evaluate stability. To assure stability, those that failed to reject ANOVA and highly correlated (over 0.8) were filtered in each subject in alpha band (8-13Hz) and composed coherence map for each participant. We concluded that considering both PSD and COH, feature filtering is necessary in order to guarantee efficient EEG based authentication.

SPO92.3 - EMG artifact removal using ICA-based dipole distribution from scalp EEG of epileptic patients

Author(s): Chunsheng Li1, Daniel Jacob1, Trevor Hilton1, Jose Martin Del Campo2, Peter L. Carlen1, Berj L. Bardakjian1
1Institute Of Biomaterials And Biomedical Engineering, University of Toronto, Toronto/Canada, 2Toronto Western Hospital, Toronto/Canada

Biomarkers used to guide the resection of the epileptogenic zone depend on proper placement of intracranial electrode sets, which in turn depend on analysis of scalp EEG. Under normal conditions, such signals are contaminated by muscle artifact. Neck, eye, face and mouth muscles are major sources of this artifact. Due to volume conduction, the artifact can be detected across the entire head. In this study, we introduce an artifact removal method based on independent source analysis to identify the generator of the muscle artifact. The goal is to objectively identify the components which would otherwise require time-consuming manual inspection.

Methods:

The proposed method examines the dipole source distribution of the independent components (ICs) produced by independent component analysis (ICA) with respect to the underlying muscle anatomy, as well as their spectral characteristics. Firstly, dipole fitting method (DIPFIT) is used to reconstruct each IC’s dipole in a four layer head model. The head model is divided by seven regions based on the anatomical basis shown in Fig. 1.

Fig.1 Sphere space partition, central region (R0), forehead (R1), temporal (R2), occipital (R3), mouth (R4), neck (R5) and outside regions (R6). (Adapted from Shackman et al. 2009).

Each dipole is assigned to one of the seven regions. Dipoles assigned to R0 are assumed to be EMG free since there are no muscle sources in that region. All other regions contain functionally independent EMG sources which can be identified by computing various spectral signatures. For example, the linear decrease of EEG power spectrum with linear increasing log frequency can be used in identification of an EMG component. Other signatures include peaks in frontalis activity around 25Hz, whereas temporals generates a low peak around 20Hz and broad plateau centered around 40–80 Hz (Goncharova et al. 2003). Scalp EEG for 4 patients with epilepsy from the Toronto Western Hospital was analyzed.

Results:

Combining the dipole distribution and spectral characteristics, artificial ICs can be removed. Sources modeled from synchronous iEEG data are used to validate sources modeled from the artifact-removed EEG.

This work is supported by NSERC, CIHR, and China Scholarship Council.

SPO92.4 - Power based features of epileptic iEEG rhythms to demarcate brain regions for resection

Author(s): Joshua A. Dian1, Yotin Chinvaran1, Peter L. Carlen1, Berj L. Bardakjian1
1University of Toronto, Toronto/Canada, 2Phramongkutklao Hospital, Bangkok/Thailand

Epilepsy impacts up to 1% of the populations and despite optimal care with anticonvulsant medications 39% of patients continue to suffer uncontrolled seizures. Resection surgery provides a subset of these patients an alternative treatment which promises seizure freedom; however, identification of regions suitable for resection remains a challenging problem and results in many patients not achieving meaningful improvement despite surgery.
Intracranial EEG (iEEG) data was obtained from grid electrodes (8x8 or 8x6) implanted in epilepsy patients in preparation for resection surgery. Recorded time series were filtered to remove line noise and differentially referenced resulting in 4x8 or 4x6 channel grids. Previous studies have identified low frequency oscillations (LFO) (<30 Hz) and their relationship with high frequency oscillations (HFO) (>80 Hz) as key markers in classifying ictal events and delineating the epileptogenic zone. In particular, our group has previously shown that amplitude modulation of the HFO activity by the delta rhythm can be used to delineate electrodes of interest for resection.

Here we investigate the use of computationally efficient power based features of the iEEG in order to identify target regions suitable for resection. Empirical mode decomposition (EMD) was used to extract rhythmic components of the iEEG which corresponded to both LFOs and HFOs. Power ratios computed on temporal windows of the extracted LFOs and HFOs formed the feature space. A support vector machine (SVM) classifier was trained/validated using the features extracted from Engel Class I patients and was subsequently used to identify grid electrodes suited for resection. Consistent with previous reports, classification accuracy was state dependent as the characteristic features varied at different phases of the ictal event. The classifier was further able to selectively mark electrodes that were consistent with good surgical outcomes (Engel Class I).

SPO92.5 - The alpha rhythm in a rodent model of epilepsy is enhanced when adenosine receptors are blocked

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There are observable spectral markers of seizures in the electroencephalograms and intracranial recordings of epileptic patients. A closer inspection of the pathological rhythms underlying these seizures may aid in the identification of certain neuronal and glial cell populations or synaptic networks involved in the transition through the seizure events. In epilepsy, it has been suggested that the ketogenic diet has a therapeutic effect on seizures by metabolically down-regulating the enzyme adenosine kinase thereby increasing ambient adenosine and activating the adenosine A1 receptor in the cortex. During seizures, it has been proposed that adenosine levels rise, which cause binding of this ligand pre- and post-synaptically to these A1 receptors, inhibiting the excitatory synaptic network and terminating seizures. Mice that have been kindled with pentylentetrazol treatment experience generalized seizures and show an increase in the cell surface expression of the A1 receptor in many brain regions, including the somatosensory cortex. This finding validates the use of a mouse model of epilepsy in the study of the adenosinergic actions on seizures. What has yet to be identified is the direct effect of the adenosine-A1 receptor complex on the rhythms underlying these epileptic events. The purpose of this investigation is to first assess whether or not a common rodent cortical seizure model shows similar spectral features as clinical cases, and then whether or not there is a pathological frequency band that is restrained due to the presence of extracellular adenosine. Local field potentials were recorded from 500um thick coronal slices from layers 2 and 3 of the mouse somatosensory cortex. Omitting the magnesium in the extracellular artificial cerebral spinal fluid induced two forms of spontaneous field events: long duration seizure like activity and short duration bursts. The pathological oscillations underlying these bursting events were characterized by time-frequency spectral analysis using the continuous wavelet transform. The A1 receptor antagonist DPCPX was applied extracellarily at various concentrations. Dose dependent changes in the power of certain frequency bands were quantified. This model was shown to contain pathological rhythms in the delta (1-3Hz) and theta (4-8Hz) bands. It has been observed that although this antagonist does not significantly alter the duration of the long duration seizure like events, it does increase the total number of shorter duration bursts between these events and selectively enhances the overall power of the alpha rhythm (9-14Hz) in a dose dependent manner. During the initial phase of the long duration seizure like events the power of the alpha rhythm was enhanced under DPCPX + low magnesium compared to similar intervals taken from seizure like events in the low magnesium model. The change in rhythms underlying subsequent phases of the long duration seizures and short duration bursts are currently being characterized.
SP093 - Health Technology Assessment and Cost Effective Technologies for Developing Countries and Usability and Human Factors Engineering for Medical Devices and System Design: Part 1

SP093.1 - The maintenance needs of oxygen concentrators in low-resource settings and implications for technician training: Experience from The Gambia

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Oxygen is an essential medicine for treating pneumonia, the leading cause of death in children under five worldwide. Yet, providing a sufficient and reliable supply of oxygen is a major challenge for many health facilities in the developing world, particularly in paediatric care units. The cost-effectiveness of oxygen concentrators versus compressed gas cylinders as a source of oxygen in low-resource health facilities has been demonstrated. However, some maintenance and repairs are required to optimize their longevity. To date, evidence of their long-term functionality in the field has been scarce.

The Biomedical Engineering Department at the Medical Research Council Unit in The Gambia manages and maintains 27 oxygen concentrators at several sites across the country, and has kept electronic records of all repairs and preventive maintenance (PM) on these devices since 2006. Through a retrospective analysis of about 800 repair and PM records between 2006 and 2013, we found that the majority of concentrator repairs were low-cost and required a low technical experience level to complete. For example, the most common repairs were filter, battery or valve replacements, and faulty tubing - all were repairable for less than US$10 each. Median cost of replacement parts per concentrator over the entire analysis period was US$9.44 [interquartile range: US$0, US$63.40]. Seven expensive and complex repairs were rare, and typically occurred after 2.5 years of operation. The concentrators had received an average of over three PM checks per year. Of the 27 concentrators introduced since 2006, 85% are still in service with a median age of over 6 years. We estimate that the useful lifespan of oxygen concentrators in low-resource settings could reasonably exceed 7 years provided a system is in place for repairs and preventive maintenance.

Additionally, we used these repair data for a skill-mapping analysis whereby we identified 31 basic biomedical engineering technician skills that would be sufficient for the repair of over 90% of observed oxygen concentrator failures. Most of the skills identified were drawn from the library of Biomedical Technician Assistant (BTA) skills developed by Duke University’s Developing World Healthcare Technologies Lab and Engineering World Health (http://library.ewh.org). Each of these skills can be taught to a BTA in 2 hours. We used this skill-mapping analysis to propose an evidence-based training curriculum specifically tailored to the maintenance of oxygen concentrators in low-resource settings.

This work has provided insight into the broader support ecosystem required to manage and maintain oxygen concentrators and other low-complexity medical devices in low-resource settings. Specifically, some of the key elements for the successful use of oxygen concentrators in our Gambian setting have been: uniform and context-appropriate device selection; trained technicians and an established health technology management program; a system for routine preventive maintenance; and resources for and access to spare parts. With this support ecosystem in place, oxygen concentrators can be an appropriate and low-cost technology for supplying medical oxygen in low-resource settings.

SP093.2 - Global Medical Devices Pricing Survey

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To guarantee equitable access to medical devices, reliable information must be available for policy-makers and procurers. Due to lack of information on medical devices pricing, Low and Middle-Income Countries (LMIC) face several disparities during the acquisition process; a public procurer in Latin America paid 300% more for the same device as a public sector organization in Europe. A few countries, such as Brazil, Japan, and Iran have made several efforts to provide reference information to procurers within their countries. However, the majority of countries have no such information available. Since health technology is an essential building block to achieving Universal Health Coverage, information transparency and pricing regulation should treated as priorities by high-level health authorities.

Since 2011, the WHO Medical Devices Unit has begun to address the issue of pricing inequity by building an evidence base. Two studies have been completed by the Medical Devices Unit. The first study detailed price components throughout the supply chain as well as a breakdown of the operational costs generated by 7 selected medical devices (excluding medicines, drugs and vaccines). This study conducted a pilot survey that includes defined parameters to measure price components and operating costs of medical devices over a worldwide representative countries sample and industry sector. The second study provided a conceptual framework for financial access to medical devices. This work supported the pilot of Global Medical Devices Pricing Survey (GMDS), which was launched in 2013. For the GMDS, quantitative information on price components of 21 medical devices were collected from several stakeholders within the health sector, qualitative information on procurement, industry and trade were collected as well. Technologies, brands and models were selected thorough research and evaluation of the products used most commonly throughout the world.

Results from surveys derived from these studies shared a common dilemma: a lack of responses with comparable and useful information. In the first case, only 6 out of 24 countries had completed the survey. For the GMDS, only 15 organizations worldwide submitted responses. Most survey responders chose to report general information on industry, procurement, and trade, rather than medical devices price components. As a result, it is necessary to do an extensive review of the selected medical devices as well as the surveyed participants.

In order to improve global data collection for the forthcoming GMDS, WHO is taking into account the outcomes of the pilot of GMDS, the Global Atlas of Medical Devices (GAMD) 2013 and efforts made by other countries. This includes redefining qualitative information and reselection of medical devices to be included on the
Availability of reliable information on medical devices pricing is the first step in the long path to achieve transparency and pricing regulation policy, possible solutions for disparities within the medical devices market for LIMC.

**SP093.3 - Methodology to evaluate physical environment parameters in healthcare services**

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The physical environment in hospitals should provide adequate conditions in terms of lighting, thermal comfort, air quality, noise level, and workplace. If such conditions are not appropriate, both workers and patients may be negatively affected. The main objective of this work is to develop a human factors and ergonomics based methodology to enable the evaluation of the physical environment in patient care areas. In order to do so, the methodology was developed according to six steps. First, literature research was performed to determine the parameters to be evaluated, which were, then, organized in six groups: work area, noise, lighting, environmental parameters, power outlets, and medical gas outlets. Second, three methods to evaluate the selected parameters were defined: measurement, observation, and written survey. In the third step two forms were created to aid in the parameters measurement and observations. The fourth step involved the development of a written survey in the form of a questionnaire to be applied to healthcare staff. The fifth step consisted of the creation of a method to process the collected data (measurements, observations, and written survey). Finally, in the sixth step, dashboards were developed to report the collected data. The methodology was applied in two intensive care units (ICU) of a public teaching hospital, generating two reports. The analysis of these reports showed that the temperature, relative humidity, and noise in some ICUs were not always in accordance with the established limits. Moreover, the fact that some workers were negatively affected by physical environment parameters such as noise, lighting, and temperature could be verified through survey answers. In addition, there were complaints regarding risk of slip, trip or fall; reflex, glare or shadows; annoying drafts, unpleasant odors, and air quality; as well as the number and positioning of power outlets and medical gas outlets. The methodology met its targets, having generated results that allowed the diagnosis of the effect of some environmental parameters on workers. In addition, the ICU clinical board used the study results in order to develop a campaign aiming at noise reduction.

**SP093.4 - HB-HTA method for the evaluation of exclusive Medical Devices**

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**Introduction:**

The Hospital Based Health Technology Assessment (HB-HTA) method is applied to the purchasing process of exclusive and so called “irreplaceable” medical devices, to support the decision of hospital managers.

**Objectives:**

According to Lombardy region rules for transparency and anticorruption, our hospital adopted a standard procedure for the assessment of exclusive medical devices. It involves a panel of experts: clinical engineers, physicians and economists. Clinical Engineering Department collects informations and collaborates with healthcare professionals in order to write short reports about each technology for hospital decision makers.

**Methods:**

The evaluation method, according to HB-HTA approach, is focused on the most important aspects of the clinical use of the technology such as security, reliability and organization impact.

The standard procedure starts with the compilation of a form in which physicians describe the clinical needs related to a specific innovative medical device, then a scientific literature research and a market survey are carried on. From the data collected in the Italian Medical Devices Database (CND Classification) of the Ministry of Health, possible technical and clinical alternatives are evaluated and compared.

**Conclusion:**

The final aim of Medical Device assessment is a structured report for healthcare management. Quality informations make decisions more robust, consistent, transparent and verifiable in order to maximize the health gains for the patients and to minimize costs and resources, through a better purchasing method.

**SP093.5 - Applying Heuristic Evaluation on Medical Devices User Manuals**

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Driven by the importance of user manuals as a complement to training courses on the operation of medical devices, the objective of this paper is to verify if the heuristic evaluation approach proposed by Zhang and co-authors is applicable to such manuals. After applying the method in the evaluation of a non-medical device user manual and finding some difficulties to interpret the original terms and definitions, we adapted some of the usability heuristics so they would be more directly related to manuals than to devices. The adapted heuristics were applied on the usability evaluation of a linear peristaltic infusion pump's user manual. Although no healthcare professionals were present in the evaluation team, heuristic violations associated to diverse usability heuristics were identified, including some classified as usability catastrophes (the ones which could lead to patient's harm). Even with adaptations, members of the team reported difficulties in fo-cusing on the user manual when the current usability problems seemed to be on the medical device itself. Despite the difficul-ties, the evaluation provided enough data on the user manual problems to formulate some corrective recommendations for the device manufacturer. Additional studies are required to confirm if modifications to some of the original fourteen usability heuristics are really necessary and, if so, what adaptations would be most adequate.
SP094 - Biological Modelling

SP094.1 - Finite Element Analysis of Dynamics of Two Microbubbles Under Ultrasonic Field

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The finite element numerical model of the two microbubbles in the microvessel is built in our study. The model is solved by finite element analysis software. The pressure of observing point P (away from one of two microbubbles A 3 μm) is used to express the intensity of ultrasonic cavitation. The results show that the pressure on point P is higher than single microbubble case because of the aggravation of the cavitation effect, and with the increasing of the distance of two microbubbles, the effect of adjacent microbubble on point P decreases. These results lay the foundation of the research of the agent concentration effect on clinical diagnosis and treatment.

SP094.2 - The value of individual measurements for tumor control probability predictions in head and neck patients

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In the age of personalized medicine, individual measurements of in vitro radiosensitivity and proliferation parameters have great potential for predicting treatment outcome. However, cellular radiosensitivity is quite heterogeneous and therefore concerns exist towards its impact on treatment predictions. It was therefore the purpose of this study to investigate this aspect. Individually-determined radiosensitivities and potential doubling times, as well as tumor volumes from 46 head-and-neck carcinomas treated with radiotherapy, were used to predict tumor control probabilities (TCP) under various biologically-relevant assumptions for heterogeneity in radiosensitivity. TCP predictions were then compared to clinical local control using a ROC curve analysis. The analysis showed that TCP calculated under the assumption of heterogeneous radiosensitivity have the same power of distinguishing between patients with or without local control as from single values for the radiobiological parameters (a sensitivity of 66% and a specificity of 80% for an area under the curve of 0.69). The only difference was in the discrimination criterion (TCP>93% for single parameters and TCP>65% for heterogeneous parameters), illustrating the difference in appearance of the TCP curve under the assumption of heterogeneity. Nevertheless, the results showed that individually determined radiobiological parameters could be quite effective towards predicting treatment outcome for individual patients.

SP094.3 - A Novel Technique for Measuring Electrical Permittivity of Biological Tissues at Low Frequencies (100 KHz or lower)

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Accurate measurement of electrical permittivity (EP) of biological tissues is highly important for a broad range of applications including ECT (Electrical Capacitance Tomography), EPT (Electrical Permittivity Tomography), bone health assessment (Meaney et al.), interaction of electromagnetic fields with biological tissues (Peyman et al.) and food quality classifications (Ngadi et al.). As such many researchers in the past three decades have conducted numerous measurements to obtain electrical properties of biological tissues but despite the fact that most of the researchers have traditionally used an open-ended coaxial cable and vector network analyzer (VNA) for their measurements, a robust and accurate method of measuring biological tissues EP especially at low frequencies has not been developed yet. It is noteworthy that, EP imaging at low frequencies has a good potential to provide valuable diagnostic information. Gabriel et al. indicated that the uncertainty and error percentage of using open-ended coaxial probe and VNA which has been applied in the past three decades as a conventional way of measuring biological tissues EP is quite significant at low frequencies. Computer simulation also indicates that the accuracy of EP measurement for ex-vivo biological samples from conventional procedure (using open-ended coaxial probe and VNA) depends highly on the size and thickness of the samples. This implies that an accurate and reliable measurement of biological tissues EP at low frequencies (100 KHz or lower) may not be achievable by using the conventional technique. In this work we introduce a novel and reliable technique which is capable of measuring the EP of biological tissues at low frequencies in an accurate and robust way. In this technique, we use a highly sensitive capacitive sensor we developed in our laboratory. This sensor consists of two plates that sandwich the tissue sample before its electrical excitation followed by highly precise measurement of the capacitance formed by the two plates and the sample. In order to estimate the sample’s EP, an initial guess of the sample’s permittivity along with its known geometry is fed into an inverse Finite-Element (FE) algorithm we developed for this estimation. This algorithm follows a nonlinear optimization framework which changes the sample’s permittivity in its FE model systematically until the capacitance obtained from the FE model matches the experimental capacitance. The last permittivity value is considered as the estimated permittivity of the tissue sample. The mentioned technique has been utilized to extract the EP from ten freshly excised bovine heart and bone samples. Our results indicate that the average EP of 571 F/m and 22418 F/m at 32 KHz for the bone and heart samples which compare well with values reported in the literature. Also the standard deviation of 50.8 F/m and 1609.3 F/m for the mentioned samples are quite low, which suggest that the proposed technique is highly repeatable.

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Electrodermal activity (EDA) has become a promising technique for assessing sympathetic nervous system (SNS) arousal. Afferent neurons from the sympathetic axis of the autonomic nervous system innervate eccrine sweat glands, and their activity modulates conductance of an applied current. Sympathetic innervation of sweat glands is revealed in quantifiable fluctuations in skin conductance at the skin’s surface, termed EDA. EDA comprises slow and more rapid transients. Tonic EDA states have been assessed using two main measures: skin conductance level (SCL) and nonspecific skin conductance responses (NS.SCRs). The aforementioned measures require manual scoring and human visual verification in the time domain which is cumbersome and often subjective. Hence, there is a need for quantitative signal processing techniques to assess the SNS arousal. To this end, we applied power spectral density (PSD) analysis to EDA signals in order to determine correlations between frequency-domain EDA index (0.045 to 0.15 Hz) and EDA measures in the time-domain (SCL and NS.SCRs). We employed the same range of frequency used for sympathetic assessment in heart rate variability analysis, which corresponds to low frequency (LF) index. We also tested the ability of those indices to discriminate between levels of sympathetic arousal. Sympathetic arousal was elicited using orthostatic stress (supine, standing and sitting positions). Seven subjects were recruited and 4 minutes of EDA signals were recorded for each position. Two minutes of clean signal (after one minute of starting recording and one minute after asking the subject to change position) were used for further processing. LF-EDA and SCL was weakly correlated ($r = 0.374$, $p = 0.055$); LF-EDA and NS.SCRs more correlated ($r = 0.545$, $p = 0.032$) than SCL. SCL and NS.SCR presented statistically significant differences between sitting and supine, but not between standing and sitting. However, LF-EDA showed statistically significant differences between the three positions. This shows a potential of PSD of EDA for assessing sympathetic arousal under orthostatic stress.

**SP095.2 - Multivariate Analysis Classification Based on Multi-Channel EMG Multisite Microelectrode Recording, Principal Component Analysis, and Hierarchical Clustering**

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**Hypothesis/Rationale** The main HYPOTHESIS is that when a Writer’s cramp (WC) subject writes with an abnormal posture, it is difficult to determine if that posture is because of the primary dystonic force or if a compensatory force (applied by the WC subject) has overcome the primary dystonic force and has resulted in that posture. One way to differentiate between those two would be to look at the mirror movements. Mirror movements (MMs) are seen in the right hand (RH) while writing with the left hand (LH). In case the primary dystonic force is resulting in the abnormal posture while writing with right hand, the MMs would be in the same direction i.e., they would be **beconcordant**. If a compensatory force (overcoming the primary dystonia) has resulted in the posture, this would be seen in the MMs which would be in the opposite direction i.e., they would be **discordant**. We hypothesize that there is no EMG recognizable difference in MMs of concordant and discordant subjects. If the data reveal that there are significant differences in MMs of the two groups of subjects (as we expect it to be) our expectation that there is EMG recognizable difference between the groups is justified and the analysis can lead to (clinically) meaningful insight. This study showed significant quantifiable EMG differences in the signals seen while writing with the right and left hands between those writer’s cramp subjects with concordant mirror movements (C group) versus those with discordant mirror movements (D group). These differences were robust and seen in every measure of dispersion, such as in the patterns of significance of f-values for ratios of variances. Cluster analysis and more sophisticated analyses using advanced multivariate techniques leading to effective data summarization and measures of dissimilarity between subjects as reflected in the signals recorded and consequent possible clustering among them, however, did not lead to any meaningful clinical conclusions. These analyses could possibly be applied to longitudinal follow-ups and correlations with a normal control population in future to better comprehend the WC-phenomenon. The work on muscle signals and their application in neurological disorders as well as disabilities of dexterous movement, such as writing and the results in a vast data regarding the functioning on the muscles certainly and gainfully utilized by the biomedical scientists for further modeling of EDA.

**Background:** Prevalence-rate-of-generalized/focal dystonia according to various studies (Muller J and many other scientists) varies from $0.17$ to $0.05$ per 100,000 population and that of focal dystonia varied according to type of dystonia. The prevalence-rate of general dystonia was $5.3$ to $1$ per 100,000 population and that of focal dystonia varied according to type of dystonia. The prevalence-rate of general dystonia was $5.3$ to $1$ per 100,000 population and that of focal dystonia varied according to type of dystonia.

**Objective:** To develop a computational model using the model to develop a new clinical experimental setup, to design and build a multi-channel EMG machine and attempt to differentiate between those with concordant (C) and discordant (D) MMs in WC, in order to establish that there is a quantifiable difference between these two groups.

**SP095.3 - Blanket Fractal Dimension for Estimating Tidal Volume from the Smartphone Acquired Tracheal Sounds:**

**Preliminary Results**

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Tidal volume is one of the parameters used for monitoring respiratory activity. Various methods exist for measuring the tidal volume; however, all of them require the use of specialized equipment. Due to their attractive specifications and portability, smartphones are becoming more popular and suitable for measuring vital signs and health monitoring in nonclinical and everyday settings. In this paper, we propose the use of blanket fractal dimension (BFD) for estimating the tidal volume from a smartphone acquired tracheal sounds. Tracheal sounds, as part of respiratory sounds, are non-stationary and stochastic signals, and as such are suitable for fractal analysis. Blanket method creates a strip around the tracheal signal, thus closely following the changes within the signal. As the signal changes faster, the value of BFD becomes higher. In this study, we recorded tracheal sounds with an Android smartphone, while simultaneously we collected the respiratory inductance plethysmography signal via Respitrace system. Prior to every recording, the Respitrace signal was calibrated with a spirometry system, and the obtained calibration errors were less than 10 % (which is in accordance with the manufacturer's manual). Signals were collected from five (N=5) healthy and non-smoker volunteers. Each volunteer performed the experiment two times; first to obtain linear and
exponential fitting models, and then to fit new data onto the existing models. Thus, the total number of recordings was 10. The estimated volumes were compared to the true values, obtained with a Respitrace signal, which was considered as a reference. These reference volumes were limited to a range from 0.2 to 1 L, as it is the normal breathing range, and consequently, only the corresponding portions of tracheal sounds were used in analysis. Since Shannon entropy (SE) is frequently used as a feature in tracheal sounds’ analyses, we also estimated the tidal volume from the same sounds by using SE. The evaluation of the performed estimation, using BFD and SE methods, was quantified by the normalized root-mean-squared error (NRMSE). The results show that the BFD outperformed the SE (at least twice smaller NRMSE was obtained during both days). The smallest NRMSE error of 15.877 ± 9.246 % (mean ± standard deviation) was obtained with the BFD and exponential model. In addition, it was shown that the fitting curves calculated during the first day of experiments could be successfully used for at least one following day. These results indicate the possibility of obtaining a portable system for tidal volume estimation, which can be used for more than one day without the need to calculate fitting curves during every day’s experiment.

SP095.4 - A Robust and Realistic Framework for Clinical Classification of Myocardial Infarction
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Early detection of Myocardial Infarction (MI) or heart attack is important to reduce mortality rate of cardiac diseases and automatically recognize them in order to help the diagnoses and eventually effective treatment of MI patients. Although various advanced algorithms have been published previously, there are a number of issues regarding reproducibility, public availability, clarity that even some of them ‘over fitted’ the classifier and performed biased pre-processing (feature selection) with all the data set to achieve high accuracy. We aim to create a robust and realistic framework for clinical classification of MI. To achieve this, firstly, we set the requirements for realistic clinical evaluation using predictive modelling and validation as well as proposed practical guidelines for reproducibility. Secondly, to detect MI efficiently and accurately, a novel approach based on Stacked Autoencoder (SAE) is used which has deeper representation power and also needs less pre-processing. We also give essential insight on why and how SAE works for different ECG data. Thirdly, we conducted systematic comparisons of the newly proposed SAE method and Continuous Wavelet Transform (CWT) based Linear Discriminant Analysis (LDA) using real ECG data set. Lastly, based on the predefined requirements, we reflected the clinical reality and corrected some other papers mistake while considering the realistic aspect of separating training and testing dataset to avoid ‘over fitting’ and biased feature selection and thus performed cross validation (with 2 level 10 fold cross validation). SAE always outperformed CWT based LDA approach. The accuracy of SAE is 87 % while the biased and ‘over fitted’ model produced an accuracy of over 99 % which is clinically unrealistic. We are improving SAE approach as it is new for ECG application, so there are more room for future improvement. The novel classification approach developed in this paper can reliably and efficiently provide useful information to clinicians and alert when state of the heart patient changes, could help clinicians realistic diagnoses and eventually effective treatment of cardiac patients.

SP095.5 - A Mother Wavelet Selection Algorithm for Respiratory Rate Estimation from Photoplethysmogram
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Photoplethysmogram (PPG) is known as a low-cost optical measure for detecting the blood volume changes. Recently, a new attempt at estimating respiratory rate (RR) from PPG signal becomes an active area. It can be implemented by different algorithms among which wavelet based methods are commonly used with good performance achieved. In previous work, several popular mother wavelets, including db10, sym8, bior6.8, rbio6.8 and coif5, are compared and db10 exhibits the best performance on restoring the useful respiratory information from PPG signal. However, the study on the reason why different mother wavelets have different performances on RR estimation as well as how a suitable wavelet can be easily selected is insufficient. In order to explore this issue, a mother wavelet selection algorithm is proposed in this paper shown in the following figure.

![Wavelet Selection Algorithm Diagram](image)

In our approach, the input PPG signal is decomposed by six popular mother wavelets, namely db10, db12, sym8, bior6.8, rbio6.8 and coif5, and the results are compared in terms of the sum of decomposition coefficient magnitudes in every frame. The mother wavelet with maximum value is chosen to extract the wavelet coefficients containing RR information. By using the extracted coefficients, the reconstruction process is applied to form the respiratory waveform. In the experiments, the proposed algorithm is compared with the related six mother wavelets working separately. Two datasets are used, one of which has 21 PPG signal segments recorded by our PPG acquisition system and the other has 16 PPG signal segments randomly selected from the MIMIC database. Two evaluation tools, root mean squared normalized error (RMSNE) and Bland & Altman plot, are adopted. In RMSNE comparison between reference RR and estimated RR, the proposed algorithm obtains the minimum error rates of 2.373% and 1.4% on two datasets respectively. For Bland & Altman plot where smaller range between 95% limits of agreement indicates a better performance on RR estimation, the proposed algorithm obtains the minimum ranges of [-0.013, 0.011] Hz and [-0.003, 0.007] Hz on two datasets respectively. The above evaluation results demonstrate the better performance of the proposed algorithm. In addition, the finding reveals that the mother wavelet with a larger sum of coefficient magnitudes has a better performance on RR estimation from PPG signal which can be used as wavelet selection criteria in this area.

SP095.6 - Mathematical assessment of variability in respiratory airflow patterns
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Mathematical approach was used to study and determine unsteady respiratory airflow dynamics for inspiratory and expiratory breathing cycles and to analyze pulmonary data under different levels of ventilatory conditions. The work involved acquiring and processing of respiratory airflow patterns from healthy subjects under varying levels of induced obstruction. A set of mathematical equations based on the Fourier series model were developed to describe the airflow
patterns. Coefficients obtained from the Fourier series model were evaluated to obtain their ranges of values for different levels of ventilations. The goal to assess the airflow mechanics is approached by numerical modeling of the respiratory airflow network. Graphical methods were used to evaluate the goodness of fit and their statistics including the SSE, R-Square, Adj R-Sqr and RMSE. Basic statistical analysis which includes the mean and standard deviation for the airflow signals was obtained. In order to study the variability of airflow limitations, different size mouthpieces were used.

**SP095.7 - Spectral Analysis of Respiratory and Cardiac Signals Using Doppler Radar**  
**Author(s):** Philip Tworzydlo, Adrian D.C. Chan  
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Inmate injuries and deaths remain a significant problem for correctional institutions, increasing the need for continuous monitoring of inmates. A Doppler radar device is investigated for use as a contactless method of vital sign monitoring (e.g., breathing and heart rate) in a single cell setting. The recorded radar signal is analysed in both the time domain, and in the frequency domain. The radar signal and its frequency spectrum is compared against the signals and frequency spectrums obtained from an electrocardiogram and a respiratory inductance plethysmography band. The breathing and heart rate estimates obtained from the radar match up with the estimates provided by the respiratory band and electrocardiogram. Results show that the radar device demonstrates good potential for contactless vital sign monitoring.

**SP096 - Optical Imaging: Applications**  
**TRACK 01: IMAGING**

**SP096.1 - Live-cell Raman microspectroscopy to differentiate between normal and malignant ovarian surface epithelial cells**  
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Raman microspectroscopy (RMS) is a non-invasive, label-free optical technique that is based on the inelastic scattering of light by vibrating molecules. It provides a fingerprint of the common molecular bonds in specimens, including cells and tissues. This technique, in conjunction with multivariate statistical analysis methods, has been applied successfully for the label-free classification of living cells based on their molecular composition, which can be correlated to variations in protein, DNA/RNA, and lipid macromolecules. Here, RMS is applied to normal mouse ovarian surface epithelial (MOSE) cells, M0505, and spontaneously-transformed ovarian surface epithelial (STOSE) cells, which are derived from the MOSE cells and are a model for high-grade serous ovarian cancer.

The Raman spectra collected from individual cells undergo initial preprocessing (background subtraction, normalization and noise reduction) to yield true Raman spectra representative of the cells for subsequent statistical analysis. The means of these spectra are shown for both types of cells in Fig. 1. Although the corresponding images (differential interference contrast microscopy) of the MOSE and STOSE cells shown in the inset appear identical, there are clear differences observed in the spectra that are attributed to differences in molecular concentrations. Using Principal Component Analysis (PCA) followed by Linear Discriminant Analysis (LDA), a clear separation of the cells into the two groups (MOSE and STOSE), with the exception of one outlier, is evident in the preliminary data shown in Fig. 2. The objective of this ongoing work is to characterize the spectral differences between the two cell types in order to correlate them with specific molecular or structural changes. The multivariate classification model constructed using such Raman spectra of MOSE and STOSE cells could thereby potentially be utilized for early detection of ovarian cancer.
SP096.2 - Quantitative image analysis of fluorescence endomicroscopy video sequences for mesenchymal stem cell tracking in regenerative lung treatment

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Introduction: Fluorescence endomicroscopy is a powerful new minimally invasive tool that allows real-time visualization of fluorescently labeled cells within the lungs in clinical and preclinical models. In the context of regenerative medicine for lung damage, the objective of this project is to gain insight into the behaviour of mesenchymal stem cells (MSCs) in the lung of a rat model of lung injury post-radiotherapy. Interpretation and analysis of large video sequences is important to quantify the efficacy of such treatment under different experimental scenarios. In this work, we are proposing an image segmentation method to quantify the number of cells present in the field of view at each timepoint in the acquired endomicroscopy video sequence.

Materials and Methods: MSCs were labeled in culture with a membrane dye (DiD) prior to administration. MSCs were delivered endotracheally into the lung and followed by fluorescence endomicroscopic imaging. Images were acquired in the red channel (660 nm) through a tracheotomy procedure. We followed the rats for a week period and images were acquired on days 1, 2, 5 and 7. Regarding video sequence analysis, we treated each frame individually as a stand-alone image. We used a granulometry approach to determine the size of objects (cells) present in the image and performed morphological opening to detect them. Opening is a morphological operation that dilates then erodes the image with a selected structuring element, in this case a disk, in order to remove small erroneous objects and only select cells. A threshold was subsequently applied to the resulting image to select fluorescent cells over background and each detected object was counted.

Results: We were able to detect labeled MSCs in the lungs in vivo and followed them for a period of one week. At any given time point during the movie we were able to obtain an estimate of the corresponding number of cells present in the field of view. Figure 1 shows a representative endomicroscopy image with the resulting corresponding cell count of 15 cells. We compared this automated method to manual cell counting on a test set of 30 frames and achieved a good accuracy with a root-mean-squared error (RMSE) of 4 cells per frame.

Conclusion: We determined the feasibility of lung fluorescence endomicroscopy for tracking of MSCs in vivo and developed an automated image analysis method to quantify the number of cells in different experimental conditions.

SP096.3 - Shape-Based Diffuse Optical Tomography for Reconstruction of Photothermal Lesions in Prostate Focal Therapy

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Near-infrared interstitial photothermal therapy is undergoing clinical trials as an alternative to watchful waiting or radical treatments for patients with low/intermediate-risk focal prostate cancer. MRI-based thermography is currently used to monitor target tumor destruction based on the measured tissue temperature and calculated thermal energy dose. This indirect method of imaging the treatment zone is used to assess if treatment fully covers the target volume while avoiding damage to adjacent normal tissues, particularly the rectal wall. As an alternative, we are developing transrectal diffuse optical tomography (TRDOT) to directly monitor the photothermal therapy by imaging the photocauterization boundary based on changes in tissue optical scattering.

In this presentation, we describe the development of shape-based diffuse optical tomography as applied to the particular problem of monitoring the expanding photothermal lesion. Standard methods of diffuse optical tomography present an ill-posed inverse problem since the number of source-detector combinations is less than the variant parameters (optical properties within the volume). Hence, there are typically no unique solutions for standard DOT reconstructions. Current practice resolves this situation by imposing spatial or spectral constraints on the solutions.

In our clinical problem, the shape of the coagulated/treated tissue rather than the optical properties is of primary interest. We present a shape-based diffuse optical tomography solution in which shape parameters are used to set varying optical properties within the tissue volume. The shape is an ellipse symmetric about its short axis for a general lesion shape plus spherical harmonics to model small variations from the general ellipsoidal shape. The optical properties of the thermal lesion may vary, but with the assumption that these properties are invariant within the lesion shape.

The solution is applied to simulations of photothermal focal therapy, modelling a growing thermal lesion around a linear 10mm diffusing treatment fiber placed 10mm from the prostate wall. The modelled lesion grows in 1mm radius increments to a final radius of 9mm. Tissue scattering of the thermal lesion was set at 4X the scattering of the surrounding tissue, similar to measured tissue results. Axial and longitudinal source-detector configurations relative to the essentially elliptical thermal lesion were modelled.
The shape-based tomography successfully recovered the correct shape of the thermal lesion for lesion radii >3mm, with the error in the radius <0.5mm. Accuracy improved as the radius increased, equivalent to the lesion boundary approaching the prostate surface. Increasing noise added to the simulated data had little impact on the shape recovery: for lesions within 4mm of the prostate surface, radii error < 1mm up to 16% noise, for smaller lesions, ellipse radii error <3 mm when the noise was greater than 10%. Since the actual optical properties of the lesion may be difficult to recover, the robustness of the shape-based tomography to recover a correct solution when the reconstruction assumes different optical properties than the actual properties of the lesion was tested. Over a large range of optical properties, the shape parameters were recovered within ±1mm.

Shape-based DOT is a viable, accurate method of recovering thermal therapy treatment lesions.

SP096.4 - Transrectal diffuse optical tomography to monitor photocoagulation during interstitial photothermal therapy of focal prostate cancer
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Near-infrared interstitial photothermal therapy is undergoing clinical trials as an alternative to watchful waiting or radical treatments for patients with low/intermediate-risk focal prostate cancer. Currently, MRI-based thermography is used to monitor thermal energy delivery and determine indirectly the completeness of the target tumor destruction while avoiding damage to adjacent normal tissues, particularly the rectal wall. As an alternative, transrectal diffuse optical tomography (TRDOT) is being developed to directly monitor the photothermal therapy by imaging the photocoagulation boundary on the changes in tissue optical properties, particularly scattering. Numerical simulations of optical signals were performed using Nifast to assess the sensitivity of changes in the optical signals to a growing coagulated lesion with higher optical scattering contrast to normal tissue, for varying light source-detector separations in both longitudinal and transverse imaging geometries. The simulations were validated experimentally in tissue-simulating phantoms using an existing continuous-wave TRDOT system. A MR compatible TRDOT applicator probe with a source-detector configuration that is capable of acquiring optical measurements and representative of the potential intended clinical use is assembled and used in these experiments. Phantom measurements and numerical simulations provide critical guidance for the optimum design of a further version of the transrectal applicator probe, in achieving maximum sensitivity to the presence of the coagulation boundary and, consequently, the highest accuracy in determining the boundary location relative to the rectal wall.

SP096.5 - The first in vivo, optical images of neuroblasts migrating away from the subventricular zone deep in mouse brain reveal two patterns of migration: implications for future therapeutic use
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Neural stem cells exist naturally in the adult brain in humans, mice and other animals. Their existence has sparked hope for treating neurodegenerative diseases, stroke and brain injury. In mammals, adult neural stem cells divide and begin differentiating in one of two bilateral germinal zones. One of these is the lateral subventricular zone (SVZ). Partially differentiated cells exit the SVZ and migrate to other regions of the brain. When neural stem cells in the SVZ of mice begin to differentiate into neural precursor cells, or neuroblasts, they normally travel in clusters to the olfactory bulb. This pathway is called the rostral migratory stream. However, after a cortical injury, some of these migrating cells change course and migrate into the cortex. This has piqued interest in manipulating the mechanisms of neurogenesis to repair neural damage. Yet, what is known about neuroblast migration relies predominantly on brain slice studies. These studies have produced conflicting observations regarding mechanisms that drive proliferation and migration, and the rates of movement. To overcome the limitations and confounds inherent in slice preparations, an in vivo imaging system was created using a permanently implanted, optimized gradient index (GRIN) lens and multiphoton microscopy. The SVZ is in a subcortical region that is beyond the reach of standard multiphoton microscopy. The implanted lens overcomes this depth limitation. A preliminary longitudinal study was conducted using mice that express green fluorescent protein under the dcx promoter to label neuroblasts. This study is the first to produce images of neuroblasts migrating away from the SVZ in live mice. As expected, most neuroblasts traveled in clusters toward the rostral migratory stream. Surprisingly, a few neuroblasts did not travel with a cluster. These individual cells moved at markedly faster rates and frequently changed directions. In future studies, we will determine what factors influence the migratory path of these lone neuroblasts with the goal of redirecting large numbers of neuroblasts for future therapeutic uses.
SP097 - Quantitative Imaging: Part 2

SP097.1 - Ischemia-time dependent CBF threshold for infarction determined in a porcine model of stroke using CT Perfusion and F-18 FFMZ PET imaging

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**Introduction:** CT Perfusion (CTP) derived cerebral blood flow (CBF) has been proposed as the optimal parameter for delineating the infarct core prior to reperfusion (1), however lack of ischemia-time dependent CBF thresholds for infarction has been problematic. Previous CTP-CBF threshold derivation studies have been limited by uncertainties caused by infarct expansion, and DWI lesion reversibility (2). This study proposes a porcine model for determining ischemia-time dependent CBF thresholds for infarction using contemporaneous CTP and 18F-fluoroethylfluoromazenil (FFM2) PET imaging, with the objective of deriving a CBF threshold for infarction after 3h of ischemia.

**Methods:** Cerebral ischemia was induced in the left hemisphere of 11 pigs by injecting endothelin-1 (ET-1) into the cortex through a burr hole in the skull. CTP scans were completed at baseline, 10, 30 then every then every 30 until 180min post ET-1 injection. If the CBF map at any time point showed reperfusion of the ischemic tissue then a second dose of ET-1 was administered. F-18 FFMZ was injected 2.5h after the first ET-1 injection and a 25min PET acquisition was started 25min post F-18 FFMZ injection. CBF maps from each CTP imaging time point were co-registered and a median CBF map was produced by taking the median value of each pixel. The median CBF maps, the PET images, average images from the baseline CTP study, and blood volume (BV) maps from the 10min post ET-1 CTP study were co-registered. ROIs were drawn on the cortex on the affected and contralateral side and superimposed onto all maps and images. Infarct pixels were identified on PET images as having ischemia-time dependent CBF thresholds for infarction using contemporaneous CTP and 18F-fluoroethylfluoromazenil (FFM2) PET imaging, with the objective of deriving a CBF threshold for infarction after 3h of ischemia.

**Results:** 6 of the 11 animals developed infarction with an average infarct volume of 1.4±0.38cm³. The optimal operating points of the ROC curves corresponded to CBF values of 14.2, 11.8, 18.9, 13.4, 13.9, and 19mL100g⁻¹min⁻¹. The average of these 6 values was calculated to find a 3h ischemia-time CBF threshold for infarction of 15.2±1.2mL100g⁻¹min⁻¹.

**Conclusions:** The 3h ischemia-time infarction CBF threshold of 15.2mL100g⁻¹min⁻¹ agrees well with the threshold of 12mL100g⁻¹min⁻¹ derived in a previous study (3). The ET-1 stroke model has the potential to derive CBF thresholds for infarction at other ischemia times by varying the time between the ET-1 injection and the start of PET imaging.

SP097.2 - Characterization of scatter factors in thyroid studies using a pinhole collimator by Monte Carlo Simulation.

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To study the scatter factors during I-131 thyroid scintigraphic studies with a pinhole collimator (5mm hole) was developed a Monte Carlo (MC) simulation using GAMS code. First, to check the accuracy of the Monte Carlo model, simulated and measured data using a thyroid phantom were compared. The accuracy of the Monte Carlo model was verified by the good agreement between measured and simulated energy spectra and the maximum discrepancies of 2% in the counts/sec/MBq. Next, simulations to investigate scatter were performed for different tissue thickness between the thyroid and collimator (5-15mm). The image's scatter contribution was significant in the 5mm pinhole, being between 27-40%. On the basis of the separated scatter from direct count included in window energy spectra, a preliminary evaluation of multiple window energy correction methods was performed. For the simulated thyroid geometry with pinhole, the reduce inferior double energy window methods (15% on 364keV photopeak window) provides a reasonable correction for scatter. This study is the first approach; we recommend including real thyroid geometry with different thyroid depth-thickness and mass.

SP097.3 - Fluid Quantification Using Temporal Subtraction: Comparing Single to Dual-Energy Digital Chest Radiography

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**Background:** Accurate quantification of thoracic water content is integral to assessing patient health in many disease states. Computed tomography (CT) provides tissue characterization and quantification but is generally not available for critically ill patients. Portable chest radiography (CXR) is often the only imaging modality available to inpatient patients; however, it has limited ability for estimating fluid content. Temporal subtraction (TS) provides temporally separated projections for quantifying differences in tissues over time, but performance is limited by image misregistration. Dual-energy (DE) CXR removes overlapping ribs and can reduce structures that are challenging to register. This research investigates the utility of portable TS-CXR and TS-DE-CXR for the detection and quantification of thoracic water.

**Evaluation:** Temporal subtraction of CXR images taken pre- and post-operation were used to determine change in fluid volume. The algorithm utilized the difference in x-ray attenuation signal between images to derive water thickness and to estimate the difference in water volume. 1-5 solid water blocks (40 ml each) were added (total volume of 200 ml) into the thoracic cavity of a static anthropomorphic chest phantom. CXR (120 kVp) and DE-CXR (60/120 kVp) were acquired after addition of each solid water block. A set of TS-CXR and TS-DE-CXR images were generated by subtracting the no-water image from the set of images with added water, from which volume estimates were derived. The experiment was repeated on a horizontally-moving phantom to simulate motion. Intensity-based rigid image registration was performed between pre- and post-op-
eration images followed by temporal subtraction. Image segmentation of the lung region was improved with TS-DE-CXR due to a clear demarcation between lung space and remaining thoracic region without the confounding impact of ribs. In addition, TS-DE-CXR had fewer misregistration artifacts resulting in improved registration performance and superior accuracy in estimation of water volume. The root mean squared error (RMSE) was 4.74 ml using TS-DE-CXR and 8.9 ml using TS-CXR. The range of error percentage was -7% to +2% with TS-DE-CXR and +6.3% to +16% with TS-CXR.

**Discussion:** TS-DE-CXR images are superior to TS-CXR images in providing accurate estimation of thoracic water volume. TS-DE-CXR has potential to enhance the diagnostic utility of DE-CXR for immobile patients.

**Conclusions:** TS-DE-CXR provides an accurate estimation of the volume of thoracic water. Further work will target validation of the TS-DE scheme on clinically acquired CXR images.

**SP097.4 - Quantitative low-kVp CT angiography in carotid artery imaging**

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Shading and streaking artifacts brought by beam hardening and photon starvation is commonly observed in low-kVp CT angiography (CTA) for carotid artery imaging. Image quality is thus significantly degraded and a faithful observation of carotid artery is impeded. In this paper, we propose a novel quantitative image postprocessing scheme to eliminate these artifacts. In shading correction, we follow general knowledge of the relatively uniform CT number distribution in one tissue component, and continuous and low-frequency shading artifact distribution in projection domain. Coarse image segmentation is first applied to construct an ideal template image where each structure is filled with the same CT number of that specific tissue. By forward projecting the difference between uncorrected CT image and the ideal template, we estimate the continuous and low-frequency shading error signal in projection domain low-pass filtering. An error map is then reconstructed using standard filtered back-projection algorithm from the error signal and added to the original image to correct for the shading artifacts. To suppress the increased noise and streaking artifacts, we first perform a texture extraction to estimate the noise distribution in the image and then incorporate the estimated noise variation into a nonlocal filtering method. The proposed scheme is evaluated in carotid CTA scan using a dual-source CT at 80 kVp, in which the shading and streaking artifacts can be successfully corrected by reducing the CT number error from 246 HU to 63 HU and spatial non-uniformity by a factor of 2.2, respectively. In the volume rendering generated from the corrected CT images, the visualization of carotid artery is improved substantially and comparable to that generated from a CTA scan at 140-kVp. The proposed method is implemented directly on the CT image without access to the raw projection data and is thus attractive for clinical application in low-dose CTA.

**SP097.5 - Evaluation of the ΔV Ventilation Calculation Method Using In Vivo XeCT Ventilation Data**

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Ventilation distribution calculation using 4DCT and deformable image registration (DIR) has shown promising potential in several clinical applications. This study evaluated the direct geometric ventilation calculation method, namely the ΔV method in which the local volume change is calculated geometrically using a deformation transformation, with Xenon-enhanced CT (XeCT) ventilation data from four sheep as the gold standard. The results are also compared to two other published ventilation calculation methods, namely the Jacobian and the Hounsfield Unit (HU) methods. The Diffeomorphic Morphons (DM) method was applied as the deformable image deformation (DIR) technique, and it was evaluated using the 4DCT data of the sheep with manually delineated landmarks in the end-expiration and end-inspiration phases in this study. Spearman correlation coefficient (SCC) and Dice similarity coefficient (DSC) were used for evaluation and comparison. The average target registration error of the landmarks by the DM method was 1.9 ± 1.5 mm. The average SCC with one standard deviation was 0.49 ± 0.13 with a range between 0.36 and 0.67 between the XeCT and ΔV ventilation distributions; 0.50 ± 0.13 (range 0.37 - 0.67) between the XeCT and the Jacobian ventilation distributions, and 0.31 ± 0.10 (range 0.23 - 0.44) between the XeCT and the HU ventilation distributions. The average DSC value for upper 30% ventilation volumes between the XeCT and ΔV ventilation distributions was 0.82 ± 0.03 with a range between 0.79 and 0.86, while for the upper 50% volumes, it was 0.70 ± 0.05 (range 0.64 - 0.77). The average DSC results between XeCT and Jacobian ventilation distributions were the same while between XeCT and HU they were 0.64 ± 0.05 for the upper 50% ventilation volumes (range 0.60 - 0.70) and 0.79 ± 0.03 for the upper 30% ventilation volumes (range 0.75 - 0.82). High ventilation volumes in ventilation distributions generated from 4DCT data were more accurate compared to low ventilation volumes. Ventilation difference introduced by deformable image registration errors improved with smoothing. The following figure shows the SCC values between the XeCT and the ventilation calculated using the three algorithms versus smoothing.

![Graph showing SCC values between XeCT and ventilation calculated using different methods.](image)

In conclusion, ventilation distributions generated using ΔV-4DCT and deformable image registration are reasonably accurate and therefore potentially useful in clinical practice. This evaluation study and previous reports support the use of ventilation calculated using 4DCT in clinical applications in areas such as radiation treatment planning and pulmonary function assessment.
The optimal tumour volume thresholds were 25 cm³, 42 cm³ and 20 cm³ for CMET, FLT and Gd-MRI respectively. There was a significant difference in survival time for tumour volumes above and below these thresholds for CMET-PET (p=0.02), but not for FLT-PET or Gd-MRI.

Conclusion: CMET-PET defined viable tumour volumes may discriminate between high and low survival times in post treatment glioma. FLT-PET or Gd-MRI defined volumes do not appear to be predictive of survival time. Further analysis with more subjects is required to verify the utility of method.

The dose deposited in air was estimated using a thimble ionization chamber at isocenter of the micro-CT scanner. We performed a histological study (H&E and Movat staining) to ensure no damage to the lungs resulted from the x-ray dose received.

Images were reconstructed with 0.05 mm voxel spacing using a FBP algorithm. The concentration of both contrast agents was calculated based on multi-energy equations. To improve the accuracy of the concentration calculations, we tested different denoising methods (on projections and the reconstructed volume).

**Results:**

The dose of each low- and high-energy scan was estimated to be 96.5 mGy and 91.2 mGy respectively. An example of the concentration of contrast agent map is shown Figure 1. Analysis was performed on the H&E stained histological sections to quantify the percentage of inflamed area over the total area of the lung section and the number of white blood cells present.

**Conclusion:**

High-resolution imaging of the vasculature and airways in rodents is achievable at low dose with contrast-enhanced micro-CT using subtraction methods. Because the K-Edges of the two most common CT contrast agents are very close, the multi-energy protocol was more difficult, and would benefit from advanced signal processing and reconstruction algorithms.

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**SP097.8 - High-resolution micro-CT protocol for assessing lung ventilation and perfusion: image subtraction versus multi-energy analysis**

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**Introduction:**

Micro-CT allows full-organ, high-resolution imaging of airways and lung vasculature in rodents when using contrast agents. Advantages include linearity of the measured signal versus the concentration of the contrast agent and co-registration between scans with high resolution leading to a good accuracy. We propose to compare a multi-energy imaging protocol and an image subtraction method to estimate the concentration of two contrast agents at an acceptable x-ray dose level for longitudinal monitoring.

**Methods:**

Respiratory-gated micro-CT imaging (CT120, Gamma Medica) was performed on 6 rats. Each rat was anaesthetized with isoflurane (1.5-2% in O2), intubated and mechanically ventilated. Low-energy images (50 kV, 63 mA, and 0.1 mm copper filtration) and high-energy images (120 kV, 40 mA, and 0.6 mm copper filtration) were obtained at baseline and post-injection of a vascular contrast agent (Binitio eXIA 160XL, 0.45 mL/ 100g). Rats were euthanized and ventilated with xenon while images were obtained with both the low- and high-energy protocols. The spectrum of each protocol was evaluated using HVL measurements and by simulation with the Spetkr freeware.
Abdominal aortic aneurysm (AAA) is a cardiovascular disease occurring when the aorta becomes weak and develops a balloon expansion in its wall. This balloon diameter can reach sizes up to 4 times the normal aortic diameter, with the diameter enlarging at rates of 0.2–1.0 cm/year. Ruptured aneurysm leads to death in 78% – 94% of diseased aortas [1]

Aneurysm rupture is a biomechanical event that occurs when the mechanical stresses in the wall of the aorta exceed the failure strength of the aortic tissue [2].

In medical practice, when the maximum diameter of AAA exceeds 5 cm it is considered at risk of rupture. Surgical repair is usually not considered until the diameter reaches at least 5 cm. However, it is frequently observed that AAAs with diameters less than 4 cm can rupture which raise the need of finding a more reliable method to assess rupture risk.

The role of the intraluminal thrombus (ILT) which exists in more than 75% of AAA was examined using variable thickness and material properties of the thrombus. The role of the ILT has been experimentally examined in number of studies [4; 5; 6].

ILT with variable thicknesses were used here to examine the effect of ILT on wall stresses compared with AAA without ILT.

High-frequency ultrasound (10-100 MHz) is particularly sensitive to small vascular structures that are close in size to the ultrasound wavelength (15-150 mm). The ability to rapidly determine the degree of vascularization in small animals in vivo would provide a useful characterization tool for regenerative medicine. The objective of this study was to determine if direct ultrasonic measurements in the 10-100 MHz range could be used as a vascularization assay for small animals and tissue specimens. To accomplish this, a study was performed at the Ludwig Boltzmann Institute for Experimental and Clinical Traumatology (Vienna, Austria), where the femoral artery in one hind limb of each of sixteen mice was ligated and tested for eight days. Eight of the ligated limbs were treated with vascular endothelial growth factor (VEGF, “treated”) while the remaining eight ligated limbs were not treated (“untreated”). All of the ligated limbs were then allowed to grow ischemic. The unilateral limbs were controls. Pitch-catch and pulse-echo measurements were acquired using a 50-MHz immersion transducer (Olympus NDT, V358-SU), a high-frequency square-wave pulser/receiver (UTEX, UT340), and a 1-GHz digital oscilloscope (Agilent, DSOX3104A). The ultrasonic transducers were coupled to the limbs using glycerol, and triplicate waveforms were acquired from each limb every other day. The ultrasonic parameters analyzed were wave velocity and peak density. Peak density is the number of peaks and valleys in the ultrasonic spectrum between 20–80 MHz, and provides a measure of spectral complexity. In two hospital studies on breast cancer surgical margins, peak density was demonstrated to be sensitive to microstructural changes in tissue due to both benign and malignant processes. The mice were also evaluated with laser Doppler interferometry (LDI), multispectral optoacoustic tomography (MSOT), micro-CT (computed tomography), and histopathology. The results indicated that ultrasonic signals from untreated limbs displayed a steady decrease in wave velocity over the test period as compared to the treated limbs. Peak density displayed no trends for either untreated or treated limbs. The peak density results were consistent with the other evaluation methods, which primarily reveal changes in tissue microstructure and showed no significant differences between the untreated and treated limbs. In contrast, wave velocity is sensitive to the stiffness of the tissue, a material property that is not measured by the other methods. The decrease in wave velocity for the untreated limbs indicates a softening of the muscle tissue, possibly due to inflammation or edema, whereas the decrease and then return to normal for the treated limbs indicates recovery of the tissue. The high-frequency ultrasound may therefore have detected effects due to ischemia and revascularization that were hidden to LDI and histopathology (MSOT and micro-CT data have yet to be analyzed). The study results indicate that high-frequency ultrasound, in particular wave velocity measurements, may provide an added dimension to small animal imaging methods for detecting revascularization. The method is currently being expanded to include high-resolution imaging.

In the 21st century the medical field has majority of its equipment coming in contact with blood is manufactured from plastic polymers. This causes a major concern, where exposure may result in undesirable protein–material interactions that can potentially trigger deleterious biological processes such as thrombosis. To address this problem, we have developed an ultrathin antithrombogenic coating based on monoethylene glycol silane surface chemistry. The strategy is exemplified with several polymers including: polycarbonate and poly (vinyl chloride) -plastic polymers increasingly employed in the biomedical industry. The various straightforward steps of surface modification were characterized with X-ray photoelectron spectroscopy supplemented by contact angle goniometry. Anti-thrombogenicity was assessed after 2,5,10 and 60 min exposure to whole human blood dispensed at a shear rates of 300, 900, 1000 and 1500 s⁻¹. Remarkably, platelet adhesion, aggregation, and thrombus formation on the coated surface was greatly inhibited on all shear rates and both surfaces (>92% decrease in surface coverage) compared to the bare substrate and, most importantly, nearly nonexistent.
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RESULTS

The architecture of collagen fibers ranged from highly organized and parallel fibers at the periosteum, to loosely woven strands in muscle attachment sites, and then to irregular and thin fibers at the perimysium (Fig. 1). The elastin fibers were spring-like, short, and of irregular architecture and arrangement. Elastin fibers were also primarily abundant in the major centroidal axis, and formed a 3D mesh in the z-stack (Fig. 1).

DISCUSSION

Collagen fibers are mechanically robust, flexible and able to resist tensile loading. The network of fasciae, comprising of mostly wavy collagen fibres branching from the perimysium to the periosteum (Fig. 1), suggest that fascia may be mechanically significant in supporting tissue structures, e.g. preventing distension between the muscle and bone.

Since centroidal axes correlate within 5% of anatomical axes, variations in the arrangement and composition of elastic fibers can be associated with its function. Hence the abundance of elastin in the posterior major CA may be functionally associated with the prevalence of greater muscle bulk in its corresponding anatomical aspect.

CONCLUSIONS

Therefore, by harnessing the “smart” properties of nature’s own biological materials and applying a bottom-up approach to engineering novel materials, we aim to facilitate the development and engineering of functional and biomimetic materials. First applications are ongoing for development of novel functional textiles to prevent and...
treat lymphoedema as well as to provide an optimal interface (liner sleeve) for trans-tibial and femoral prostheses.

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SP098.5 - Vascular endothelial cell adhesion and hemocompatibility of biochemically- and topographically-modified poly(vinyl alcohol)

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Currently available synthetic small diameter vascular grafts used for bypass or replacement of native arteries fail within the first 10 years. The lack of mechanical properties matching native arteries, thromboresistance and capacity to stimulate in situ endothelialization prevent the long-term application of small diameter vascular grafts. Thus, there is a critical need for new synthetic small diameter vascular grafts that can achieve compliance, hemocompatibility and endothelialization. Poly(vinyl alcohol) hydrogel (PVA) is an excellent candidate for vascular grafts due to its tunable mechanical properties, high water content and high tensile strength. Yet the bio-inерт-ness of PVA must be addressed to improve endothelialization in situ. Both biochemical and topographical modifications have been used to stimulate specific vascular endothelial cell behaviours on synthetic materials by mimicking the physiological cellular niche. Thus, we hypothesize that the modification of PVA with both biochemical and topographical modifications can provide a hemocompatible microenvironment that stimulates endothelialization. PVA modified by the immobilization of fibronectin, RGDS peptide, and cyclic RGD (cRGD) peptide showed slight increase in the adhesion of human umbilical vein endothelial cells (HUVECs) while PVA modified with immobilized heparin showed significant decrease in the endothelial cell adhesion. The cRGD modified PVA did not exhibit any significant change in platelet adhesion, activation and morphology when compared with unmodified PVA in an in vitro hemocompatibility assays using LDH assay, microparticle release percentage and scanning electron microscopy, respectively. Using solvent casting, unmodified and cRGD-modified PVA were incorporated with micro-gratings or microlens topography. Combination of cRGD and micro-gratings or microlens topography on PVA showed significant increase in endothelial cell viability compared with unpatterned and unmodified PVA. Platelet adhesion on all PVA modified with microgratings was comparable with unpatterned and unmodified PVA. PVA with microlens topography significantly increased platelet adhesion, while PVA with both convex and cRGD modification showed no difference with unpatterned and unmodified PVA. Platelets also changed from the fibrous, activated phenotype on PVA with microgratings or microlens to round and less active phenotype on PVA with both cRGD and topography (Figure 1). The in vitro vascular endothelial cell adhesion tests and hemocompatibility tests demonstrated that modification of PVA with both biochemical and topographical cues may serve as an excellent surface for hemocompatible vascular grafts with enhanced endothelialization.

Figure 1. Platelet adhesion on PVA surfaces modified with cRGD and topography.

SP012.1 - Effects of PEMF on Neuroblastoma Cells Previously Exposed to Antidepressants

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PEMF on Neuroblastoma Cells Previously Exposed to Antidepressants

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Interaction between magnetic field and living systems is inevitable; in fact, we are immersed in an ocean of magnetic field due to the magnetic field of the earth and the technology developments. Interaction between magnetic field and living systems is inevitable; in fact, we are immersed in an ocean of magnetic field due to the magnetic field of the earth and the technology developments, this one already have medical applications, currently, the pulsed electromagnetic fields (PEMF) are an alternative option for the treatment of some mental illness as the depression or schizophrenia. In order to have estimation of the side effects from PMF and drugs used for treat this kind of disorders. In this work, it is presented a comparison of the effects of imipramine, a drug for the treatment of depression, and the effects of PMF on cells from the line SHSY5Y, which provide us a representative model of neuronal tissue. The assays were done in both ways, the separately effects and the jointly effects. The imipramine at high dosage for a short period (120 mg/mL, for 20 min) shows cell damage on both, the morphology and the metabolism. Meanwhile, the PMF (50 Hz, 7 mT for 8 h) shows a cell proliferation and a decrease of their metabolism. The jointly assay indicates that the PMF balances the morphological negative effects from imipramine. In the long term these results can impact a therapy that may be more efficient. However, more research is needed in this area

SP012.2 - Porous bio-SiC ceramics from wood: approaching new medical implants

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Introduction

Silicon carbide ceramics (SiC) are porous structures derived from different wood sources. The porosity and pore size of such ceramics may repeat the structure and porosity of specific bones in human body. Additional coating of SiC ceramics with hydroxyapatite (HA) and tricalcium phosphate (TCP) using a novel gas-detonation deposition method (GDD) could be advantageous with regard to bone replacement. This work investigates the porosity of SiC ceramics and explores the method to obtain bioactive surfaces.

Methods

Biomorphic porous SiC ceramics were synthesized using forced infiltration with liquid silicon of carbon matrices derived from different hardwood precursors (Hornbeam, Sapele, Tilia and Pear). This process involves impregnation of carbon matrices by silicon and synthesis of SiC ceramics. The porosity of SiC ceramics was analyzed based on 10 images taken using a Carl Zeiss Stereo Discovery.V12 microscope. The HA and TCP coatings were obtained utilizing the GDD method by transporting the powder using a detonation wave at high velocities [1]. The surface morphology of SiC ceramics and deposited coatings was characterized using a scanning electron microscope (SEM).

Results

The GDD method allowed obtaining high-adhesive and structurally perfect bioactive coatings onto SiC ceramics derived from different wood sources (Figure 1). The surface morphology of synthesized SiC ceramics was regular throughout the surface. The smallest pores were observed for SiC ceramics synthesized from Tilia (27.2±10.1 μm), whereas Sapele-derived ceramics yielded the pores with a mean size of 131.2±41.1 μm. The calculated highest porosity was inherent to Hornbeam-derived SiC ceramics (45.3±3.4%). Moreover, the porosity was greater for more dense SiC ceramics and was also dependent on mean pore size.

Acknowledgments

The authors acknowledge the exchange program with East European Countries funded by DAAD and are looking for further funding of the project.

References


Conclusions and outlook

In this study, the bio-SiC ceramics synthesized from different wood precursors were characterized for surface morphology, porosity and pore size distribution; whereas the GDD method was used to generate bioactive HA and TCP coatings. The advantage of these ceramics is that the porosity and pore size can be optimized for different bones by varying the initial wood source. In turn, application of biocompatible and bioactive surfaces onto SiC ceramics could accelerate bone substitution.
SP099 - SPECIAL SESSION: Current situation of dosimetry in radiology and radiation protection

TRACK 05: DOSIMETRY AND RADIATION PROTECTION

SP099.1 - Current situation of dosimetry in radiology and radiation protection

Author(s): Madan M. Rehani1, Harry Delis2, Pablo Jimenez3, Joanna Izewska4

Radiation protection in medicine essentially poses dosimetry issues pertaining to patient dosimetry with some aspects of occupational dosimetry mainly relating to the lens of the eye. Dosimetric measurements in diagnostic radiology are required for the establishment and use of guidance levels, for the assessment of equipment performance and for comparative risk assessment. However, since radiology involves a diverse range of examination types, from simple projection radiography to advanced cross-sectional imaging, several dose quantities have been developed and have been well worked out by IAEA and ICRU. Further, data on the status of patient doses in different radiology procedures enable comparisons with diagnostic reference levels. The reference dose quantities have been well deciphered by the IAEA and ICRU. Some information about patient doses has become available through multi-national studies on patient doses to adults and children in CT, image guided interventional procedures (as relatively high dose procedures), as well as in mammography and conventional radiography of other organ systems. Image quality has been considered in some situations. Important findings include frequent lack of optimization in paediatric CT. There is a need for coordinated actions by different international organizations and professional bodies to improve optimization of protection which requires management of the radiation dose commensurate with the medical purpose. Particular to medical imaging, this equates to the lowest possible dose necessary to acquire diagnostic quality images. Regarding occupational radiation protection, cataract risk is important among staff in interventional suites. Currently, there is near absence of monitoring of eye lens doses and actions are needed to develop and implement practical methods for eye lens dosimetry. This issue has attained greater significance granted the drastic reduction of the occupational eye lens dose limit from 150 mSv/year to 20 mSv/year, recommended by the International Commission on Radiological Protection (ICRP) and adopted in the new BSS. The IAEA has been working on promoting and supporting best practices in dosimetry, including traceability of measurements to the International System of Measurement, and strengthening the medical physics capacity throughout the world since the early sixties. As it represents one of the main resources for the medical physicists, and often, especially in developing countries, the only one, work is done in producing guidelines on dosimetry in diagnostic radiology, (Dosimetry code of Practice (TRS-457), Dosimetry for Paediatric Patients (HIPS-24), Dosimetry of Wide beam CT (HHR-5)) to support dosimetry in the clinical environment. Therein exists a role for international organizations to promote and support actions on patient and staff dosimetry to improve both patient and occupational safety. This joint session will discuss modalities of cooperation. This joint session will address the current and future activities and areas for cooperation in the field.

SP100 - Dose Optimization: Focus on DRLs

TRACK 05: DOSIMETRY AND RADIATION PROTECTION

SP100.1 - A Contribution to the Establishment of Diagnostic Reference Levels in Computed Tomography in Brazil

Author(s): Lucas D.L. Narciso, Ana M. Marques Da Silva, Nathan W. Lima, Caroline M. Dartora

Faculdade De Fisica, PUCRS, Porto Alegre/BRAZIL

Diagnostic reference level is important to guarantee dose optimization, and can be defined nationally, regionally or locally, using dose descriptors, such as volumetric computed tomography (CT) dose index (CTDIvol, mGy) and dose-length product (DLP, mGy.cm). The aim of this work is to present the local DRL values for a CT department located in Porto Alegre, Brazil, intending to determine, in the future, national and regional DRL. For this purpose, retrospective data have been collected and analyzed, from head, chest and abdomen non-contrast CT adult (>15 years old) and pediatric (<15 years old) exams. The DRL values have been compared to those described on previous national studies from UK, US, Germany and Switzerland. The results are shown in the following table. These values are similar to the DRLs from Germany, UK, US and Switzerland. The present study is the first of its kind to determine the DRL for scanners operating in the south region of Brazil. Similar studies in other regions of Brazil are necessary in order to establish a National Dose Reference Level.

Table 1 CT service DRLs values for head, chest and abdomen exams by age group.

<table>
<thead>
<tr>
<th>CT Centre DRLs</th>
<th>Age group</th>
<th>CTDIvol (mGy)</th>
<th>DLP (mGy.cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Head</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-1</td>
<td>18</td>
<td>290</td>
<td></td>
</tr>
<tr>
<td>1-5</td>
<td>30</td>
<td>550</td>
<td></td>
</tr>
<tr>
<td>5-10</td>
<td>35</td>
<td>670</td>
<td></td>
</tr>
<tr>
<td>10-15</td>
<td>44</td>
<td>880</td>
<td></td>
</tr>
<tr>
<td>&gt;15</td>
<td>50</td>
<td>950</td>
<td></td>
</tr>
<tr>
<td><strong>Chest</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-1</td>
<td>5</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>1-5</td>
<td>7</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>5-10</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>10-15</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>&gt;15</td>
<td>10</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td><strong>Abdomen</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-1</td>
<td>4</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>1-5</td>
<td>5</td>
<td>170</td>
<td></td>
</tr>
<tr>
<td>5-10</td>
<td>6</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td>10-15</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>&gt;15</td>
<td>12</td>
<td>380</td>
<td></td>
</tr>
</tbody>
</table>
Increasing numbers of Computed Tomography (CT) scanners, examinations and CT’s relatively higher patient dose (compared to planar x-ray) have resulted in increased focus on the modality, both in Canada and world-wide. The key pillars of safe imaging, justification and optimization, are becoming especially important to follow. It follows that as CT use increases; protocol optimization (reduction of patient dose while maintaining necessary image quality) is an ever crucial part in reducing patient dose. A widely endorsed and adopted method is the establishment of diagnostic reference levels (DRLs) – typically accepted as the 75th percentile of CTDIvol and/or DLP distributions for a given patient exam type/indication – which help identify protocols that may benefit from further investigation and any necessary dose reduction initiatives.

The establishment of DRLs requires a significant and representative pool of scanning practice data – Canada’s National CT Survey collected data from 381 CT units across the country via distributed survey booklets (1 per CT unit) divided into four (4) sections: General CT information (e.g. Vendor/Model), Routine Protocols (as available), Individual Patient data (as applied) and limited CTDIvol measurements. The resultant electronic database includes a large cross-section of general vendor/model data, 2896 routine protocol samples (3494 sequences), 18 985 individual (actual) patient exam samples (24 280 sequences) and some CTDIvol measurements.

The national survey database covers seven (7) common exam types (Table 1) and is a significant step toward establishment of national DRLs which will help support protocol optimization efforts. Of course, prior to calculation of any reference levels, applied data quality assurance is essential. In our experience, key issues had to be addressed: (i) booklet, patient and sequence numbering mistakes were vetted by an iterative algorithm to verify their accuracy and association (ii) CT vendor/model names were inconsistent, thus a standard convention was applied to facilitate future analysis (iii) incomplete patient mass, potentially limited DRL sample sizes. Implementation of iterative, logical algorithms allowed AP and LAT measurements to act as a surrogate, increasing representative sample numbers (iv) Other, incomplete exam descriptors (contrast/ non, modulated/ fixed etc.) presented potential issues, but similar iterative, logic algorithms were also applied to help “complete” samples. E.g. string based search/flag clarification.

Table1: Common CT protocols (anatomical region) polled and clinical indications (not exhaustive) – Adults ≥ 19 yrs. and 70±20 kg, Pediatric ≤ 13 yrs. and < 50 kg.

<table>
<thead>
<tr>
<th>EXAM TYPE/ANATOMICAL REGION</th>
<th>CLINICAL INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine Head [Adult]</td>
<td>Headache, Cerebrovascular Accident (CVA), or Transient Ischemic Attack (TIA)</td>
</tr>
<tr>
<td>Chest [Adult]</td>
<td>Primary cancer, known/suspected metastasis or lung nodule follow-up</td>
</tr>
<tr>
<td>Abdomen, Pelvis [Adult]</td>
<td>Primary/metastatic work-up or abscess</td>
</tr>
<tr>
<td>Chest, Abdomen, Pelvis [Adult]</td>
<td>Lymphoma staging, follow-up or Trauma</td>
</tr>
<tr>
<td>Head [Pediatric]</td>
<td>Trauma, including non-accidental injury</td>
</tr>
<tr>
<td>Chest [Pediatric]</td>
<td>Detection of malignancy, Trauma</td>
</tr>
<tr>
<td>Abdomen [Pediatric]</td>
<td>Detection of malignancy, Trauma</td>
</tr>
</tbody>
</table>

Ultimately, the large national sample will provide DRLs, based upon dose metrics for 7 common CT examinations, supporting local optimization efforts and radiation protection of patients across Canada.
Methods

After undergoing $^{99m}$Tc-HDP bone examinations, 143 patients were studied. Dose rates [H*($^{10}$)] were measured from the mid thorax after radiopharmaceutical injection and after bone scan with a Geiger dose-meter at 0.1, 0.5, and 1.0 m. A number of different scenarios were carried out during absorption period and after leaving the Department of Nuclear Medicine. A dose of 1 mSv/year was used upon which restrictions should be imposed. The results were evaluated using the 95th percentile.

Results

The injected activity [median (min-max)] was 744 (370-844) MBq while absorption time and time for imaging procedure were 160 (80-280) and 55 (25-117) minutes.

The median dose rates measured at the three distances were 112.4, 29.8 and 11.5 μSv/h after the $^{99m}$Tc-HDP administration and 29.9, 9.8 and 4.3 μSv/h after the image scan.

The absorbed doses were:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Delay 0 h</th>
<th>Delay 1 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>The escort Incorporation time (0.5m)</td>
<td>108.2</td>
<td>---</td>
</tr>
<tr>
<td>Attending physician 5min @1m + 10min @0.5m + 5 min @0.1m</td>
<td>21.0</td>
<td>18.7</td>
</tr>
<tr>
<td>Coffee shop 30min @0.1m</td>
<td>82.5</td>
<td>73.5</td>
</tr>
<tr>
<td>Restaurant 1h @1.0m</td>
<td>39.5</td>
<td>35.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Delay 0 h</th>
<th>Delay 1 h</th>
<th>Delay 2 h</th>
<th>Delay 3h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public transport 1h @0.1 m</td>
<td>52.7</td>
<td>47.0</td>
<td>41.8</td>
<td>37.3</td>
</tr>
<tr>
<td>Private transport 1h @1.0m</td>
<td>7.9</td>
<td>7.5</td>
<td>6.3</td>
<td>5.6</td>
</tr>
<tr>
<td>Work place 8h @1.0m</td>
<td>---</td>
<td>38.9</td>
<td>34.7</td>
<td>30.9</td>
</tr>
<tr>
<td>Attending physician 5min @1m + 10min @0.5m + 5 min @0.1m</td>
<td>7.6</td>
<td>6.8</td>
<td>6.0</td>
<td>5.4</td>
</tr>
<tr>
<td>Coffee shop 30min @0.1m</td>
<td>27.1</td>
<td>24.2</td>
<td>21.5</td>
<td>19.1</td>
</tr>
<tr>
<td>Restaurant 1h @1.0m</td>
<td>15.0</td>
<td>13.4</td>
<td>11.9</td>
<td>10.6</td>
</tr>
<tr>
<td>Spouse/partner 6h @1m + 8h @0.1m</td>
<td>169.9</td>
<td>150.9</td>
<td>134.5</td>
<td>119.8</td>
</tr>
</tbody>
</table>

During an incorporation interval of 4 hours, the absorbed dose to which a subject could be exposed to due to contact with an injected patient in the waiting room would be 543, 134, and 52 μSv at a distance of 0.1, 0.5, and 1.0 m.

Conclusions

The people with higher doses are those who are in close contact with the patient (the escort and the spouse/partner). Nevertheless, the imposition of restrictions is not needed. However depending on the workload of the physicians, some restrictions might be required. Furthermore, the dose received in the waiting room from an injected patient is comparable to a bone scan.
SP101 - Stimulation and Monitoring

TRACK 11: NEUROENGINEERING, NEURAL SYSTEMS

SP101.1 - Biological Targets of Seizure Therapy in Major Depressive Disorder using EEG Microstate Analysis

**Author(s):** Sravya Atturi1, Willy Wong1, Daniel M. Blumberger2, Zafiris J. Daskalakis2, Faranak Farzan2

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**Introduction:** Understanding the exact mechanism of action of electroconvulsive therapy (ECT) can support the optimization of alternative treatments such as magnetic seizure therapy (MST) towards high efficacy and less side effects. Recent evidence suggests that major depressive disorder (MDD) may be associated with impaired brain functional connectivity and that ECT may achieve high efficacy in treatment-resistant MDD by normalizing abnormal neural connectivity. Resting-state EEG microstate analysis is one promising method that classifies global neural activity into discrete and short periods (80-120ms) of quasi-stable functional brain topographic maps (known as microstates) that change over time to represent dynamic states of global functional connectivity. **Methods:** For this study, pre- and post-treatment 60-channel resting state EEG data of 14 MDD patients (7 responders and 7 non-responders) receiving ECT and 13 MDD patients (3 responders and 10 non-responders) receiving MST were obtained from the Temerty Centre at the Centre for Addiction and Mental Health. The criterion for treatment response was a minimum of 50% improvement in the Hamilton Depression Rating Scale (HAM-D) score. Three main analyses were conducted with the data: (a) Spectral analysis was performed to determine whether previous findings of ECT-induced EEG slowing could be replicated. (b) Microstate analysis was performed to assess seizure therapy-related changes in the dynamic states of global functional connectivity. Four microstate classes were identified and four features were calculated for each class: (i) frequency of occurrence, (ii) transition time between each class, (iii) average duration and (iv) coverage time (fraction of total time covered by a class). (c) Finally, correlation analyses were performed to examine whether baseline microstate and power features could predict response (change in HAMD score) to seizure therapy. **Results:** (a) Similar to previous findings, frontal delta (0.5-3.5Hz) and midline theta (4-7Hz) were found to be significantly larger in ECT responders than non-responders. However, this effect was not observed in MST treatment. (b) Also following ECT treatment (but not MST), the frequency of appearance of each microstate class was significantly lower in responders than non-responders (p = 0.03). The transition time between two consecutive microstate classes increased in responders but did not significantly change in non-responders (p = 0.04). The average duration of all four microstate classes was significantly longer for both responders and non-responders (p = 0.001). A change in HAMD score was associated with an increased coverage time of class C (r = 0.56, p = 0.03) and a decreased coverage time of class A (r = -0.62, p = 0.02). (c) Lastly, the frequency of microstate class C pre-treatment was correlated with reduced response to ECT (r = -0.61, p = 0.02) and an increased response to MST (r = 0.54, p = 0.05). **Conclusion:** Preliminary results suggest that microstate features from resting-state EEG data may provide new and predictive information about the effect of seizure therapy in MDD and should be further explored with larger datasets.

SP101.2 - Magnetic Seizure Therapy for Treatment Resistant Depression: Insights from TMS-EEG Measures

**Author(s):** Yinning Sun1, Faranak Farzan2, Daniel M. Blumberger2, Willy Wong1, Zafiris J. Daskalakis2

1Ibbme, University of Toronto, Toronto/ON/CANADA, 2Psychiatry, University of Toronto, Toronto/ON/CANADA

Magnetic seizure therapy (MST) is a potential therapeutic option for treatment resistant depression (TRD) that has shown comparable efficacy and less side effects relative to electroconvulsive therapy. Since cortical inhibition is abnormal in TRD patients, measures of inhibition from combined transcranial magnetic stimulation and EEG (TMS-EEG) may further the understanding of MST treatment and provide predictors of its treatment response. Thirty-three TRD patients were recruited in this TMS-EEG study. Before a course of MST treatment, responses from single pulse TMS over the motor cortex and dorsolateral prefrontal cortex (DLPFC) were recorded using EEG. The peak value of the TMS evoked potential near 100 ms (i.e. N100) was computed for each patient and correlated with changes in clinical measures of depression (Hamilton Depression Rating Scale, HDRS-24) and suicidality (Scale of Suicidal Ideation, SSII) collected before and after treatment. For DLPFC stimulation, the N100 value over the frontal electrodes was significantly correlated with a decrease in the HDRS-24 (max at F2, R = -0.51, p = 0.006) and SSII (max at F6, R = -0.61, p = 0.001) values. Moreover, when patients were grouped into responders and non-responders based on SSII change (responder: 50% or more decrease from baseline), the N100 value can predict the label with 80% sensitivity and 89% specificity. These results were not found for motor cortex stimulation. Correlation and classification results suggest that frontal N100 values resulting from TMS stimulation of the DLPFC can be a potential predictor of clinical response to MST treatment for resistant depression.

SP101.3 - Deep Transcranial Magnetic Stimulation Using Figure-of-Eight and Halo Coils

**Author(s):** Mai Lu1, Shoogo Ueno2

1Key Lab. Of Opt-electronic Technology And Intelligent Control Of Ministry Of Education, Lanzhou Jiaotong University, Lanzhou/CHINA, 2Department Of Applied Quantum Physics, Graduate School Of Engineering, Kyushu University, Fukuoka/JAPAN

Transcranial magnetic stimulation (TMS) is a technique for noninvasive stimulation of the human brain, which has become a major tool in brain research and, potentially, a promising treatment for various neuro-behavioral disorders. Recently, interests in stimulating deeper cortical, subcortical and limbic areas have arisen and have become an active research topic in TMS, because several studies show that activation of deeper prefrontal and limbic regions may increase the antidepressant effect. The Halo coil, a large circular coil being placed around the head was developed for deep transcranial magnetic stimulation(dTMS). It was shown that the Halo coil working with a typical round coil at the top of the head can increase the fields at depth in the brain. The present study was to study the field characteristics of a figure-of-eight coil (Fo8) which was placed at the left dorsolateral prefrontal cortex (DLPFC) working with a Halo coil which was parallelly placed with that of Fo8 coil (Fo8-Halo assembly) as shown in Fig. 1. The same pulse currents with amplitude of I=5 kA and working frequency 2381 Hz was fed into each of the coils. A 3D realistic human head model with 1 mm resolution has been employed in this study. We have calculated the magnetic fields, electric fields and current density in head tissues by using impedance method. Figs. 2(a)-(c) show the variation of induced electric field in the cross section of the head model at 80 mm slice (coronal) for Fo8, Halo and Fo8-Halo assembly coils, respectively. It was observed that the field intensity in deep brain regions have been improved by Fo8-Halo assembly coil. Results suggest that the conventional Fo8 coil can be applied for dTMS by working with a...
Halo-coil for DLPFC stimulation.

Cortical theta burst stimulation (TBS) could modulate motor plasticity via long-term potentiation/depression (LTP/LTD)-like mechanisms and enhance motor performance, which makes TBS a potential non-invasive therapy for motor deficit diseases such as Parkinson’s disease (PD). In our previous rodent study, we had demonstrated that long-term cortical electrical stimulation (CES)-TBS protocols were capable to regulate motor-evoked potentials (MEPs) and enhance motor performance in chronic PD rats. However, the immediate effect of CES-TBS on motor performance in awake, freely moving rat was constrained by wired electrode and stimulators. Since CES excited all types of neurons surrounding the electrode in cortex, it is difficult to differentiate the effect of TBS on specific neural circuit that responds to motor plasticity and performance. It is also known that LTP/LTD occurred dominantly at glutamatergic synapse. The aim of this study is to apply the cell type-specific optogenetic TBS scheme in M1 could be an efficient therapy scheme for neural disorders like PD via targeting specific neural circuit. Ongoing project is working toward the observation of animal behavior during and after optogenetic-TBS treatment of free-moving rat.

Our results showed that the local field potentials were recorded in high fidelity and responded well to the optical stimulation. The averaged MEPs amplitude were increased after optogenetic TBS treatment. The observations indicate that motor plasticity was modulated resulting from TBS on glutamatergic neurons in M1. However, there was no significant change in cortical excitability revealed from LFPs. In summary, our results suggested that LTP/LTD-like effects induced by cortical TBS treatment might be located at glutamatergic projections downstream of M1. The modulation of motor plasticity using cell type-specific optogenetic TBS scheme in M1 could be an efficient therapy scheme for neural disorders like PD via targeting specific neural circuit. Ongoing project is working toward the observation of animal behavior during and after optogenetic-TBS treatment of free-moving rat.

Functional electrical stimulation (FES) is used to artificially induce contractions in paralyzed muscles as neuroprosthesis to substitute lost motor functions, in individuals with spinal cord injury or other neuromuscular impairments. The dynamic response of muscles to FES is an integral component of closed-loop controlled neuroprostheses such as neuroprostheses for standing balance. This study aimed at identifying the dynamic response of ankle muscles to FES in a standing posture with FES as an input and the exerted isometric ankle torque as an output using both first-order and critically-damped second-order models.

Thirteen healthy subjects participated in the experiment. Each subject stood on a standing frame with his/her extended knee and hip mechanically locked. The ankle plantarflexors and dorsiflexors were separately stimulated bilaterally through surface electrodes using a programmable functional electrical stimulator (Compex Motion II, Compex SA, CH). The subject’s feet were fixed firmly to the footplates connected to a torque transducer (TS11-200, Durham Instruments, DE) that recorded the exerted isometric ankle torque. The stimulus waveform was rectangular with pulse frequency of 20Hz and pulse duration of 0.3msec. The pulse amplitude was modulated on sinusoids between 20mA and 60mA at frequencies of 0.07, 0.15, 0.3, 0.75, and 1.2Hz. The sinusoids of FES pulse amplitude and fitted to the generated ankle torque curve were considered as input and output, respectively. A Bode diagram was plotted based on the five obtained amplitude gains and phase lags between the input and output. The first-order and critically-damped second-order linear models were fitted to the diagrams and their parameters were estimated for each subject.

**ABSTRACTS | IUPESM 2015 WORLD CONGRESS ON MEDICAL PHYSICS & BIOMEDICAL ENGINEERING**

**SP101.4 - Optogenetic Stimulation and Wireless Cortical Recording in Modulating Motor Plasticity and Performance of Free-Moving Rat**

**Author(s): Chun-Wei Wu, Cho-Han Hsieh, Jia-Jin J. Chen**

Biomedical Engineering, National Cheng Kung University, Tainan/TAIWAN

Cortical theta burst stimulation (TBS) could modulate motor plasticity via long-term potentiation/depression (LTP/LTD)-like mechanisms and enhance motor performance, which makes TBS a potential non-invasive therapy for motor deficit diseases such as Parkinson’s disease (PD). In our previous rodent study, we had demonstrated that long-term cortical electrical stimulation (CES)-TBS protocols were capable to regulate motor-evoked potentials (MEPs) and enhance motor performance in chronic PD rats. However, the immediate effect of CES-TBS on motor performance in awake, freely moving rat was constrained by wired electrode and stimulators. Since CES excited all types of neurons surrounding the electrode in cortex, it is difficult to differentiate the effect of TBS on specific neural circuit that responds to motor plasticity and performance. It is also known that LTP/LTD occurred dominantly at glutamatergic synapse. The aim of this study is to apply the cell type-specific optogenetic stimulation and wireless recording of local field potentials (LFPs) to reveal the functional roles of glutamatergic neuron in motor plasticity of freely moving rat.

CaMKIIalpha promoter driven channelrhodopsin-2 (CaMKIIalpha-ChR2) was expressed in glutamatergic pyramidal neuron in primary motor cortex (M1). Optogenetic stimulation was achieved using blue laser guided by optical fiber, which was connected by a rotary joint to allow freely rotation. Then the fiber was connected to optical cannula implanted on skull. Optical cannula was homemade of a stainless tube containing a short segment of optical fiber inside. Both ends of the fiber were polished to minimize optical scattering when Laser was emitted into cortex. Stainless tube of the optical cannula was functioned as cerebral electrode to collect electrophysiological signal. Brain biopotentials were then amplified, band-pass filtered and converted to a frequency modulated radio-frequency (RF) signal sent by a small and light (2.7 g) wireless transmitter headstage connected to stainless tube. RF signals were transmitted to the host unit and was demodulated into analog signal and sampled by DAQ card. Optogenetic evoked potentials were analyzed and displayed using average calculation during and after optogenetic TBS treatment.

In summary, our results suggested that LTP/LTD-like effects occurring from TBS on glutamatergic neurons in M1. However, there was no significant change in cortical excitability revealed from LFPs. Our results showed that the local field potentials were recorded in high fidelity and responded well to the optical stimulation. The averaged MEPs amplitude were increased after optogenetic TBS treatment. The observations indicate that motor plasticity was modulated resulting from TBS on glutamatergic neurons in M1. However, there was no significant change in cortical excitability revealed from LFPs. In summary, our results suggested that LTP/LTD-like effects induced by cortical TBS treatment might be located at glutamatergic projections downstream of M1. The modulation of motor plasticity using cell type-specific optogenetic TBS scheme in M1 could be an efficient therapy scheme for neural disorders like PD via targeting specific neural circuit. Ongoing project is working toward the observation of animal behavior during and after optogenetic-TBS treatment of free-moving rat.

**SP101.5 - Identification of calf muscles response to functional electrical stimulation as linear models**

**Author(s): Hossein Rouhani1, Michael Same2, Ya Q. Li2, Kei Masani2, Milos R. Popovic2**

1Lyndhurst Centre, Toronto Rehabilitation Institute - University Health Network, Toronto/CANADA, 2Institute Of Biomaterials And Biomedical Engineering, University of Toronto, Toronto/CANADA

Functional electrical stimulation (FES) is used to artificially induce contractions in paralyzed muscles as neuroprosthesis to substitute lost motor functions, in individuals with spinal cord injury or other neuromuscular impairments. The dynamic response of muscles to FES is an integral component of closed-loop controlled neuroprostheses such as neuroprostheses for standing balance. This study aimed at identifying the dynamic response of ankle muscles to FES in a standing posture with FES as an input and the exerted isometric ankle torque as an output using both first-order and critically-damped second-order models.

Thirteen healthy subjects participated in the experiment. Each subject stood on a standing frame with his/her extended knee and hip mechanically locked. The ankle plantarflexors and dorsiflexors were separately stimulated bilaterally through surface electrodes using a programmable functional electrical stimulator (Compex Motion II, Compex SA, CH). The subject’s feet were fixed firmly to the footplates connected to a torque transducer (TS11-200, Durham Instruments, DE) that recorded the exerted isometric ankle torque. The stimulus waveform was rectangular with pulse frequency of 20Hz and pulse duration of 0.3msec. The pulse amplitude was modulated on sinusoids between 20mA and 60mA at frequencies of 0.07, 0.15, 0.3, 0.75, and 1.2Hz. The sinusoids of FES pulse amplitude and fitted to the generated ankle torque curve were considered as input and output, respectively. A Bode diagram was plotted based on the five obtained amplitude gains and phase lags between the input and output. The first-order and critically-damped second-order linear models were fitted to the diagrams and their parameters were estimated for each subject.
Correlation coefficient and RMS error between the experimental and fitted data were calculated to evaluate the fitting. Two-way ANOVA (factor1: first-order or second-order models, factor2: plantarflexors or dorsiflexors) revealed that both models were not significantly different in correlation coefficient and RMS error for both amplitude gain and phase lag (p>0.6) (Table 1). The inter-subject variability was expressed as CV (=100×SD/mean). The CV of the time constants obtained by the second-order model for plantarflexors (18.1%) was significantly smaller than the CV of the time constants obtained by the first-order model (79.9%) (F-test, p<0.001). Therefore, the time constant obtained by the critically-damped second-order model was more consistent among subjects for plantarflexors. This finding should be considered in the design of closed-loop controlled neuroprostheses when immediate torque generation is expected. In the future, the physiological interpretation and nonlinear components of this modeling should be further investigated.

Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Plantarflexors</th>
<th>Plantarflexors</th>
<th>Dorsiflexors</th>
<th>Dorsiflexors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st order</td>
<td>2nd order</td>
<td>1st order</td>
<td>2nd order</td>
</tr>
<tr>
<td>Correlation coefficient for fitting Amplitude gain</td>
<td>0.92±0.14</td>
<td>0.90±0.19</td>
<td>0.55±0.40</td>
<td>0.55±0.37</td>
</tr>
<tr>
<td>Correlation coefficient for fitting Phase lag</td>
<td>0.88±0.18</td>
<td>0.89±0.30</td>
<td>0.75±0.38</td>
<td>0.83±0.32</td>
</tr>
<tr>
<td>RMS error for fitting Amplitude gain</td>
<td>0.21±0.29</td>
<td>0.20±0.21</td>
<td>0.14±0.14</td>
<td>0.13±0.15</td>
</tr>
<tr>
<td>RMS error for fitting Phase lag</td>
<td>14.6±18.8</td>
<td>16.4±22.7</td>
<td>14.6±16.7</td>
<td>15.3±16.6</td>
</tr>
<tr>
<td>Estimated zero-frequency gain</td>
<td>2.90±1.04</td>
<td>2.75±0.98</td>
<td>0.67±0.36</td>
<td>0.64±0.35</td>
</tr>
<tr>
<td>Estimated time constant</td>
<td>0.26±0.21</td>
<td>0.11±0.02</td>
<td>0.19±0.11</td>
<td>0.09±0.03</td>
</tr>
</tbody>
</table>

SP101.6 - Establishment of Real Human Head Conductivity Model with Ventricular Structure used in TMS Simulation Study

**Author(s):** Chen Zhao, Huanhuan Cheng, Zhipeng Liu, Tao Yin

Institute Of Biomedical Engineering, Chinese Academy of Medical Sciences, Tianjin/CHINA

For accurate simulation studies on distribution of electromagnetic field induced by Tran-cranial Magnetic Stimulation, a real human head conductivity model with deep cerebral structure was reconstructed from MRI raw data, by using of MIMICS and ANSYS. This model reflects geometric structural information of Scalp, Skull, Cerebrospinal Fluid (CSF), Gray Matter, White Matter, Cerebellum, Ventricle and Eyeballs. The ventricular structure has relatively higher conductivity, whose effect on induced field could not be neglected. This paper mainly introduces the method to establish the ventricle part of the entire head model, which is used for ANSYS low-frequency magnetic simulation, while the way to generate other parts is similar and accomplished. On the platform offered here, study on specific individual subject would be easy and practicable. Deep structures will be produced vectorial in the future work.

SP101.7 - Study on electric field in real head model induced by H-coil

**Author(s):** Huanhuan Cheng, Chen Zhao, Zhipeng Liu, Tao Yin

Institute Of Biomedical Engineering, Chinese Academy of Medical Sciences, Tianjin/CHINA

To study the distribution of induced electric field in human brain under the H-coil and to explore the deep character of H-coil, this paper builds a real head model with limbic system inside, and an H-coil model close to the real head model. The electric field distribution in scalp and limbic system induced by H-coil was calculated via finite element method and the results were compared with those of figure-of-eight coil. It is found that the deep field performance of H-coil was much better than figure-of-eight coil. Although the induced electric field by H-coil is not focusing on scalp, it can concentrate deeply on anterior cingulate cortex, which is an important part of limbic system. It provides a valid evidence for H-coil to stimulate deep brain structures.
De-escalation of therapy will result in cure and toxicity rates which are different from the current standard-of-care. This balance between the two is explored implicitly by clinical trials which are explicitly examining de-escalation of therapy. The currently accepted equilibrium did not evolve through a quantifiable methodology, nor do the current trials address the issue of determining the optimal operating point.

Methods:
We developed an outcome model for oropharyngeal cancer which combines cure rates and late toxicity effects into a single quality of life metric. We chose an Influence Diagram to model the decision process because it can incorporate probabilities from previous clinical trials, retrospective analysis, and the beliefs of experienced physicians. We used a Markov model to calculate Quality-Adjusted Life Years (QALYs) for outcomes.

We performed sensitivity analysis to determine the robustness of the model predictions to model parameters, see Fig. 1. In particular, the sensitivity of individual patient preferences was explored in the event that a single standard-of-care approach cannot be taken for this disease site.

RESULTS AND DISCUSSION:
In order to change clinical practice the QALYs for de-escalated therapy must be higher than for standard therapy. We delineated the outcomes of the trials which would and those which would not change clinical practice, within the boundaries of our sensitivity analysis. This type of model has broad applicability to other disease sites in radiotherapy and to clinical trials in medicine in general. Developing the clinical decision model up front could help design a trial that can provide the necessary information for changes in clinical practice.

References

SP102.2 - Large-scale data of basic patient and treatment characteristics significantly improve predictions for post-radiotherapy dyspnea

Author(s): Timo M. Deist1, Arthur T.C. Jochems1, Cary Oberije1, Andre Dekker1, Katrien Vandecasteele1, Yolande Lievens2, Johan Van Soest1, Philippe Lambin2
1Department Of Radiation Oncology (maastro Clinic), GROW - School for Oncology and Developmental Biology, Maastricht University Medical Center, Maastricht/NETHERLANDS, 2Radiation Oncology Department, University Hospital Ghent, Ghent/BELGIUM, 3Department Of Radiation Oncology (maastro), Maastricht University Medical Centre+, Maastricht/NETHERLANDS

Purpose
Dyspnea is a known side effect of lung radiotherapy. Personalized medicine approaches require reliable models predicting the patient-specific risk. As the number of events is limited, large datasets are needed for model building and these can be obtained by using data from routine clinical practice. This approach limits data to basic patient and treatment features with an increased likelihood for incompleteness and errors. We show that such models for post-treatment dyspnea enhance predictions even if solely based on basic data from clinical practice.

Materials/Methods
Clinical data were collected retrospectively (2008-2014) from MAASTRO Clinic, the Netherlands, consisting of dyspnea levels before and after radiotherapy, chemotherapy type, and total tumor dose during therapy. 1031 lung cancer patients with a pre-treatment dyspnea score below 2 (according to CTCv.3 or 4) were selected to ensure non-iatrogenic dyspnea did not bias the results. A validation set of 82 patients was provided by Ghent University Hospital, Belgium. A Bayesian Network was learned to predict an increase in the dyspnea score given pre-treatment dyspnea, chemotherapy type, and total planned radiation dose. For comparison, another estimator was constructed solely based on pre-treatment dyspnea which is known to carry high predictive value.
SP102.3 - Substituting human MRI-observed tumor length with automated tumor length calculations for prediction model application

**Author(s):** Johan Van Soest¹, Jeroen Buijsen¹, Philippe Lambin¹, Vincenzo Valentini², Andre Dekker¹

¹Department Of Radiation Oncology (maastro), Maastricht University Medical Centre+, Maastricht/NETHERLANDS, ²Department Of Radiotherapy, Università Cattolica del Sacro Cuore, Rome/ITALY

**Introduction**

The development and use of prediction models in radiation oncology is emerging, especially in the context of individualized medicine. Although prediction models can indicate clinical outcomes, automated execution is a problem when information is only available as unstructured text (or missing). For example, van Stiphout et al. (PMID: 21176986) developed 3 prediction models to predict a pathologic complete response (pCR) in rectal cancer patients. In two out of three prediction models, tumor length (determined by radiologists on MRI scans) is used as a model variable, which needs to be manually extracted from free-text radiological reports. In this study, we attempted to find another measurement method for tumor size in already available data, and to measure its influence when applying it to the pre-treatment (clinical) pCR prediction model as a substitute for tumor length measured by a radiologist on MRI.

**Methods**

We used a dataset of 71 patients having a pre-treatment PET-CT scan and clinical radiotherapy gross tumor volume (cGTV) delineations available. For 41 of these patients the tumor length observed by a radiologist on an MRI was available. We used either this cGTV directly or a semi-automatic PET-threshold based GTV (tGTV) using 40% of the maximum of the standardized uptake value on the PET-CT scan. For both cGTV and tGTV, we calculated the volume, maximum Euclidian and axial distances (transversal perspective). Afterwards, we determined the correlation between MRI-observed tumor length and the computed metrics; using univariate regression analysis. Finally, we substituted the tumor length for the computed metrics in the clinical prediction model, and calculated the area under the receiver operating curve (AUC).

**Results**

Results of the correlation and substitution are shown in the table below. Based on this table, there is a significant correlation for the Z-axis, determined by a regression coefficient closest to 1 for both cGTV and tGTV. For the cGTV and tGTV, substituting the tumor length along the Z-axis resulted in a reasonable performance comparable to the original model (AUC 0.69 and 0.70), and resulted in a better performance for tGTV volume (AUC 0.78).

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**Results**

The enhanced model and the estimation only using pre-treatment dyspnea have been cross-validated using 10 folds. The enhanced model outperforms the univariate estimation with an average AUC of 0.7319 versus 0.6852. The additional features yield a significantly different AUC (p-value<0.01, Wilcoxon signed-rank test). These findings are externally validated with the enhanced model increasing the AUC from 0.5740 to 0.6236.

**Conclusions**

Improvements in the prediction of worsened dyspnea after lung radiotherapy are achieved using only clinical patient and treatment data. This example provides additional evidence for the potential of prediction models based on clinical data to improve patient care and furthering the goal of personalized medicine.
Conclusion
We have shown a correlation between the MRI-based tumor length and GTV-based distances; specifically for the Euclidian, Z-axis distance and volume. In general, the semi-automatic IGTV dimensions are better for substitution of the MRI-observed tumor length. Although the results are promising, this dataset is too small (N=71; positive events: 14) to make final conclusions and requires an external validation.

<table>
<thead>
<tr>
<th>N=71</th>
<th>Correlation with MRI tumor length (N=41)</th>
<th>Model substitution AUC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regression Coefficient (p-value)</td>
<td></td>
</tr>
<tr>
<td>cGTV Euclidean distance</td>
<td>0.58 (1.75*10^-4)</td>
<td>0.57</td>
</tr>
<tr>
<td>cGTV absolute max X-axis</td>
<td>0.36 (4.96*10^-2)</td>
<td>0.57</td>
</tr>
<tr>
<td>cGTV absolute max Y-axis</td>
<td>-0.06 (6.91*10^-1)</td>
<td>0.67</td>
</tr>
<tr>
<td>cGTV absolute max Z-axis</td>
<td>1.01 (1.55*10^-8)</td>
<td>0.69</td>
</tr>
<tr>
<td>cGTV volume</td>
<td>0.03 (3.48*10^-4)</td>
<td>0.63</td>
</tr>
<tr>
<td>tGTV Euclidean distance</td>
<td>0.79 (1.03*10^-4)</td>
<td>0.72</td>
</tr>
<tr>
<td>tGTV absolute max X-axis</td>
<td>1.23 (1.86*10^-4)</td>
<td>0.71</td>
</tr>
<tr>
<td>tGTV absolute max Y-axis</td>
<td>0.59 (4.67*10^-2)</td>
<td>0.69</td>
</tr>
<tr>
<td>tGTV absolute max Z-axis</td>
<td>0.92 (2.68*10^-6)</td>
<td>0.70</td>
</tr>
<tr>
<td>tGTV volume</td>
<td>0.09 (2.66*10^-4)</td>
<td>0.78</td>
</tr>
</tbody>
</table>

SP102.5 - Design and implementation of an IT management system for a Medical Physics Department activity workflows.  
Author(s): Leonello Servoli1, Massimiliano Paolucci1, Bruno Cechucci1, Roberto Di Lorenzo2, Mariano Gattafori2, Mario Tiburzi2, Alessandro Carnevale2  
1Istituto Nazionale di Fisica Nucleare, Sezione Perugia/ITA-LY, 2BTREE Srl, Foligno/ITALY

The everyday activities of a Medical Physics Department, either in a single Hospital or in a network of Hospital and Medical Institutions, are very complex and the management of the data flow coming from the different tasks, of the scheduled quality controls and mainte-
widely used illumination correction methods in the segmentation stage. The first illumination correction technique was developed by making use of morphological operators, specifically the morphological closing. The second illumination correction technique was the algorithm known as Retinex. Performance measurements of the Mean Shift implementations were included with further comparisons of two existing segmentation techniques; image thresholding using Otsu’s method and Gradient Vector Flow (GVF) Snakes. The classification results of using two different classifiers are also demonstrated as part of the complete melanoma detection system. The first classifier was based on Support Vector Machines (SVMs). The second classifier used linear discriminant analysis with various discriminant functions: linear, quadratic and mahalanobis distances. This approach demonstrates enhanced classification capabilities of melanoma detection which can also be extended to other dermatologic applications.

SP102.7 - Fuzzy-state machine for Triage priority classifier in emergency room

**Author(s):** Agustín I. Cabrera Llanos1, María G. Ramírez-Soto-lo2, Emmanuel S. Sánchez Velarde2, Itxamñá O. Rico-Aseñención2, Nayely R. Budar-Alemán2, Alejandro A. Soto-De Ávila2, Rodrigo Sánchez-González2

1Bioprocesos, Unidad Profesional Interdisciplinaria de Biotecnología - IPN, Distrito Federal/MEXICO, 2Bioprocesos, Unidad Profesional Interdisciplinaria de Biotecnología, Distrito Federal/MEXICO

In this paper, a fuzzy classifier stage of a patient in the emergency room is presented. This classifier is divided into 3 stages: data entry by staff health, the evaluation provided by the software and finally the creation of a report for electronic patient file. A clinical classification system called triage give us the severity and priority of the patient, taking into consideration parameters like consciousness, blood pressure, appearance, temperature, heart rate and respiratory rate, achieving an effective pre valuation. The program is designed for adult patients aged 18 to 40 years.

SP102.8 - An Australian mining boom: development of an Australian radiotherapy datamining network for rapid learning from clinical data to support improved clinical decisions

**Author(s):** David Thwaites1, Lois Holloway2, Michael Bailey3, M Samir Barakat4, Martin Carolan4, Geoff Delaney5, Matthew Field1, Andrew Miller5, Johan Van Soest5, Shalini Vinod5, Sean Walsh1

1Institute Of Medical Physics, School Of Physics, University of Sydney, Camperdown, Sydney/AUSTRALIA, 2Department Of Radiation Oncology, Liverpool & Macarthur Cancer Therapy Centres and the Ingham Institute, Liverpool/NSW/AUSTRALIA, 3Medical Physics/medical Informatics, University of Wollongong, Wollongong/AUS- TRALIA, 4Radiation Oncology, Illawarra Cancer Care Centre, Wollon- gong/AUSTRALIA, 5Department Of Radiation Oncology (maastro), Maastricht University Medical Centre+, Maastricht/NETHER- LANDS, 6Department Of Radiation Oncology, Liverpool & Macarthur Cancer Therapy Centres, Liverpool/NSW/AUSTRALIA

**Objective:** Large amounts of data are routinely collected on radiotherapy patients, which can potentially provide additional clinical evidence to inform better clinical decisions. A collaborative project has begun between the MAASTRO clinic and a pilot network of Australian cancer centres, to validate and implement MAASTRO-developed prediction models (PMs) in Australian clinical practice and assess their impact on decisions for future patient treatment. Wider objectives include developing multi-institutional rapid learning, to enable PM evolution by incorporating more centres/data, using a distributed learning approach of transporting the model to the data, rather than data out of the centres, thereby protecting data privacy.

**Methods:** Two initial stand-alone pilots were conducted: one on datasets for radically-treated Stage I-IIIB non-small cell lung cancer (NSCLC) patients in the Liverpool Hospital Cancer Centre and the second on radically-treated Stage I-IV larynx patient datasets in the Illawarra Cancer Care Centre, both Pinnacle+Mosaiq users. Open-source rapid learning systems, using Semantic Web based tools, were installed, supporting collection of data, from the TPS and OIS databases, relating to the patients, diseases, treatments and recorded outcomes. The MAASTRO PMs were learned (on ‘training cohorts’) and validated against local datasets (‘clinical cohorts’). Further lung studies are currently underway in three other hospitals (Eclipse+Aria and Pinnacle+Mosaiq users).

**Results:** For the lung patients, of 419 datasets identified meeting the PM criteria, 159 had all required data to be eligible for inclusion in the clinical cohort. Some missing data were imputed using Bayesian methods, increasing eligible datasets to 225. The larynx data were relatively complete: 109/125 datasets identified had all data parameters recorded to be eligible for inclusion. For both pilots, the MAASTRO PMs successfully predicted better and worse prognosis groups, but showing some differences to the models, which reflect ed differences between the Dutch and Australian patient groups and practice. For example, the PM-predicted good prognosis lung group was differentiated from a combined medium/poor prognosis group (2-year overall survival, 69% vs. 27%, p<0.001) in the Australian data. Stage was less able to identify prognostic groups; most good prognosis patients in this clinical cohort having higher stage disease. For larynx, the proportion of clinical cohort patients in the predicted poor/medium/good prognosis groups were 47%/42%/11%, compared to the training cohort defined as 25%/50%/25%. Thus the larynx model could classify different clinical cohort prognosis groups, but the good prognosis group was smaller, as the clinical cohort was older and had more advanced cancers, nodal spread and non-glottic cancers than the training cohort.

**Conclusion:** The technical infrastructure and the basic MAAS TRO prediction models support the prognosis prediction of lung and larynx patients in Australian clinical cohorts, showing promise for support of future personalized treatment decisions, improved treatment quality and potential practice changes. The infrastructure is being extended: for an initial distributed learning pilot between multiple NSW centres; for expansion into more NSW centres, other states and linkage to trials databases; and for model parameters to include radiomics data. Data quality for routine patients is vital when creating a rapid learning infrastructure, to maximize the information’s potential.

SP103 - Health Technology Assessment and Cost Effective Technologies for Developing Countries and Usability and Human Factors Engineering for Medical Devices and System Design: Part 2

TRACK 16: CLINICAL ENGINEERING, CLINICAL PHYSICS, AND PATIENT SAFETY

SP103.1 - Novel Medical Device Procurement Tracking Approach
Author(s): Gleb Donin, Ilya Ivlev, Silvie Jeřábková, Jakub Vacek, Peter Kneppo
Department Of Biomedical Technology, Czech Technical University in Prague, Kladno/CZECH REPUBLIC

This paper presents approaches implemented in the medical device procurement tracking system in the Czech Republic. The System was created to enable the monitoring and assessment of procurement efficiency and to provide valid information to different stakeholders during future medical equipment purchases planning. Data collection process was proposed and implemented into practice. Several reports run on the grounds of a multi-criteria comparison based on comprehensive data model, which enable to analyse the procurement data and to formulate hypotheses relative to procurement efficiency. The multi-criteria approach is based on the valuation of the medical equipment procurements upon the set of criteria specified by the user, such as procurement terms and conditions, medical equipment price and technical specifications. The System developed allows users to compare purchase contracts with the purpose of identifying their weaknesses and planning future purchases.

SP103.2 - Influence of shifting patients with off-axis tumor for Tomotherapy
Author(s): Yingjie Xu, Jianrong Dai, Zhihui Hu, Peng Huang, Pan Ma, Kuo Men, Ke Zhang, Minghui Li, Dawei Jin, Wenting Ren
Department Of Radiation Oncology, Cancer Institute & Hospital, Chinese Academy of Medical Sciences, Beijing/CHINA

Objectives:
For tomotherapy, it’s common practice to set up a patient centrally no matter where a tumor is in his or her body. Here is to evaluate the influence of shifting the patient on plan quality and treatment time if the tumor is off the rotational axis of tomotherapy machine.

Methods:
15 patients with off-axis tumor were chosen for planning in tomo-therapy planning system (Accuray Inc.). The off-axis distance ranged from 2 to 12 cm. In one group of plans, all patients were shifted in the planning system to make the tumor center coincide to the machine’s rotation axis (HiArt) while in the other group, all patients were not shifted. Except center position, all planning settings such as pitch, field width, and modulated factor were the same for two groups. Conformal index, homogeneity index and mean dose of normal tissue were compared in these two groups. So did the treatment time and monitor units.

Results:
The CI, HI and DNTmean were 0.84±0.053, 1.06±0.023, and 12.37 (quartile range 5.78) for the first group of plans (the plans with patients shifted), and were 0.84±0.053, 1.07±0.027, and 12.4 (quartile range 5.91) for the second group, respectively. There was no significance. But the treatment time was shorter for the first group, and the difference became larger with off-axis distance. So did the MUs. When the distance was more than 6 cm, the treatment time saving was over 10%. These changes were mainly caused by the machine’s flattening filter free design.

Conclusion:
For patients with large off-axis tumor, treatment time and MUs can be reduced significantly if the patients are shifted so that the tumor center coincides to the machine’s rotational axis.

SP103.3 - Smart pump user interface evaluation
Author(s): Carlos A.B. Viviani1, Saide Calil2
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There are at least 73 infusion pump manufacturers registered with the Food and Drugs Administration (FDA).

Many events reported by the FDA occurred due to usability problems of medical devices, which are often related to lack of consistency in the interface. This may induce the user to error and consequently the occurrence of problems during the device operation.

To minimize such events, it is required a careful evaluation of the interface device and also its standardization.

Infusion pumps are always present in ECRI's reports as one of the devices that have the highest probability of risk to the patient.

The objective of this study is to verify the interfaces consistency of four infusion pumps developed by leading manufacturer in world market.

The methodology is structured in two stages. The first stage referred to the development of an appropriate set of criteria for comparing the interfaces of the smart infusion pumps. In the second stage, it was applied the developed criteria to the interfaces using the four pumps as a practical study.

Evaluation results showed that there is no standardization for designing medical devices of the same type and category; in this case study the smart pumps. It also suggested that each manufacturer designs a device considering only aesthetic issues and does not maintain any consistency with other manufacturers and even with other models or different version devices.

This preliminary study provides us with evidence that this lack of consistency between the interfaces of these devices can lead to usability problems, and can lead untrained users to error. Additional studies are needed to further investigation and thereby demonstrate qualitatively results.
A software to manage the data from continuous monitoring has been implemented in paediatric intensive and cardiac critical care units of a large, tertiary hospital, in Canada, but in its current version has not been integrated in clinicians' work. In this study, we present two components of a proposed four-phase project which each approach the human-computer interface (HCI) from two directions. Established human factors methods will be employed: first, from the computer side using heuristics or “rules of thumb”, frequently used in software design, and second, from the human-user side, using cognitive task analysis. These two phases aim to inform an optimized interface design eventually used to study the impact of this cognitive task analysis. These two phases of a proposed four-phase project which each approach the human-computer interface (HCI) from two directions.

In this phase, the interface was assessed using 14 heuristics, developed by leading experts in interface design and modified for medical devices. Three evaluators assessed the same version of the software for issues and their heuristic violations and severity. The first assessment was performed by a “double-specialist” with novice-level knowledge of both the clinical work and human factors; the second was performed by two domain experts each from clinical nursing and human factors fields.

In total, 68 usability issues were found; 23 were found in the first assessment, 45 were found in the second assessment, and 18 found in both assessments. These were associated with over 200 violations to the heuristics generally, of severity 2 (minor usability problem) or 3 (major usability problem). The most common types of heuristic violations were visibility, match, memory and error.

Cognitive task analysis (CTA) is generally referred to as the set of methods used to identify the mental demands and cognitive skills needed to complete a task. Monitoring and decision-making in the technology intense environment of an ICU requires a high degree of staff expertise to carry out these cognitive tasks. A cognitive task analysis was used to understand how different clinicians in the ICU use the information at their disposal to make decisions regarding patient care. Physicians, nurses and respiratory therapists make decisions for a range of tasks required for continuous care. They obtain their information from disparate monitoring technologies and an understanding of their prioritized information sources is key to the design of software interfaces aimed at facilitating their access and integration of this information. We designed four simulated, paper-based, scenarios to aid the CTA.

By using tools from decades of knowledge of software interface design and from structured methods of understanding the work of clinicians, basic usability issues and tasks can be identified. Results from these two directions will inform the next phase of testing, a low-fidelity usability study, using true-to-work tasks and inherent software interface issues.

**SP103.4 - Studying the human computer interface of a continuous monitoring software by approaching it from both directions**

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**SP103.5 - Analysis and experimentation of plantar foot segmentation from thermographic digital images for preventive diagnosis of diabetic foot**

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Plantar foot surface temperature is an important feature in type II diabetes as it is an early sign of foot ulcer. We have reviewed the scientific and technical foundations for the use of digital thermography of the sole of the foot as a prevention procedure to avoid foot ulceration. This project has progressed in the implementation of a new segmentation algorithm to analyze plantar foot temperature and its assessment by qualitative judgment. We have processed thermographic images of the feet. To achieve this we first proceeded to capture images from two soles of feet -surrounded or not by a foam block- and then to segment them using two different methods each of which include the iterative closest point (icp) Method: 1) fuzzy clustering modeling (FCM) and 2) growing seeds. Images properly segmented were judged by three observers who have estimated the quality of the contour tracing. Medians and quartile deviations are calculated to estimate the segmentation's quality. As a result, the quality contour tracing was less suitable when there was not a foam block surrounding the sole of foot while imaging was performed. Likewise, the segmentation using FCM was less suitable than the segmentation by growing seeds. Overall, these results suggest the possibility of avoid using foam block by optimizing the software with growing seed method which increase the comfort of patients and asepsis inside hospitals.
SP104 - Phantoms

SP104.1 - Monte Carlo simulation of interventional cardiac scenarios using a newborn hybrid phantom and MCNPX code

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We developed exposure scenarios of pediatric interventional cardiology using a newborn hybrid phantom and the radiation transport code MCNPX. Six angiographic projections (AP, PA, LAO45, RAO45, LAO90 and RAO90) were simulated considering three X-ray energy spectra (60, 70 and 80 kVp), focus-skin distance (FSD) not less than 45 cm and a 7 x 7 cm² field size. Equivalent and effective doses were computed and normalized by kerma-area product (KAP) resulting the conversion coefficients HT/KAP and E/KAP. The results showed highest HT/KAP values in AP projection at 80 kVp. Increasing photon energy, average E/KAP values presented relative differences of 18% (60 to 70 kVp) and 15% (70 to 80 kVp). E/KAP values were compared with those published for mathematical newborn phantom. Results showed relative differences of 14% for AP projection (70 kVp) and 60% for lateral projections (60 kVp).

We showed the simulator’s capabilities by the introduction of a small calcium block into a coronary artery of the beating heart phantom. Its detectability was tested while changing the simulated heart rate variability. The calcium block was easily detectable in the reconstructed images when simulating acquisition during normal cardiac rhythm. When heart rate variability was increased to 10%, the coronary artery block was not detected in the reconstructed images.

SP104.2 - Computed tomography of a beating heart: High resolution simulator for the assessment of motion artifacts during CT scan of the heart

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Computed tomography of internal organs is an important diagnostic tool for the clinician in spite the use of ionizing radiation with the potential for causing harmful deterministic and stochastic effects to the patients. CT angiography, that allows detecting and evaluating coronary heart disease, is a technological challenge as the image acquisition process is done while the heart is moving resulting in information loss. Fast acquisition and precise synchronization to cardiac motion are common techniques to reduce information loss, but they fail when irregular cardiac rhythm is encountered.

We have developed a computerized CT simulator to investigate the effect of irregularities in cardiac cycle during CT scan on the obtained image quality. The CT simulator utilizes high resolution computer phantom mimicking realistic cardiac motion with anatomically realistic heart and associated vasculature. Normal cardiac motion is generated using XCAT/HADES phantom generator with anatomical resolution exceeding 0.25 mm. Irregular cardiac rhythm is controlled by a dedicated ECG simulator capable of generating normal and abnormal rhythms. The simulator allows simulation of prospective gating technique (“Step and shoot”). Various reconstruction algorithms have been incorporated in the simulator. Effects of geometry of the scanner, pixel size, gantry rotation speed and other physical parameters on image quality can be studied.

We showed the simulator’s capabilities by the introduction of a small calcium block into a coronary artery of the beating heart phantom.

We suggest that such computerized simulator have the potential be used in future development of CT techniques, to investigate the effects of anatomy and motion on acquisition protocols and to customize imaging protocols for individual patients based on their measured heart rate variability.

SP104.3 - Development of Dynamic Anthropomorphic Heart Phantom for Computed tomography

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**Background:**

Currently available large detector CT scanners with high rotational speed and dual-source have demonstrated good diagnostic accuracy for coronary artery disease. However, the appearance of a coronary stenosis during computed topographic coronary angiography (CTCA) does not always equate the actual blockage in the arteries. This discrepancy is due to calcified plaque can cause bloom artifact or similarly measured density of non-calcified plaque is strongly affected by partial volume artifact from adjacent densities including luminal contrast. Higher or irregular cardiac motions has significant role in producing these artifacts, hence multiple scans are required with different gating techniques. These limitations can be addressed by improvement in image reconstruction algorithms and acquisition techniques.

**Method:**

This project presents development of a realistic dynamic anthropomorphic heart phantom (DHAP), which can mimic any heart rhythm of patient while waiting in the holding area. The dynamic heart phantom driven in real time from the patient’s ECG; then can be scanned in the CT to establish the best gating protocol suitable to current heart rhythms of the patient. Once the protocol is established the patient can be scanned only applying single gating technique; hence significant radiation dose can be reduced for these patients.

The phantom can also support research studies addressing the detection issues due to cardiac motion in space and time domains. Thus phantom can also serve as a useful tool in building new CTCA.
can be used to understand and validate the impact of tumour motion on hybrid PET/MRI.

The phantom’s main torso compartment has internal dimensions of 274.5mm long with an oval profile of 292mm by 240.5mm. The lung compartments have oval profiles with internal dimensions of 89mm by 125.5mm, by 274.5mm long. The spine compartment also has an oval profile with internal dimensions of 32.3mm by 23.6m, by 274.5mm long. The superior-end cap has two fill holes; one to fill the spine compartment and a larger one to fill the torso compartment. The inferior-end cap has two through holes to match the profiles of the lung compartments, which allow a spherical tumour compartment with a stem to be mounted to an MRI-compatible motion stage. This motion stage from Vital Biomedical Technologies can provide user-defined motion profiles to move the tumour (Figure 1A).

The 3.5cm diameter spherical tumour compartment was filled with saline and 17kBq/mL of F18 to mimic tumour uptake of FDG. The torso compartment was filled with saline and 4.27kBq/mL of F18 to mimic normal background uptake in a patient body. The motion stage was programmed to produce a repeating 4 second sinusoidal cycle of linear motion that was 2cm long in the superior/inferior direction. PET/MR images were acquired on a Siemens Biograph mMR via T1-VIBE sequence with simultaneous list-mode PET acquisition.

Figure 1B shows that the co-registration of the PET and MRI was achieved with no post-processing, despite the presence of motion. The PET/MR/CT-compatible Tumour Motion Phantom can be used to generate accurate images of known geometries and reproducibly simulate respiration motion or user-defined motion profiles of a tumour.

**Specifications:**

- **Fluid Pump** (piston type):
  - Capacity: 270 ml
  - HR: 50 to 125 BPM
  - Piston stroke (max) = 140 ml@120 bpm

- **Heart module** (Urethane rubber 30A/ 60HU@120kVp; wall thickness = 1cm):
  - Chambers: Two; LV & RV; 70ml each at relaxed state.
  - End-diastolic volume [EDV] = up to 130 ml (typical 120 ml)
  - End systolic volume [ ESV] = down to 40 ml (typical 50 ml)
  - Arterial angular displacement around the axis = up to 2 cm

- **Software:**
  - NI LabVIEW Control Design and Simulation Module running on PC with the help of Quanser Q2-USB H.I.L control board. A pressure wave corresponding to the heart chamber movements is simulated and fed into the closed-loop PI position controller to drive the linear shaft of piston-pump.

**Results:**

Attached figure: Two trans-axial 0.5mm computed tomography images through the basal left ventricle (top right) and apical left ventricle (bottom right) show the presence of non-calcified plaque causing eccentric (top) and central (bottom) luminal stenosis.

Currently following studies are being carried out with the help of DAHP at UHN.

Study.1 - Optimal image reconstruction for detection and characterization of mixed coronary plaque during CTCA.

Study.2 - Influence of X-ray pulse duration on lung nodule sharpness during digital radiography in a dynamic anthropomorphic chest phantom.

**SP104.4 - Development of a PET/MR/CT Compatible Tumour Motion Phantom**

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The development of PET/CT scanners has improved staging for lung cancer, especially for nodal and distant metastatic sites. In the case of chest wall infiltration and mediastinal tumours, MRI is superior to PET/CT. PET and CT are acquired sequentially and thus motion in PET that is acquired over minutes cannot be corrected with the CT, which is acquired over several seconds. Siemens’ hybrid PET/MRI acquires both modalities simultaneously, eliminating the impact of respiratory motion due to sequential scanning. This could have a major impact on respiratory-gated lung cancer radiotherapy. Before implementing PET/MRI for lung cancer radiotherapy clinically, the benefits of this novel imaging technique should be validated in an appropriate phantom. Therefore, the goal of this work is to demonstrate a PET/MR/CT compatible respiratory motion phantom that
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SP105 - MRI: Novel Approaches and Molecular Imaging & Applications

TRACK 01: IMAGING

SP105.1 - Advancing MRI for Non-invasive Physiological and Cellular Imaging
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Magnetic resonance imaging (MRI) is a non-invasive, high-resolution whole-body imaging modality for probing deep tissue structures without requiring exposure to ionizing radiation. The exquisite soft-tissue contrast MRI affords is unparalleled, thus firmly establishing its importance in clinical diagnostic imaging. MRI also has great potential for imaging events at the physiological, cellular, and molecular level. Although most of these efforts currently remain within the domain of pre-clinical research, advancing MRI beyond conventional anatomical imaging is key to opening new avenues for exploration.

In this talk, I will describe the efforts in our laboratory to advance MRI for physiological, cellular, and molecular imaging for eventual translation to humans. Our emphasis is on “quantitation”, meaning that we use imaging to “measure” biological events. This focus is critical to improving the way we detect disease, since early changes in cells and tissue function often occur long before physical abnormalities become apparent, and having the ability to detect and measure these changes is crucial to early diagnosis and intervention. It will also enable us to tackle emerging applications, such as tissue engineering, where the ability to track transplanted cells and determine their fate or to monitor tissue development in vivo, can be assessed realistically only inside a living subject. The technical capabilities we are developing will be described alongside their application to guiding tissue-engineering approaches for regeneration and to new concepts for cancer detection (Figure 1) and cardiovascular imaging (Figure 2).

SP105.2 - Detection of Regional Radiation-Induced Lung Injury using Hyperpolarized 129Xe Localized Magnetic Resonance Spectroscopy
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Introduction: Radiation induced lung injury (RILI) remains one of the most important limitations of radiotherapy of the thorax. Magnetic Resonance Spectroscopy (MRS) using hyperpolarized 129Xe may be useful for early detection of RILI by quantification of gas exchange between lung air spaces, lung tissue (T), and red blood cells (RBC)1. Previous work using whole lung irradiation and 129Xe MRS has shown detection of inflammatory changes associated with RILI (i.e. pneumonitis) as early as two weeks post-irradiation in rats2. This work extends these methods to regional detection of RILI using localized MRS in a rat model involving irradiation of the right versus left lung.

Methods: Sprague Dawley rats were used following Western AUC-approved protocols. One cohort was irradiated with 18 Gy to the right thorax and incubated for two weeks, while the other cohort served as unirradiated controls. Localized 129Xe spectra were obtained from an 8x8 matrix in the coronal plane and processed to yield total tissue signal (ST) and total RBC signal (SRBC) for the whole lung as well as each of the left and right lungs, similar to Thind et al.3 For each rat, whole lung and individual lung (right and left) SRBC/ST ratios were calculated, after which ratios of SRBC/ST between right and left lungs (R/L) were calculated. Afterwards, lungs were removed, fixed, sectioned and stained (H&E) for histology.

Results: Eight rats were analyzed (three irradiated, five unirradiated). R/L was significantly different between the two cohorts (p = 0.009) with mean values 0.91 (± 0.08) and 0.69 (± 0.07) for the unirradiated and irradiated cohorts respectively. The difference between SRBC/ST between the cohorts was less significant for the left lung (p = 0.056) compared to the right (p = 0.019), while whole lung comparison was intermediate (p = 0.022).

Discussion: These results confirm that regional RILI differences are detectable at two weeks using hyperpolarized 129Xe localized MRS of rat lungs following single-lung irradiation of 18 Gy. The strong
Results and Conclusions: Similar to results given by Heikal et al., Fig. 1(g) shows that the spatial frequency response for the CS implementations was markedly lower than the fully sampled acquisition that they are intended to imitate (black plot). CMaCS (blue plot) provided a near two-fold increase in spatial frequency response compared to standard CS. However, due to potential B0 field variations across the FOV, a zero-order phase correction may prove insufficient for robust CMaCS, requiring more complex phase-handling.

References:

Acknowledgements: Philips Medical Systems for technical support in this work.

SP105.4 - Gadolinium Labeled Glycosylated Nanomagnetic Particles as Metabolic Contrast Agents in Molecular Magnetic Resonance Imaging

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Difficulties in the use, preparation, and cost of radioactively-labeled glycosylated compounds led us to this research and development study of a new gadolinium-labeled glucose compounds that do not
have a radioactive half-life or difficulties in its synthesis and utilization. Despite its good resolution, Magnetic Resonance Imaging (MRI) has low sensitivity, therefore, using MRI contrast agents, such as GD-DTPA (Magnevist) will improve tissue discrimination in MRI images.

The purpose of this study is the synthesis and physicochemical characterization of glycosylated gadolinium as metabolic contrast agent for molecular MRI (mMRI), in-vitro T1 relaxivity measurement and signal intensity of the glycosylated compounds has been also performed in comparison with magne-vist (GD-DTPA). Based on the structure of the 2-fluoro-2-deoxy-D-glucose molecule (FDG), first compound consisting of D-glucose conjugated with diethyleneglycol via N,N-carbonimidamide (CDI) mediated reaction, to achieve GD-DEG-DG, and characterized by various analytical technique, utilizes dynamic light scattering (DLS) to determine the size distribution. The nanoparticle size and morphology were using high resolution transmission electron microscopy (HTEM). In our study, the Gd-DTPA-DG were well defined nanoparticle with size 40 nm in diameter TEM images. While Gd-DEG-DG were 10 nm. The mean hydrodynamic diameter of nanoparticles, as measured by DLS, were 300 nm and 70 nm for GD-DTPA-DG and GD-DEG-DG, respectively. The synthesized GD-DTPA-DG and GD-DEG-DG were shown higher relaxometry rates in vitro relative to magne-vist. GD-DEG-DG and GD-DTPA-DG demonstrated shorter T1 than GD-DTPA at the same concentration.

This study shows that MRI of hyperpolarized $^{129}$Xe in the gas space and in the lung tissue is feasible, and can be used to detect increases in tissue signal in the lungs of irradiated rats as early as two weeks post-irradiation. An increase of approximately 50% in tissue signal was observed in the right lungs of the irradiated cohort compared to the unirradiated cohort corresponding to increases in tissue area (ie, pneumonitis) measured using histology. These methods should be readily translatable to human subjects given the growing availability of hyperpolarized gas technology in the clinic. Early detection of pneumonitis may allow adjustment to the radiotherapy plan and/or the application of alternate therapies to mitigate RILI.


SP105.5 - Hyperpolarized $^{129}$Xe Magnetic Resonance Imaging of a Rat Model of Radiation-Induced Lung Injury Involving Single-Lung Radiation Therapy

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Radiation therapy is a common treatment for lung cancer, but is limited by radiation-induced lung injury (RILI)[1]. It has been previously shown that Magnetic Resonance Imaging (MRI) with hyperpolarized $^{129}$Xe can detect changes in both lung tissue signal as well as exchange between gas and tissue (ie, pneumonitis) as early as two weeks following whole thorax irradiation in rats[2]. In this study, a novel MRI approach is developed for imaging of hyperpolarized $^{129}$Xe both in the gas phase and dissolved in lung tissue. The method is applied to a rat model of RILI involving single-lung irradiation.

The right thorax of three Sprague Dawley rats were irradiated with a cobalt-60 irradiator (18Gy), following previously described methods[2]. Three rats served as non-irradiated controls. 2D coronal spiral IDEAL[3] images were acquired using a repetition time (TR) of 300ms. Following three wash-in breaths of hyperpolarized $^{129}$Xe, IDEAL gas images and tissue images were acquired from the lungs within a breath-hold time of 6 seconds. Signal-to-noise ratios (SNR) of the averaged IDEAL gas images and the lung tissue images, for both the left lung (SGL, STL) and the right lung (SGR, STR) of both cohorts were calculated. To account for potential differences in ventilation and polarization, the lung tissue SNR values were normalized by respective gas SNR values for both left and right lungs (STL/SGL and STR/SGR). Following imaging, lungs were removed for histological examination.

Fig.1 shows coronal IDEAL gas (a) and tissue (b) images from a representative non-irradiated rat. STL/SGL and STR/SGR was strongly correlated with tissue area measured by histology (R=0.75), with a Pearson coefficient P-value=0.005 at p<0.01.

**References:**

SP105.6 - Ultra-short Echo Time (UTE) Magnetic Resonance Imaging of Cortical Bone: An Undersampled Acquisition Study

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Purpose: Ultra-short echo time (UTE) sequences have shown great utility in visualizing short T2 tissues like cortical bone which shows little or no signal with conventional clinical magnetic resonance imaging (MRI) techniques. Several short T2 contrast mechanisms have been developed to enhance bone contrast by suppressing signals from surrounding long T2 tissues including muscle and fat. These contrast mechanisms may significantly prolong the acquisition times.

**Methods:** A series of UTE pulse sequences were implemented on a 3-T Signa TwinSpeed scanner (GE Healthcare Technologies, Milwaukee, WI, USA) with a maximum gradient performance of 40 mT/m and slew rate of 150 mT/m/ms. In this paper, UTE, dual echo UTE (dUTE), adiabatic inversion recovery prepared UTE (IR-UTE) and adiabatic inversion recovery prepared dual echo UTE (IR-dUTE) with different undersampling acquisition ratios were compared by measuring signal-to-noise ratios (SNRs), contrast-to-noise ratios (CNRs), signal distortion, contrast, image sharpness and streak artifact power. The feasibility of using undersampling acquisition in UTE approaches was demonstrated by imaging cortical bone in vitro and in vivo using the clinical 3T scanner.

**Results:** Results showed that UTE, dUTE, IR-UTE and IR-dUTE data acquisitions can be highly undersampled to save scan time, while providing images with limited undersampling artifact especially for IR-UTE and IR-dUTE acquisitions. Figure 1 shows the dUTE
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imaging that can provide the Fractional Anisotropy (FA) index which evaluates many parameters that could be used as biomarkers to find biomarkers that help us in the diagnosis of this disease and in improving its medical treatment.

Among the MRI advanced techniques are: a) The diffusion tensor imaging that can provide the Fractional Anisotropy (FA) index which takes values between 0 and 1 and it is used to evaluate the integrity of the white matter; b) The Voxel-wise morphometry that helps to quantify the volume and the amount of gray and white matter in the brain; c) The functional Magnetic Resonance Imaging (fMRI) based on the Blood Oxygen Level Dependent (BOLD), that is used to identify different brain areas that are activated during specific tasks and to infer the connectivity between different brain regions that may be interconnected, as it is shown in the resting state connectivity.

Methods:

A total of 16 voluntary subjects participated in this study, 8 patients with ALS (age 18-54) and 8 control subjects, age matched, without antecedents of neurologic or psychiatric disease. The images were acquired with a Philips magnetic resonance scanner, Ingenia 3.0 T with a 32 channel head coil. We acquired sagittal T13D-weighted images with spatial resolution of 1x1x1mm³, axial diffusion tensor images with 33 independent directions of diffusion and b of 1000 s /mm². Axial fMRI based on BOLD with echo planar images (EPI) technique, TR=2s and 150 dynamics. Axial T2FLAIR-weighted images were also acquired to identify intra cortical and supra cortical lesions. The software FSL v.2.0 was used for the analysis of the data.

Results:

The FA is decreased in the corticospinal tract in bilateral form and in the posterior limb of the internal capsule. The Voxel-wise Morphometry analysis shows a decrement of the volume of all the brain in patients with ALS. The motor network obtained by the resting state

Conclusion: This study has shown that UTE imaging of cortical bone with highly undersampling acquisition (acceleration factor up to 23) is feasible when surrounding long T2 tissues are efficiently suppressed.

Figure 1: dUTE undersampling study of in-vivo distal tibia. dUTE undersampling images of distal tibia.

The purpose of this study was to discriminate the brain activation patterns associated with the anxiety-provoking distracter during the working memory (WM) maintenance for the human faces between patients with obsessive compulsive disorder (OCD) and healthy controls by using a function magnetic resonance imaging (fMRI).

Twelve patients with OCD (mean age = 31.3±7.4 years) and 12 healthy controls (mean age = 33.3±7.8 years) underwent the functional MRI on a 3.0 Tesla MR Scanner (Siemens Medical Solutions, Germany). The activation paradigm consisted of a string of “encoding - WM maintenance - distracter - retrieval.” In the encoding task, three different human faces sequentially appeared once on a quarter coordinate of a screen monitor. During the delay time following the encoding, the subjects were asked to maintain the WM for the encoded faces. Then, distracters were given to the subjects while maintaining the WM of the encoding step, in which the distracters consisted of an anxiety-provoking picture and a neutral picture. In the retrieval task, either of the face presented in the encoding task or a new face was presented. The brain activation mapping and the resulting qualification were processed by SPM8.

The average scores of perceived anxious emotion for anxiety-provoking picture were 7.8±1.4 and 7.2±1.4 in patients with OCD and healthy controls, respectively. The scores for the face recognition task with anxiety-provoking distracters were 67.8±9.1% and 68.3±11.9% in patients and healthy controls, respectively, while the scores for neutral distracters were 62.1±15.7% and 70.0±12.1%, respectively. The patients with OCD showed significantly decreased activities in the ventrolateral prefrontal cortex, superior parietal gyrus, middle temporal gyrus, and fusiform gyrus during the WM maintenance with the anxiety-provoking distracters as contrast to healthy controls, whereas the patients with OCD significantly increased activities in the inferior temporal gyrus and median cingulate gyrus (p<0.001).

It is concluded that our findings provide an evidence for the differential brain activation patterns associated with anxiety-provoking distracter between patients with OCD and healthy controls during the delay interval of the WM task. This finding will be helpful to understand the neural mechanism related to general impairment of emotional function in patient with OCD.

SP105.8 - Fractional Anisotropy, Voxel Wise Morphometry and Resting State in Patients with Lateral Amyotrophic Sclerosis

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Introduction:

The Amyotrophic Lateral Sclerosis (ALS) is a degenerative disease that is characterized by the damage of the Upper Motor Neurons (UMN) and the Lower Motor Neurons (LMN). Many studies have found that motor areas are affected by this disease, being the main affected areas the corticospinal tract, the posterior limb of the internal capsule and the anterior and medial parts of the corpus collosum; other studies have also found a general decrement of the gray matter in all the brain. The ALS has a difficult prognosis because the symptoms can be misleading; therefore it is really important to find biomarkers that help us in the diagnosis of this disease and in improving its medical treatment.

The Magnetic Resonance Imaging (MRI) is a non invasive neuroimaging method that offers information in vivo of the brain structures. This method counts with different advanced techniques which evaluates many parameters that could be used as biomarkers to identify distinct diseases or disorders.
SP106.1 - Proton therapy – close to becoming mainstream
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The number of patients treated with proton therapy is now well over 100,000. The field of proton therapy is growing at a remarkable and stable growth rate: the numbers double every ten years. To make this growth rate sustainable, and for proton therapy to become mainstream, we argue that two goals must be achieved: First, proton therapy must become cheaper and more compact. Secondly, we must be able to fully exploit the physical potential of proton therapy.

Many developments are underway to help with the first goal. Single room solutions and “compact” proton machines are becoming increasingly available. We will give an overview of the available options and report on our own experience with proton therapy retrofitted in a conventional treatment area. The biggest proton therapy component and one of the most expensive ones is the gantry. Based on an analysis of almost 5,000 patients treated with gantries in our center, we find that the vast majority of them could have been treated without the gantry. Developments of robotic patient positioning and immobilization, advanced in-room imaging solutions, as well as advances in pencil beam scanning delivery, will further reduce the need for a gantry.

The second goal requires the precise localization of the end of range of the proton beam in the patient. There are a number of developments underway to reduce range uncertainties. We will report on advances of measuring the proton range through the prompt gamma radiation produced by the proton beam in the patient. This will allow one to determine the proton range with millimeter precision in realtime.

SP106.2 - Monte Carlo-based Inverse Treatment Plan Optimization for Intensity Modulated Proton Therapy
Author(s): Yongbao Li¹, Zhen Tian², Ting Song², Zhaoxia Wu¹, Yaqiang Liu¹, Steve B. Jiang², Xun Jia²
¹Department Of Engineering Physics, Tsinghua University, Beijing/CHINA, ²Department Of Radiation Oncology, University of Texas Southwestern Medical Center, Dallas/UNITED STATES OF AMERICA

Intensity-modulated proton therapy (IMPT) can achieve a better dose distribution than passive scattering or uniform scanning. For IMPT optimization, Monte Carlo (MC) is desired for spots dose calculations because of the high accuracy in heterogeneous cases. Due to its capability of computing linear energy transfer (LET), MC-based IMPT planning is preferred in biological optimization scheme. However, MC simulation is too slow to be used for this purpose. Although GPU-based MC engine has been developed, the achieved efficiency is still not ideal. The purpose of this work is to develop a new scheme to include GPU-based MC into IMPT. The conventional approach for this purpose is simply using MC repeatedly for each spot dose calculations. However, this is not the optimal approach, because of the unnecessary computations on spots that turned out to have very small weights after IMPT optimization. Memory writing conflict also poses a challenge, if one sequentially compute dose at each spot. To solve these problems, we have developed a new MC-based IMPT plan optimization framework that iteratively
performs MC dose calculations and plan optimization. At each dose calculation step, the particles are sampled from different spots based on previously optimized spots intensity map with Metropolis sampling method. Simultaneous handling multiple spots also solves the memory writing conflict problem. We validated the proposed MC-based optimization schemes in one prostate case. It took 5-6 min of total computation time including both spots dose calculation and optimization with only one GPU card for the proposed method, whereas a conventional method naively using MC for spot dose calculations would be ~2-3 times slower.

**SP106.3 - FoCa: a protontherapy treatment planning system written in object-oriented MATLAB**

**Author(s):** Daniel Sanchez-Parcerisa, Alejandro Carabe

**Radiation Oncology, Hospital of the University of Pennsylvania, Philadelphia/UNITED STATES OF AMERICA**

**Purpose:** Monte Carlo transport codes are useful in protontherapy research as they provide accurate calculations, but at the cost of long calculation times. On the other hand, commercial treatment planning systems provide fast dose calculation but with limited access to the calculation engine behind them. To address these issues, we developed FoCa, an in-house treatment planning system, developed entirely in object-oriented MATLAB, which includes forward dose and LET calculation of proton radiotherapy plans in both active and passive modalities as well as a generic optimization suite for inverse treatment planning. **Methods:** Our approach was to provide the user with a set of classes dealing with the different aspects of a treatment planning system (CT importing, structure sets, dose kernel calculation, et cetera). We chose MATLAB for its fast prototyping capabilities, its speed at matrix calculations and its extensive geometry libraries. FoCa implements the proton-convolution-superposition algorithm for dose calculation and a similar pencil beam algorithm for analytical LET calculation. We included a user-friendly GUI for basic user interaction, as well as scripting capabilities for advanced operations. The inverse treatment planning framework is presented with an open architecture, not specific to any treatment mode or optimization algorithm, which allows researchers to work on their own optimization methods or therapy modalities. **Results:** We developed and tested the FoCa code. The validation results show a good agreement with the commissioning data, the 3D dose distributions based on patient-specific CT data calculated by a commercial treatment planning system, and 3D Monte Carlo calculations of dose and LET performed with Geant4. Finally, the inverse treatment planning suite was used to produce the first prototype of intensity-modulated, passive-scattered proton therapy, using 13 passive scattering proton fields and multi-leaf modulation to produce a concave dose distribution on a cylindrical solid water phantom without any field-specific compensator. **Conclusions:** We have demonstrated the validity and capabilities of the FoCa TPS in a wide range of setups. Its current and potential uses range from the fast calculation of any physical, radiobiological or clinical quantity in a patient CT geometry, to the development of new treatment modalities not yet available in commercial treatment planning systems. FoCa is currently available within our institution to a selected number of test users and it will be made available to the research community after all the necessary testing has been completed.

**SP106.4 - Assessment of the limitations of the dose calculation algorithm of a commercially-available treatment planning system for proton pencil beam scanning**

**Author(s):** Jessica E. Scholey, Liyong Lin, Christopher G. Ainsley

**Department Of Radiation Oncology, The University of Pennsylvania, Philadelphia/PA/UNITED STATES OF AMERICA**

This study evaluates the accuracy and limitations of a commercially-available treatment planning system's (TPS) dose calculation algorithm for proton pencil-beam scanning (PBS) and quantifies the sensitivity of the accuracy to the proton beam source modeling. In-air fluence profiles of PBS spots were modeled in the TPS alternately as single- (SG) and double-Gaussian (DG) functions, based on fits to commissioning data. Uniform-fluence, single-energy-layer square fields of various sizes and energies were calculated with both beam models and delivered to water. Dose was measured at several depths (Figure 1). For lower energies (100-150 MeV), the DG model fits the measurements well at all depths, while the SG model does not. For higher energies (150-225 MeV), both the SG and DG models fit the measurements well at shallow depths (< 4 cm), but not deeper, where dose contributions from proton-nuclear interactions become important, suggesting a limitation of the algorithm. The possibility of using, instead, a third model, based on double-Gaussian functions with parameters contrived to offset this inadequacy (DGC) was therefore investigated.

Eleven cuboid-dose-distribution-shaped fields with varying range/ modulation and field size were subsequently generated in the TPS, using each of the three beam models described, and delivered to water. Dose was measured at the middle of the spread-out Bragg peak. Percent differences between calculated and measured doses (Table 1) were greatest for the SG model, increasing the smaller the field. The DG model showed improvements for all field sizes in shorter range beams, though the percent differences for smaller fields persisted in longer range beams. The DGC model was, however, able to predict the measurements to within 2% for all beams.

It can be concluded that while neither SG nor DG models, employed as intended, are ideally suited for routine clinical use, the TPS's DG model can be tuned judiciously to yield acceptable results.
SP106.5 - Impact of the microdosimetric spread on cell survival data analysis

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¹McGill University, Montreal/CANADA, ²Uppsala University, Uppsala/SWEDEN

Purpose/Objective

The microscopic uncertainty of the energy imparted (microdosimetric spread, MDS) at the cellular/cell nuclei level due to the stochastic nature of ionizing radiation is normally not explicitly considered during parameterization of experimental survival fraction data. The magnitude of the MDS is higher for protons than for photons because of the known differences in track structures. The aim of this work is to present a method to quantify the impact of MDS on the biological radiation response. We estimate the effect on the α and β parameters of the linear quadratic (LQ) model used to describe experimentally obtained cell survival curves in different volumes sizes for various radiation qualities.

Materials and Methods

The Monte Carlo transport code LionTrack was used to simulate event-by-event proton tracks in liquid water for the energies 0.91, 1.4, 1.72, 3.18, 3.59, and 4.97 MeV/u, as well as for a 60Co source. The frequency distribution of specific energy for one track f(z,D) and the dose dependent frequency distribution of specific energy f (z,D) were calculated with in-house analysis codes for a range of spherical volume sizes typical of cell nuclei. Experimentally obtained survival curves intrinsically account for the MDS. When the specific energy z given by f (z,D) is weighted with the LQ equation, \( \alpha + \beta z^2 \), the α and β values based on D instead of z exclude the MDS variations and can be determined by fitting α and β to survival curves calculated from published αexp and βexp values. The RBE10 at 10% survival with 60Co as the reference radiation for the αexp and βexp was also factorized into a factor equal to the RBE for the fitted α and β values (RBEinh), and a factor representing effects of the MDS (RBEMDS), RBEMDS for a tissue with variable cell nuclei sizes was calculated by weighting f (z,D) with the size distributions presented by Poole et al [Submitted to Med. Phys. 2015] for healthy and tumor tissues.

Results

The f(z,D) can be quite well represented by a narrow normal distribution for the lowest LET radiation (60Co) even at small volumes, becoming wider and skewed towards lower specific energies with increasing particle LET. The relative MDS increases with decreasing dose and decreasing volume. The RBEMDS factor decreases with increase in LET and volume thereby reducing the RBEinh. For a heterogeneous size sample, the RBEMDS for healthy tissue reduces the RBEinh the most when compared to the tumor tissue.

Conclusions

Our data suggests that the MDS in experimental data smears out the higher efficiency of the inherent RBE. The MDS component in a clinical scenario with an irradiated volume that consists of cells with different sizes might be smaller for tumor tissues than for healthy tissues due to the higher number of larger nucleus sizes in tumor tissues.

SP106.6 - Magnetically scanned-beam proton radiography using Micromegas detectors

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Purpose: While the energy of therapeutic proton beams can be adjusted to penetrate to any given depth in water, range uncertainties arise in patients due in part to imprecise knowledge of the stopping power of protons in human tissues. Proton radiography is one approach to reduce the beam range uncertainty, thereby allowing for a reduction in treatment margins and dose escalation.

Methods: The authors have adapted a novel detector technology based on Micromes Gaseous Structure ("Micromegas") for proton therapy beams and have demonstrated fine spatial and time resolution of magnetically scanned proton pencil beams, as well as wide dynamic range for dosimetry. In this work, proton radiographs were obtained using Micromegas 2D planes positioned downstream of solid water assemblies. The position-sensitive monitor chambers in the IBA proton delivery nozzle provide the beam entrance position.

Results: Radiography with Micromegas detectors and actively scanned beams provide spatial resolution of up to 300 μm and water-equivalent thickness (WET) resolution as good as 0.02% (60 μm out of 31 cm total thickness). Dose delivered to the patient by the proton radiography technique would be 2 cGy. The spatial resolution as a function of sample rate and number of delivered protons is found to be near the theoretical Cramer-Rao lower bound. Using the CR bound, we argue that the imaging dose could be further lowered to 1 mGy, and still achieve sub-mm spatial resolution, by relatively simple instrumentation and beam delivery modifications.

Conclusion: For proton radiography, high spatial and WET resolution can be achieved, with minimal additional dose to patient, by using magnetically scanned proton pencil beams and Micromegas detectors.
SP107 - Beam Delivery

SP107.1 - A Quantitative Analysis of Teletherapy in Low Resource Settings: Cobalt or Linac?

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1University of Texas MD Anderson Cancer Center, Houston/UNITED STATES OF AMERICA, 2University of St. Tomas Hospital, Manila/PHILIPPINES, 3University of Alabama Birmingham, Birmingham/UNITED STATES OF AMERICA, 4Groote Schuur Hospital and University of Cape Town, Cape Town/SOUTH AFRICA

**Purpose:** There exists a deficit of more than 6,500 megavoltage teletherapy units worldwide, many in low resource-settings. Medical linear accelerators and cobalt units would address this need, and the tradeoffs between them have been compared qualitatively in the literature. Often discussed are dose rate, power infrastructure, and machine downtime all of which affect machine availability and treatment time. We have quantitatively addressed these topics and their effect on patient throughput (treatments/day).

**Methods:** Patient treatment time was calculated as the sum of patient set-up, beam-on, and mechanical motion time, with input data from clinical observation and electronic records (1000+ patients). The following treatment techniques were considered: linacs (conformal with MLC, Step-and-Shoot IMRT, Dynamic IMRT, and VMAT), and cobalt units (conformal therapy with and without MLC). Power data from The World Bank for 44 African countries were divided into three power scenarios based on frequency of outages. We assumed that cobalt units remain operable during outages using a backup generator. Machine downtime data was acquired from in-house records (linacs) or experienced users (cobalt).

**Results:** Low dose rates associated with cobalt units increase conformal treatment beam-on time between 0.6 and 2 minutes, depending on source activity. This represents between 14% and 28% of the total treatment time. Advanced modalities increase treatment time, particularly step-and-shoot IMRT which requires the most mechanical motion time, an average of 2.6 minutes (28% of total treatment time). VMAT and Dynamic IMRT treatments have shorter mechanical motion time (0.5 and 1 minutes, respectively) but longer beam on time (2 and 1.9 minutes, respectively). Patient throughput, under each of the seven treatment techniques and three outage scenarios, is shown below. In scenarios of “fewer” or “few-est” outages, the two machines are comparable when linac delivers conformal or VMAT treatments. If linac downtime is increased to account for availability of service parts and personnel, throughput is decreased by 6%, but conclusions remain unchanged. If a cobalt unit uses blocks instead of MLCs, throughput is reduced by 14-24% (1-3 block changes per fraction). Additionally, effects of machine utilization, IGRT usage, geographically specific cancer incidences (IARC data), fractionation schemes, and palliative or curative treatment goals were investigated.
**Discussion:** While additional aspects, including cost comparisons, dosimetric advantages, and personnel requirements remain to be addressed, this work establishes a framework for teletherapy implementation in low resources settings, and identifies power as the predominant influence on patient throughput.

**SP107.2 - The study of Total Marrow Irradiation Based on Rotational Intensity-modulated techniques**

**Author(s):** Shouping Xu1, Chuabin Xie2, Baolin Qu2, Wei Yu2, Wei Xu2, Xiaohu Cong2, Xiangkun Dai2

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Total body irradiation (TBI) is a special form of radiotherapy, generally as part of bone marrow conditioning regimens. Conventional TBI is difficult to achieve dose uniformity because of using the large field of simple technique. In recent years, tomotherapy technique has been used for TBI, due to delivering highly conformal and uniform target dose, and providing better normal structure avoidance. But this kind of technique isn’t widely used for its expensive cost. Volumetric-modulated arc therapy (VMAT) could achieve rotational intensity modulation based on the traditional accelerator and may obtain the efficient and accurate treatment with the imaging-guided device. The purpose of this study is to compare the dosimetric characteristics and efficiency of RapidArc and Tomotherapy in total marrow irradiation (TMI) for hematologic malignancies in order to get the reference data for the choice of clinical application. Eight patient plans were retrospectively designed and analyzed for RapidArc and Tomotherapy. Total bone marrow was contoured as clinical target volume excluding the cubitus and hand part, then plus a 3.0mm margin as planning target volume. The prescription was 12Gy in 10 fractions. ArcCHECK system was used for dose verification, and the safety and accuracy of clinical delivery would be evaluated. The results of this study showed that the two techniques could well achieve the target coverage. The conformity indexes of RapidArc and Tomotherapy were 0.54±0.05 vs 0.52±0.07 (p=0.45), but Tomotherapy plans have a visible advantage over RapidArc plans in the dose uniformity of target. The homogeneity indexes were 0.19±0.02 vs 0.13±0.02 (p=0.00). Tomotherapy plans showed better in sparing of the critical organs apart from the whole brain, oral, parotid gland, the small intestine, rectum, and the maximum dose of lens of Tomotherapy plans was reduced by 41% comparing to RapidArc plans. The MUs and treatment delivery time of RapidArc and Tomotherapy were 2608MU/560s vs 12842MU/891s. The gamma analysis passing rates for head-neck, chest-abdomen, pelvic were 98.9%±1.9%, 98.4%±1.8%, 97.4%±2.1% for RapidArc and 94.3%±1.5%, 96.5±1.2%, 94.1%±1.9% for Tomotherapy plans. This study shows that the two methods using RapidArc and Tomotherapy could achieve the acceptable dose of TMI, and the delivery efficiency of RapidArc was better than Tomotherapy. Two kinds of techniques are promising and can solve the clinic implementation of TMI.

**SP107.3 - IMRT and VMAT comparison for a case of bilateral breast carcinoma**

**Author(s):** Erick O. Montenegro1, Juan F. Lucero1, Rafael E. Lengua1, Luis A. Linares1, Milton E. Ixquiac2, Ricardo Contreras2

1Medical Physics, HOPE International Radiotherapy Center, Guatemala/GUATEMALA, 2Physics, Universidad de San Carlos De Guatemala, Guatemala/GUATEMALA

**Introduction:** A comparison was made between IMRT and RapidArc (VMAT) plans for a patient with bilateral breast carcinoma involving supraclavicular lymph nodes and skin. The prescription dose is 50Gy (25 fractions, 2Gy each), one of our goals was to maintain the organs at risk (OAR's) as low as possible.

**Objectives:**
- Select the best suited treatment modality for this case, taking into account the coverage to the PTV, the OAR's irradiation and the treatment delivery time.
- Evaluate the dosimetric parameters such as homogeneity, conformity index and monitor units.

**Methodology:** Four different treatment plans were created; three IMRT plans using 10, 11 and 16 fields and two full rotations VMAT.

All plans were optimized Eclipse (Ver.10.0) from Varian Medical Systems Inc. and delivered in a ClinaciX with Millenium Multileaf Collimator (120 MLC). The gamma evaluation was performed using the EPID AS500 and the ArcCheck from SunNuclear Corporation.

**Results:**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>IMRT 10</th>
<th>IMRT 11</th>
<th>IMRT 16</th>
<th>VMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMinPTV</td>
<td>71.60%</td>
<td>74.60%</td>
<td>75.00%</td>
<td>83.80%</td>
</tr>
<tr>
<td>V20GyLung (L)</td>
<td>35.91%</td>
<td>31.12%</td>
<td>14.05%</td>
<td>16.60%</td>
</tr>
<tr>
<td>V20GyLung (R)</td>
<td>49.60%</td>
<td>43.00%</td>
<td>27.28%</td>
<td>16.72%</td>
</tr>
<tr>
<td>DMeanHeart</td>
<td>23.16 Gy</td>
<td>20.31 Gy</td>
<td>19.61 Gy</td>
<td>9.49 Gy</td>
</tr>
<tr>
<td>DMaxSpinal Cord</td>
<td>29.00 Gy</td>
<td>28.85 Gy</td>
<td>24.92 Gy</td>
<td>23.04 Gy</td>
</tr>
<tr>
<td>Homogeneity(D5% - D95%)</td>
<td>11.94</td>
<td>10.79</td>
<td>12.74</td>
<td>5.77</td>
</tr>
<tr>
<td>Conformity Index (V95% / VPTV)</td>
<td>1.04</td>
<td>1.04</td>
<td>1.01</td>
<td>1.04</td>
</tr>
<tr>
<td>Time(min)</td>
<td>14:55</td>
<td>16:05</td>
<td>22:30</td>
<td>3:57</td>
</tr>
<tr>
<td>Gamma Evaluation γ&lt;1 (EPID)</td>
<td>95.71%</td>
<td>93.49%</td>
<td>93.09%</td>
<td>90.70%</td>
</tr>
<tr>
<td>Gamma Evaluation γ&lt;1 (ArcCheck)</td>
<td>81.85%</td>
<td>83.30%</td>
<td>64.60%</td>
<td>83.00%</td>
</tr>
</tbody>
</table>

1: Comparison of dose distributions.
Conclusions:

It was decided to treat the patient with the VMAT plan. It is observed that it presents better PTV coverage, but more importantly the OAR’s receive less dose and it reduces drastically the treatment delivery time and the monitor units.

According to the gamma evaluation, all plans are equally reproducible.

References:

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3. Q.-R. Jackie Wu, Quality of coverage: Conformity measures for stereotactic Radiosurgery MedPhys,2003;4(4)

SP107.4 - Measuring the Location and Dynamics of the Beam Spot and Field Centre on a Therapy Linear Accelerator in X-Ray Mode

Author(s): Victoria C. Foss2, Tyler S. Meyer2, David P. Spencer2

Introduction: On radiation therapy linacs the X-Ray source location, or beam spot, is critical to accurate treatment. Yet it is not measured. Instead, we accept that the vendors adjust symmetry and radiation-light field agreement. The beam spot will, therefore, be different for different photon energies. We set out to measure the location of the beam spot on a machine where the rad-light agreement was different for the 6 MV and 15 MV energies. We used images of the X-Ray projections of BBs at different source-to-object distances and 180° collimator rotations. We discovered that the beam spot actually moved during beam delivery. We believe this is due to the dynamic beam steering attempting to adjust beam parameters such as flatness and symmetry.

Methods: We mounted two 4 mm diameter Tungsten balls just off-axis on plastic trays in the upper wedge slot and in the cutout location of an electron cone. We took images at about 5 second intervals on a Varian Trilogy™ using an output rate of 100 MU/min in Service Mode on the linac and AM Maintenance High Quality mode on the aSi-1000 portal imager with a 4x4 cm field for both 90° and 270° collimator angles. We do not think the use of Service mode invalidated the use of our data for Clinical mode. Only the Collimator and Accessory interlocks were overridden. The images are analyzed using Doselab™.

Results: We observed that for 15X the field centre moved as much as 1.5 mm at the isocentre over the first 30 seconds of beam (see Figure), while our 6X beam moved about 1 mm. We also tested a stereotactic cone which showed field motion up to 0.3 mm at 6X over the first 30 seconds of beam (see Figure). This motion made it difficult to measure the location of the beam spot, since two separate images were required to determine its location. Assuming that sequential runs showed the same pattern, we paired the images to show that the beam spot moved about 0.15 mm for 6X, settling about 0.14 mm from the rotational axis. For 15X it moved 0.4 mm, settling about 0.12 mm from the rotational axis.

Conclusions: This means that beam spot size measurements assuming the beam is static may be incorrect. SRS delivery may be affected. Field symmetry and location will be time-dependent, so the QC time-scale should reflect clinical use. Investigations will continue on our other 8 linacs.

Materials and Methods:

The dose profiles along the two axes of an open and two filtered fields (filter A, and a thicker filter B) of the GB-500 were measured with a Standard Imaging (Middleton, WI) A12 ion chamber at 10cm depth in the centre of a 30×30×27cm³ (small) solid water phantom placed at various positions. These profiles were then calculated using the EGSnrc MC code (National Research Council, Canada) set to the conditions of the GB-500. Doses were calculated at selected depths in a continuous 360×120×27cm³ (large) water phantom and in the same small phantom as used in measurements. Over 60 billion histories were run on a CPU cluster to achieve an estimated dose uncertainty of <0.8% in the clinically useful field.

Results and Conclusions:

Measured and MC calculated longitudinal profiles are shown in Figure 1. For both filters, the beam flatness over 200cm treatment length for measured doses is approximately 3%. The beam flatness for MC calculated doses is slightly better for filter B (5%) than for filter A (6%). MC calculated doses (in both the small and large phantom) differ from the measured doses (in the small phantom) by a maximum and average of around 4% and 1% respectively, for all open and flattened fields. The agreement shows that the MC simulation faithfully models the GB500. Additional results showing prediction for new filter designs will be presented.
SP107.6 - Monte Carlo study for the design of a novel Gamma-Tomo SBRT system

Author(s): Grisel M. Mora¹, Omar Chibani², Ahmed Eldib², Jinseng Li², C.M Ma²

¹Institute Of Biophysics And Biomedical Engineering, University of Lisbon, Lisbon/PORTUGAL, ²Radiation Oncology, Fox Chase Cancer Center, Philadelphia/UNITED STATES OF AMERICA

Introduction: The 60Co beam emerging from the Gamma-Tomo source assembly was simulated in a previous study [1] and the authors reported the spectra of particles reaching the plane immediately (1mm) before the collimation system entrance. In the present work, we simulate the 60Co beam emerging from a novel Gamma-Tomo SBRT collimation system and calculate the output factors and dose rates for different source configurations and collimator sizes.

Methods: A Gamma Tomo system includes 13 60Co source capsules, source housing, a primary collimator and 4 different changeable collimators. The sources (6.22 mm of diameter) are located in 2 rows with different angles and distances to the longitudinal axis and the beams can be collimated to obtain four different circular field sizes at the isocenter (35 mm, 16 mm, 7mm, and 3.5mm). The BEAM-Monte Carlo [2] code is used to realistically model the collimation system geometry, including primary collimator and 4 different changeable collimators. The previously calculated phase space file [1] is used to transport particles throughout the collimation system to the patient plane for all of the changeable collimators of the Gama-Tomo System, and the respective phase space files of particles are stored at isocenter for each of the circular fields to be used as input of the GEPTS [3] to perform dose calculations. A newly designed geometry module is used to determine the dose distributions in a spherical polystyrene phantom with an 8cm radius centered at the isocenter.

Results: The characteristics of the particle spectra emerging from the collimation assembly are determined and the effect of the source-collimator position on the spectra reaching the isocenter found to be dependent on field size. We observed differences up to 5% between the energy spectra and fluence distributions calculated for different configurations of the source-collimator assembly. The effect of the source-collimator position is observed (up to 6%) on dose distributions calculated at isocenter and is dependent upon the size of the circular field.

Conclusions: The resulting data from the present study supports the machine design process and is valuable in building a well-represented source model for all sources to perform the dose calculations for all of the changeable collimators for this novel Gamma-Tomo system.

References:

SP107.7 - A dosimetric evaluation of flattening filter-free volumetric modulated arc therapy for postoperative treatment of cervical cancer

Author(s): Fuli Zhang
Radiation Oncology Department, The Military General Hospital of Beijing PLA, Beijing/CHINA

AIMS: To compare flattening filter free (FFF) beams and conventional flattening filter (FF) beams in volumetric modulated arc therapy (VMAT) of cervical cancer after surgery through a retrospective planning study. MATERIALS AND Methods: For a cohort of 15 patients, VMAT plans of FFF beams and normal flattened (FF) beams were designed. The prescribed dose was 45Gy/1.8Gy/25f, 95% of the planning target volume received this dose. Doses were computed with a commercially available TPS using Monte Carlo (MC) algorithm. Plans were compared according to dose-volume histogram (DVH) analysis in terms of PTV homogeneity and conformity indices (HI and CI) as well as OARs dose and volume parameters. Results: FFF-VMAT was similar as FF-VMAT in terms of CI, but inferior to the latter for HI. No statistically significant differences were observed between FFF-VMAT and FF-VMAT in terms of pelvic bone marrow, small bowel, bladder and rectum. Conclusions: For patients with cervical cancer after hysterectomy, the FFF beam achieved similar target and OARs dose distribution as the FF beam. Reduction of BOT in cervical cancer is beneficial.
**SP108 - Patient and Occupational Dose Assessment**

**TRACK 05: DOSIMETRY AND RADIATION PROTECTION**

**SP108.1 - Radiation dose to patients from cardiac interventions performed using image intensifier, flat detector and novel flat detector systems**

**Author(s):** Roshan S. Livingstone¹, Anna Varghese¹, Paul V. George²

¹Radiology, Christian Medical College, Vellore/INDIA, ²Cardiology, Christian Medical College, Vellore/INDIA

**Background:** Radiation dose to patients from interventional cardiology are of concern whether it is being performed using image intensifier (II) or flat detectors (FD). There are very few reports on achieving reduced doses using novel FD systems with advanced real-time image noise reduction algorithms and optimized acquisition chain. This study intends to compare radiation doses from cardiac interventions performed using II, FD and novel FD systems.

**Design and Methods:** Coronary angiography (CA) and single stent percutaneous transluminal coronary angioplasty (PTCA) were performed using Philips Integris H5000 II, Philips Xper FD10 and Philips Allura ClarityFD10 mono plane systems (Philips Healthcare, Netherlands). The novel FD - Allura clarityFD10 was equipped with real-time noise reduction algorithms and optimized acquisition chain for dose reduction. Dose area product (DAP) was measured using DAP meter available in all systems. During interventions, low dose protocol with 0.4mm Cu filter for fluoroscopy and 0.1mm Cu for cine runs were selected in all systems.

**Results:** Tables 1 and 2 show dose related information for CA and PTCA performed in II, FD and novel FD systems. During fluoroscopic screening, DAP values were similar in all systems. However, during cine runs, a reduction of the order of 60% and 30% in DAP was observed in novel FD when compared to II and FD respectively. A 20 – 50% reduction in the overall doses could be achieved with the use of novel FD systems during CA procedures following standard imaging protocol.

**Conclusion:** Though all systems utilised stringent dose reduction strategies involving heavy filtration; significant dose reduction without compromising diagnostic image quality was observed using novel FD systems involving real time image noise reduction algorithm.

**Table 1: Radiation doses from CA different angiography systems**

<table>
<thead>
<tr>
<th></th>
<th>Integris II</th>
<th>Xper FD10</th>
<th>Clarity FD10</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>28</td>
<td>39</td>
<td>140</td>
</tr>
<tr>
<td>Fluoro time(min)</td>
<td>3.96</td>
<td>2.11</td>
<td>3.24</td>
</tr>
<tr>
<td>(0.4 – 10.2)</td>
<td>(0.5 – 6.23)</td>
<td>(0.5 – 10.5)</td>
<td></td>
</tr>
<tr>
<td>cine runs</td>
<td>8.14</td>
<td>6.7</td>
<td>7</td>
</tr>
<tr>
<td>(5 – 13)</td>
<td>(4 – 10)</td>
<td>(4 – 14)</td>
<td></td>
</tr>
<tr>
<td>Fluoro DAP Gycm2</td>
<td>5.53 ± 1.13</td>
<td>5.46 ± 3</td>
<td>5.53 ± 3.6</td>
</tr>
<tr>
<td>(0.6 – 15.4)</td>
<td>(1.3 – 13.4)</td>
<td>(0.9 – 16)</td>
<td></td>
</tr>
<tr>
<td>Cine DAPGycm2</td>
<td>22.18 ± 2.02</td>
<td>11.92 ± 4</td>
<td>8.44 ± 4.2</td>
</tr>
<tr>
<td>(11.4 – 57.2)</td>
<td>(3.6 – 21.2)</td>
<td>(1.5 – 28.2)</td>
<td></td>
</tr>
<tr>
<td>Total DAPGycm2</td>
<td>27.7 ± 2.49</td>
<td>17.4 ± 5.7</td>
<td>13.9</td>
</tr>
<tr>
<td>(12.6 – 69)</td>
<td>(6.6 – 28.8)</td>
<td>(4 – 37.6)</td>
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**Table 2: Radiation doses from PTCA performed using different angiography systems**

<table>
<thead>
<tr>
<th></th>
<th>Integris II</th>
<th>Xper FD10</th>
<th>Clarity FD10</th>
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<tbody>
<tr>
<td>n</td>
<td>18</td>
<td>12</td>
<td>43</td>
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<tr>
<td>Fluoro time(min)</td>
<td>11.57</td>
<td>8.7</td>
<td>10.8</td>
</tr>
<tr>
<td>(5 – 30)</td>
<td>(3.5 – 13.4)</td>
<td>(5 – 26.5)</td>
<td></td>
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<tr>
<td>cine runs</td>
<td>17.2</td>
<td>15</td>
<td>16.2</td>
</tr>
<tr>
<td>(8 – 31)</td>
<td>(9 – 20)</td>
<td>(7 – 27)</td>
<td></td>
</tr>
<tr>
<td>Fluoro DAPGycm2</td>
<td>17.88 ± 9</td>
<td>16.1 ± 8.9</td>
<td>17.2 ± 10</td>
</tr>
<tr>
<td>(6.9 – 39)</td>
<td>(9.8 – 22.4)</td>
<td>(6 – 39.5)</td>
<td></td>
</tr>
<tr>
<td>Cine DAPGycm2</td>
<td>30.79 ± 16</td>
<td>18 ± 11.8</td>
<td>16.5 ± 9</td>
</tr>
<tr>
<td>(9 – 66.2)</td>
<td>(9.6 – 26.4)</td>
<td>(5.4 – 31)</td>
<td></td>
</tr>
<tr>
<td>Total DAPGycm2</td>
<td>48.7 ± 25</td>
<td>34 ± 33</td>
<td>33.7 ± 18</td>
</tr>
<tr>
<td>(21.3 – 98)</td>
<td>(18.6 –40.6)</td>
<td>(11.4 –70.1)</td>
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</table>

**SP108.2 - First National Occupational Radiation Dose Registry in Ministry of Health and its Validation: An Oman Experience**

**Author(s):** Arun Kumar L S, Rashid Al-Hajri, K Jaseer, Saeed Al-Kalbani

Medical Physics, Ministry of Health, Muscat/OMAN

In Ministry of Health (MOH), Oman; radiation is used for diagnosis, radiation therapy, bio-medical research and for the irradiation of blood & blood products. As per the IAEA Basic Safety Standards (2014), it is the responsibility of the employer to make arrangements for the assessment & recording of occupational exposures and for the workers’ health surveillance. Not only that, the records of occupational exposure for each worker must be maintained during and after the worker’s employment, at least until the worker attains the age of 75 years, and for not less than 30 years after cessation of the work. However, the current national radiation protection legislation...
of Sultanate of Oman does not mandate the recording of occupational doses or a national dose registry. To overcome this problem in MOH, Oman; we developed the first National Occupational Radiation Dose Registry (NORDR) for its workers.

This in-house developed NORDR - Centralised Dose Recording System (CDRS) - for the management of personal monitoring of radiation workers, is having about 1500 radiation workers in about 145 health facilities. Each one of them is monitored by issuing a Thermo Luminescent Dosimeter (TLD) every month through the CDRS by tagging the serial number of each TL dosimeter with the unique MOH staff number of each worker by post for a wear period of one month. Some of the above locations are very remote - few thousand kilometers away from the capital city, Muscat. End of every month, the TLD’s are collected back and processed for Hp(10) and Hp(3).

Upon estimation and recording of doses, individual and institutional dose reports are sent to the health facilities. The cumulative annual dose report of each worker is also dispatched from the NORDR facility to each worker.

CDRS also records age, sex, category of staff, section and department of staff, duration of work with radiation, dose received prior to joining MOH, any episode of an overexposure or any suspected over exposure, annual and cumulative radiation dose of each radiation worker etc. If a worker uses more than one TL dosimeter such as for forehead, lens, ring right, ring left etc; each will be accounted and accordingly dose will be estimated according to the type & the corresponding dose report will be generated. Also, the same software will handle the individual dose(s) of each worker on a monthly, quarterly, half-yearly, yearly basis and the dose history for the entire period of radiation job. CDRS will also perform the dose analysis of an individual worker, a group of workers in an institution and all the radiation workers available in CDRS as a whole. If a worker exceeds the annual dose limit or investigation level, the CDRS will alert accordingly. The details of our in-house national occupational radiation dose registry - CDRS - will be further discussed during presentation. This dose registry can be emulated by other countries those who do not have a national dose registry for their radiation workers especially for those who are having relatively smaller number of radiation workers.

### SP108.4 - A wireless personal dosimeter for Interventional Radiology medical personnel.

**Author(s):** Leonello Servoli, Massimiliano Paolucci, Maurizio Biasini, Lucia Bissi, Andrea Calandra, Bruno Checchi, Stefania Chiocchini, Roberto Cicioni, Elia Conti, Roberto Di Lorenzo, Anna C. Dipiato, Stefania Fabiani, Nevio Forini, Daniel Magalotti, Agostino Maselli, Daniele Passeri, Andrea Pantericci, Pisana Placidi, Maurizio Scarpignato, Andrea Scorzon

1Istituto Nazionale di Fisica Nucleare, Sezione Perugia/ITALY, 2AUSL Umbria 2, Foligno/ITALY, 3Università degli Studi di Perugia, Perugia/ITALY, 4Université degli Studi dell’Aquila, L’Aquila/ITALY, 5Università degli Studi di Modena e Reggio Emilia, Modena/ITALY, 6AUSL Umbria 1, Perugia/ITALY

A personal wireless active dosimeter prototype has been developed to be wearied by medical staff during Interventional Radiology procedures to obtain real-time measurement of the dose-rate.

It has been tested both on phantom and during several different medical procedures. It is battery powered with an autonomy up to 8 hours.

The dose-rate measurement is performed at a frequency of 5 Hz, and transmitted to the receiving station with no dead time and a packet error rate less than 1%. Even this small information loss could be recovered with simple data handling strategies, transmitting the integrated dose at the end of each procedure.

The dose-rate measurement capability, using a certified X-ray beam facility, is linear up to 400 microGy/s, higher than the rate diffused by the most demanding procedures, while there is virtually no upper limit on the dose measurement linearity, as long as the battery is working, because the sensor element is reset after each measurement ( > 1.5 Gy/h).

The sensitivity to diffused photon energy is below 10 keV.

The linearity of the response to an absorbed dose during medical procedures is shown in the following picture, where on the horizontal axis are reported the dose measured by the prototype and on the vertical axis the dose measured by the control dosimeter system (TLDs). Both systems have been calibrated simultaneously on the same certified X-ray beam.

### SP108.3 - Assessment of Patient and Staff Doses in Interventional Cerebral Angiography Using OSL

**Author(s):** Chryzel Angelica B. Gonzales, Center For Device Regulation, Radiation Health, And Research (cdrrhr), Department of Health (DOH) - Food and Drug Administration (FDA) Philippines, Manila City/PHILIPPINES

**Assessment of Patient and Staff Doses in Interventional Cerebral Angiography Using OSL**

Chryzel Angelica B. Gonzales, M.Sc.1,2 and Augusto A. Morales, Jr., D.Sc. 1,2

1The Graduate School, University of Santo Tomas, Manila, Philippines
2Center for Device Regulation, Radiation Health and Research, Food and Drug Administration, Department of Health, Manila, Philippines

**Abstract—** In interventional radiology (IR) procedures, radiation doses received by both patient and staff are relatively high. The objectives of the study are: (1) determine/measure entrance surface dose (ESD) to patient using nanoDot optically stimulated luminescence (OSL) dosimeter, (2) verify that patient doses do not exceed established international guidance levels set by IAEA and ICRP Report 103, as stated in the BSS, applied in the Philippines, (3) estimate the effective dose E to operator and using InLight OSL dosimeters, (4) estimate the annual effective dose E for the operator and staff performing interventional cerebral angiography procedure, (5) determine who among the staff have training in radiation protection in interventional radiology/cardiology, and if so, if such training is applied in practice, and (6) verify that staff doses do not exceed established dose limits set by the IAEA and ICRP Report 103, as stated in the BSS, applied in the Philippines.

Clinical data and technical factors were gathered from interventional cerebral angiography procedures (4-vessel angiogram/6-vessel angiogram) performed at the University of Santo Tomas Hospital (USTH). It was found that none of the ESD values approach the dose thresholds for induced skin injuries (erythema or epilation). The estimated weighted annual dose for all the interventional medical workers is 5.9 mSv which is lower than the dose limit given by the IAEA and ICRP Report 103, as stated in the BSS. However, the primary operator has exceeded the investigation level of 30% of the annual dose limit of 20 mSv (13.44 mSv in the case of research badge #3). The computation of the annual dose for this study was based on a survey for the maximum number of IR procedures performed per year.
SP109.1 - Development of a Thick Gas Electron Multiplier Based Multi-element Microdosimetric Detector

**Author(s):** Zahra Anjomani¹, Andrei R. Hanu², Sahar Darvish-Molla¹, William V. Prestwich¹, Soo H. Byun³

¹Medical Physics And Applied Radiation Sciences, McMaster University, Hamilton/Canada, ²NASA Goddard Space Flight Center, Greenbelt/United States of America

A prototype multi-element gaseous microdosimetric detector using Thick Gas Electron Multipliers (THGEM) has been designed and constructed for monitoring mixed neutron–gamma radiation fields. The multi-element design was employed to increase the neutron detection efficiency, particularly for weak radiation fields commonly encountered in radiation protection applications. Owing to the absence of wire electrodes, the THGEM multi-element detector offers flexible and convenient fabrication. The prototype THGEM multi-element detector consists of alternating layers of tissue-equivalent plastic hexagons and each layer houses an array of cylindrical gas cavity elements with equal height and diameter. The fundamental signal and stability performance of the THGEM detector was tested using a $^{244}$Cm alpha source and the detector responses to various neutron fields are currently under comprehensive investigation using the $^7$Li(p,n) neutron source at the McMaster Tandetron accelerator. A preliminary result on the neutron microdosimetric and absorbed dose responses of the prototype detector will be presented in contrast to the responses of a commercial detector.


SP109.2 - Development of a 2-D THGEM Microdosimetric Detector

**Author(s):** Sahar Darvish-Molla¹, Andrei R. Hanu², Zahra Anjomani¹, William V. Prestwich¹, Soo H. Byun³

¹Medical Physics And Applied Radiation Sciences, McMaster University, Hamilton/Canada, ²NASA Goddard Space Flight Center, Greenbelt/United States of America

Inspired by our prototype THick Gas Electron Multiplier (THGEM) detector [1,2], an advanced two-dimensional microdosimetric detector is currently under development at McMaster University. This detector aims to measure the spatial distributions of high and low linear energy transfer radiation doses simultaneously in mixed radiation fields, which will enable us to overcome the operational limitation of the classical tissue-equivalent proportional counters (TEPCs), particularly for high dose rate fields. Compared to the traditional TEPCs, wire electrodes were replaced by THGEM, which not only enhances the gas multiplication gain but also offers a flexible and convenient fabrication process for building two-dimensional detectors.

A prototype detector consists of an array of 3x3 gas cavities, equivalent to 9 TEPCs, each of which has a dimension of 5 mm diameter and length. By filling its sensitive volume with propane based tissue
equivalent gas, at a pressure of 167 torr, each detector simulates a spherical soft tissue of 2 μm in diameter. To process nine detector signals simultaneously, taking the overall cost, size and flexibility into account, we developed a multi-input digital pulse processing system using a modern microcontroller interfaced with an ADS807 12-bit sampling ADC with a sampling rate of 42 Msps. The prototype signal processor was tested using a NaI(Tl) detector and the test results have proven that it is faster than a traditional analogue system and a commercial digital system. Using the McMaster Tandetron 12L(p,n) accelerator neutron source, both signal performance as well as neutron dosimetric response of the detector have been extensively investigated. A preliminary test result will be presented.

In condensed media, the quantum wave nature of electrons may be non-negligible for simulation of sub-1 keV transport. These results within a simplified model of electron transport in condensed media suggest that electron transport is strongly affected by the structure of the medium and that inelastic scatter does not necessarily improve agreement between QM and MC simulations.

**SP109.4 - Investigation of the relations between absorbed dose to cellular targets and to bulk tissue for kilovoltage radiation using Monte Carlo simulations and cavity theory**

**Authors:** Patricia Oliver, Rowan Thomson

Physics, Carleton University, Ottawa/CANADA

Relationships between macroscopic (~1 mm) and microscopic (cellular) dose descriptors for incident photon energies between 20 and 370 keV are investigated using Monte Carlo (MC) simulations and cavity theory.

MC simulations of clusters of cells, single cells, and single nuclear cavities embedded in phantoms are carried out for various normal and cancerous tissues; cell (nucleus) radii range from 5 to 10 microns (2 to 9 microns). Results are compared to cavity theory predictions for the dose to a cavity of nuclear size and elemental composition embedded in a bulk tissue phantom (Dnuc), relative to the dose to the corresponding average bulk medium (Dmed). Large (LCT), small (SCT), and various intermediate (ICT) cavity theory approaches are investigated. The ICT approach (see figure) is a weighted sum of SCT and LCT contributions (stopping power and energy absorption coefficient ratios, respectively).

Approaches for computing the weighting parameter \( d \) include MC simulations determining the fraction of cavity dose due to electrons set in motion by photons interacting in the surrounding medium ('ICT: NFW method') and others involving Burlin’s approach (1969) where \( d = \frac{1-\exp(-\beta L)}{\beta L} \) with \( \beta \) given by \( \exp(-\beta \text{RCSDA})=0.01 \) or \( \exp(-\beta \text{RCSDA})=0.001 \) and \( L \) is the cavity’s mean chord length, taking RCSDA as the CSDA range corresponding to the most energetic electron or using a weighted sum of photoelectron and Compton electron components ('ICT:photo/Compton').

The ratio \( \frac{D_{\text{nuc}}}{D_{\text{med}}} \) varies considerably with tissue type, cell and nucleus size and elemental composition, and source energy. ICT predictions for \( \frac{D_{\text{nuc}}}{D_{\text{med}}} \) are highly sensitive to the method used to estimate the parameter \( d \). The figure provides example results for
the dose ratio $D_{nuc}/D_{med}$ for one cell model (cell and nucleus radii of 7.35 and 5 microns, respectively) in melanoma tissue; MC results give dose to the nucleus of the central cell in a multiple cell model. At low energies, LCT qualitatively predicts nuclear doses, whereas at energies above 50 keV, SCT predictions are reasonable. In general, over the range of energies and simulation geometries (tissues, cell types) considered, ICT with Burlin’s approach ($ICT: \exp(-\beta \frac{RCSD}{IA})=0.01$) provides the best estimate of $D_{nuc}/D_{med}$, resulting in an average discrepancy of 4%. However, no cavity theory method accurately predicts MC results over the entire range of energies and simulation geometries; thus, there is no general conversion method to obtain dose to the cellular nucleus from macroscopic dose descriptors. Further, neither dose to water nor dose to medium provides an accurate estimate of nuclear dose.

Results

γH2AX staining showed that the number of DNA DSBs was six-fold higher for 5 hour irradiated cells compared to controls. The incidence of 6 and more DSBs in an irradiated cell was 22 times higher compared to control cells. These numbers correspond to more than 5000 transmitted α-particles.

Conclusion

Timepix can be used effectively as a transmitted microdosimetry detector, providing high resolution images and excellent spatial resolution of detected α-particles. The relationship between the number of transmitted α-particles and the number of the DNA DSBs is being evaluated for us in targeted alpha therapy.

Figure 1: A) Experimental setup: Timepix chip was mounted above the A549 monolayer with an evaporated Ra-223 α-source underneath. B) Detection of transmitted α-particles using Timepix.

SP109.5 - Development of transmitted alpha particle microdosimetry using Timepix: Investigation of A549 lung carcinoma cells exposed to alpha particles irradiated from Ra-223

Author(s): Ruqaya Al Darwish, Alexander H. Staudacher, Eva Bezak

1Department Of Medical Physics, Royal Adelaide Hospital, Adelaide/AUSTRALIA, 2Centre For Cancer Biology, Translational Oncology Laboratory, Adelaide/SA/AUSTRALIA

Aim

To investigate the survival of A549 human lung carcinoma cells when irradiated with α-particles.

To correlate the number of DNA double-strand breaks (DSBs) per cell with the number of transmitted α-particles from Ra-223.

Materials and Methods

A549 cells were seeded at 15,000 cells on transwell inserts (0.14 cm²). The transwell system consists of two compartments: a larger well containing an evaporated Ra-223 source and an insert with a 10 µm thick polycarbonate membrane to which cells adhere.

The Timepix detector, Amsterdam Scientific Instruments, is a hybrid semiconductor pixel radiation detector. It consists of a pixelated silicon layer of 256 x 256 pixels (55 µm² each) bump-bonded to a CMOS pixel readout chip. Experiment setup is shown in figure 1 (A). Transmitted α-particles were detected and imaged with respect to seeded cells (figure 1 (B)). The quantitative correlation between the distribution of α-particle hits and cell damage was investigated for 1-5 hours irradiation times.

To assess the cell radiation damage, unirradiated (controls) and irradiated cell monolayers were stained with the DNA DSB marker γ-H2AX (green staining) and cell nuclei were counterstained with DAPI (blue staining). The number of DNA DSBs per cells after irra-
SP110.1 - Optical Navigation in Functional Neurosurgery

Author(s): Karin Wårdell
Department of Biomedical Engineering, Linköping University, Linköping/SWEDEN

Learning objectives:

Understand the basic principle of blue-light fluorescence microscopy

Be able to present two different fluorescence methods used in neurosurgery

Give examples of intraoperative navigation options used during DBS-implantations

Optical Navigation in Functional Neurosurgery

During the last decade, the use of optical techniques for navigation during neurosurgery has increased. Neurosurgical microscopes, introduced already in the 1950s, are today available with video recording and fluorescence imaging. Among these the blue-light setting is designed for visualization of malignant tumours by means of 5-aminolevulinic acid (ALA) [1]. In order to also quantify the fluorescence during tumour surgery, we have developed a handheld optical probe adapted to the requirements of the operating room [2]. The performance of the probe-system has been compared with fluorescence microscopy and biopsies and the results show that it is superior in detecting weak fluorescence when using the recommended microscopy-dose of ALA (20mg/kg). By combing the blue-light microscope and the hand-held probe both an overview of the operational field as well as the point specific fluorescence can be visualized.

Laser Doppler perfusion monitoring (LDPM) and imaging (LDPI), and diffuse reflectance spectroscopy (DRS) are other optical techniques currently under assessment as navigation support during neurosurgery. DRS allows for extraction of information from tissue chromophores and thus makes estimations of for instance saturation tissue of oxygenation possible [3].

With LDPI the cortical blood perfusion can be visualized whereas high resolution detection of differences in blood flow and tissue greyness can be achieved by LDPM. This dual function has been compared with fluorescence microscopy and biopsies and the results show that it is superior in detecting weak fluorescence when using the recommended microscopy-dose of ALA (20mg/kg). By combing the blue-light microscope and the hand-held probe both an overview of the operational field as well as the point specific fluorescence can be visualized.

Physical localized delivery based on electrospray process utilizes the bombardment of accelerated droplets containing the therapeutic molecule on targeted tissue, facilitating the entrance of the molecule into the cells. Electrospray process is based on Coulomb repulsion of charged particles, and to generate and accelerate the aerosol high electrical potential difference between a capillary and a counter electrode is required.

To transfer this method into clinical application single-port access instruments are needed providing the accelerating power and the fluid to the intraluminal region. The electrical field is applied by connecting the targeted tissue with ground potential, at the tip of the devices thus acting as counter electrode, while the high voltage is connected to the capillary axially placed within a working chamber. This configuration assures a predefined working distance and provides repeatable conditions of application.

References


SP110.2 - Endoscopic Electrospray: A minimal invasive tool for physical targeted gene delivery

Author(s): David Hradetzky1, Stephan Boehringer1, Paulius Ruzgys2, Prosper A. Fiave3, Karin F. Blaser1, Thomas Geiser2, Amiq Gazdhar3, Karin Wårdell1, Stephan Bohringer1
1Institute For Medical And Analytical Technologies, University of Applied Sciences and Arts Northwestern Switzerland (FHNW), School of Life Sciences, Muttenz/SWITZERLAND, 2Department For Pulmonary Medicine, University Hospital Bern, Bern/SWITZERLAND, 3Department Of Clinical Research, University of Bern, Bern/SWITZERLAND

Targeted gene or chemotherapeutic drug delivery offers a great potential for various diseases. In comparison to systemic delivery, side effects can be reduced and the quantity of delivered agent may increase. Also physical delivery is expected to reduce inflammatory and immunological reactions which often accompany targeted delivery utilizing viral vectors [1].

Physical localized delivery based on electrospray process utilizes the bombardment of accelerated droplets containing the therapeutic molecule on targeted tissue, facilitating the entrance of the molecule into the cells. Electrospray process is based on Coulomb repulsion of charged particles, and to generate and accelerate the aerosol high electrical potential difference between a capillary and a counter electrode is required.

To transfer this method into clinical application single-port access instruments are needed providing the accelerating power and the fluid to the intraluminal region. The electrical field is applied by connecting the targeted tissue with ground potential, at the tip of the devices thus acting as counter electrode, while the high voltage is connected to the capillary axially placed within a working chamber. This configuration assures a predefined working distance and provides repeatable conditions of application.

Based on described concepts, different instruments were designed and realized (Figure 1). First standalone devices (Ø10mm, adjustable working distance 0-10mm, rigid, fabricated with additive manufacturing) for endoscope assisted application and second miniaturized
A multi-modality intraoperative imaging system has been developed for hybrid cone-beam computed tomography (CBCT) and fluorescence diffuse optical tomography (FDOT). This translational research demonstrates that the use of CBCT spatial priors improves the quantitative performance of fluorescence tomography. Experiments with ICG inclusions embedded in liquid phantoms demonstrate that fluorescence signal of eGFP was detected after 24hrs incubation at 37°C using fluorescence imaging. GFP after electrospray expression indicates the successful transfection.

Both, the rigid and the miniaturized flexible electrospary instrument successfully transfected the plasmid into the cells, proving the suitability of electrospray for physical targeted delivery and providing a feasible concept of rigid and flexible electrospary instruments for gene therapy in clinical application.

This work was supported by the School of Life Sciences of the University of Applied Sciences and Arts Northwestern Switzerland, the Department for Pulmonary Medicine at University Hospital of Bern and the Scientific Exchange Program NMS.CH.


SP110.3 - Cone-Beam CT-Guided Fluorescence Tomography for Intraoperative 3D Imaging
Author(s): Michael Daly, Nidal Muhanna, Harley Chan, Brian C. Wilson, Jonathon Irish, David Jaffray
Princess Margaret Cancer Centre, Toronto/Canada

A multi-modality intraoperative imaging system has been developed for hybrid cone-beam computed tomography (CBCT) and fluorescence diffuse optical tomography (FDOT). This translational research system is under investigation for clinical applications in head and neck surgery including oral cavity tumour resection, lymph node mapping, and free-flap perforator assessment. The fluorescence imaging system is configured for use with indocyanine green (ICG) using a collimated 760 nm laser diode and a 14-bit near infrared (NIR) camera. Frehand image collection in a non-contact geometry is achieved using a stereoscopic optical camera for real-time localization of the laser source and camera. Intraoperative CBCT images with sub-mm spatial resolution are acquired with a flat-panel C-Arm. FDOT is implemented using a finite element method for diffuse tissue optics (NIRFAST), with structural information from CBCT used directly in the optical reconstruction algorithm using Laplacian-type regularization (“soft priors”). The light rays from the laser source and camera pixels are geometrically projected onto the boundary elements of the tissue mesh using algorithms for ray-triangle intersection and camera lens distortion. Registration errors between real and projected boundary points are <2 mm for typical acquisition geometries. Surface flux is converted from CCD photon counts using free-space radiometry models and camera photon transport calibrations (e.g., filter transmittance, camera quantum gain, sensor noise). Pre-clinical studies using tissue phantoms and small animals are presented to characterize 3D imaging performance as a function of sub-surface fluorophore size, depth, and concentration. Experiments with ICG inclusions embedded in liquid phantoms demonstrate that the use of CBCT spatial priors improves the quantitative performance (<15% error, a reduction of 50% relative to no priors) in the tomographic reconstruction of fluorescence yield at depths <2 cm.

SP110.4 - An Optimal Motion Profile for a Wireless Endoscopic Capsule Robot
Author(s): Sina Mahmoudzadeh, Hamed Mojallali
Faculty Of Engineering, University of Guilan, Rasht/IRAN

Purpose: The inner parts of the GI tract such as the small intestine are inaccessible using conventional methods. We propose an optimal model of motion profile for a wireless endoscopic capsule robot (capsubot) for obtaining diagnostic data from the GI tract. Critical criteria such as the size and smoothness of the movement of the capsubot are taken into consideration for the optimization process, making it possible to fabricate the capsobut smaller in size, making it easier for the patient to swallow, and causing less discomfort during the procedure.

Methods: The legless capsubot model used in this work mainly consists of two parts: the inner mass and the capsule body which would contain the diagnosing equipment. The inner mass can move back and forth inside the capsule body. By applying a force to the inner mass in the proper direction, the capsule body can be moved forward or backward. An optimization model was developed for the motion of the capsubot which takes into account the limitations on the capsule body, such as shape, length and weight. The optimization model, uses non-linear optimization to minimize the power consumption and maximize the traversing distance given a limited battery source. Finally, a sensitivity analysis was performed to test the robustness of the proposed model to fabrication errors.

Results: The results showed 82% reduction in battery consumption for the movement of the capsubot compared to the other work in the literature, which allows the capsubot to be smaller than those in the literature. The results for simulation of the trajectory and the speed of the capsubot showed a smooth movement of the capsubot without any backward movement. Under the same conditions (same duration and available power for moving the capsubot) the capsubot moved a distance 89% longer than the best result of other work in the literature with the same power consumption. The sensitivity analysis results showed very low variability among the quality of movement of capsubot and distance traversed under small variations in different parameters of the capsubot such as size and length of the capsule body.
Conclusions: The results for the proposed model showed significant improvement in the motion of the capsulebot and the required power. Since the dimensions of the battery could be decreased due to the reduced required power, the model can be used to fabricate a potentially smaller capsulebot. This allows fabrication of a smaller capsulebot that could be swallowed more easily by the patient causing less discomfort, or a better use of the capsule space for adding additional features such as drug delivery and biopsy equipment.

SP110.6 - Orthogonal IR System for Instrumental tracking in Minimally Invasive Spine Procedures for training using Wiimote Technology
Author(s): Juana E. Martínez, Daniel Lorias, Arturo Minor Electrónica, CINVESTAV, México, D.F./MEXICO

In this paper we present a system for track the movements of the training instrumental in 3D space, using two infrared Cameras from two Nintendo Wii Remotes in order to evaluate the progress surgeons during the learning phase for making incisions and placement of screws in the spine throw minimally invasive procedures. The cameras are positioned orthogonally, and they detect the position of IR markers that are placed in the training instrumental.

SP110.7 - Use of a Patient-Specific Ventriculostomy Surgical Simulator to Develop a Model for Preoperative Risk Assessment Based on Measures of Anatomical Variation
Author(s): Ryan Armstrong, Roy Eagleson, Sandrine De Ribaupierre University of Western Ontario, London/CANADA

Insertion of a ventricular catheter—an external ventricular drain—is a common neurosurgical procedure. Though considered a simple procedure and often performed by residents, catheters are inserted blindly, most often without image guidance, relying on the surgeon’s spatial abilities and anatomical landmarking. The relatively high malplacement rates reported by some institutions reflect the difficulty. We used a virtual reality surgical simulator with patient-specific scenarios to examine the anatomical factors that influence user performance. Using objective metrics to quantify user performance and anatomical variations, we developed a model to predict malplacement risk based on measures of anatomical variation.

A diverse set of patient scenarios were created by segmenting the lateral and third ventricles from MR and CT images and incorporating the geometries into a custom ventriculostomy module within the NeuroTouch simulator. The simulator consists of a mannequin head with a pointing tool. Users are tasked to select a burr hole location and indicate the trajectory into the lateral ventricle. Metrics to evaluate user performance were devised to reflect clinical outcome using a single aggregate score. A model was constructed to estimate the difficulty of a given case based on the mean and variance of user performance. To examine the role of anatomical variations, we examined measures thought to influence performance, including ventricle volume, midline shift, Evan’s ratio and maximal width of the anterior horn. One neurosurgical expert and seven residents were recruited for a user study and each performed the surgical task of burr hole and trajectory selection a number of times on various cases. We found that anatomical variation in the simulator had a significant impact on user performance. Correlation with performance was seen for all anatomical measures, although the strongest predictors of performance were ventricle volume, midline shift and anterior horn maximal width. By determining the difficulty of each case based on user performance, we were able to produce a model to predict malplacement risk (based on targeting accuracy) using an optimized weighting of each anatomical variant measure considered.
SP111.1 - Ultrasound-induced heart rate decrease: Role of age in female rats

Objective:
Use of ultrasound in therapy has been increasing and new techniques have been developed as, for instance, in cardiac diseases. Animal models for cardiovasculardise disease support the hypothesis that female sex and/or the sex hormone estrogen may contribute to the sexual dimorphism in the heart and to a better outcome of cardiac diseases in females. Aging is associated with reduced responsiveness of many hormone receptors. The goal was to investigate the age-dependent changes in the cardiac system in female rats exposed to pulsed ultrasound that may benefit therapeutically with heart rhythm abnormalities.

Methods:
Transthoracic ultrasonic exposure experiments were divided into two female Sprague-Dawley rat groups (n=5 ea): Group 1: Five 3-mo-old 200-250-g rats and Group 2: Five 24-mo-old 250-400-g rats. The ultrasonic exposure protocol was the same for both groups: 3.5 MHz pulses of 2.0 MPa peak rarefactional pressure amplitude (equivalent to spatial peak intensities of 133 W/cm²), variable pulse repetition frequencies (6, 5, 4, 5, 6 Hz), 10-s each sequence (0.5% duty factor), see Figure. Cardiac conditions were evaluated before (at baseline) and at 3 and 15 min after ultrasonic exposure ceased (3 and 15 min results normalized to each rat’s baseline values).

Results:
Group 1: at 3 and 15 min, respectively, the heart rate decreased 12% and 15%, and the cardiac output decreased 16% and 14%. Group 2: at 3 and 15 min, respectively, the heart rate decreased 12% and 15%, and the cardiac output increased 14% and 15%. There was no significant difference between the younger and older rats for the heart rate or for the cardiac output.

Conclusions:
Pulsed ultrasonic exposure caused similar decreases in the heart rate and cardiac output in the two rat-age groups, that is, there were no age-dependent differences in the cardiac system of young and old female rats stimulated by pulsed ultrasound. The results are promising for therapeutic application in cardiology as treatment for heart rhythm abnormalities in women of different ages. This work was supported by NIH R37EB002641.

SP111.2 - Low cost pulsed wave Doppler ultrasound system for vascular studies

Objective: To implement a Doppler ultrasound system with user interface for visualizing the blood flow profile relative to Doppler shift spectrum. Data visualization occurs by RGB mode with 9 bits color depth, 8 bits for velocity resolution and 7.5 ms of time resolution. The visualization of the sonogram is at 130 frames/s. Digital processing and user interface are implemented on a Xilinx Spartan-3E FPGA. This low cost alternative for diagnosing vascular pathologies on superficial vessels helps to prevent and assist the high number of cases affected by vascular diseases in Cuba.

Keywords — vascular diseases, ultrasound, FPGA, low cost.

SP111.3 - Real-Time Three Degree-of-Freedom Measurement of Catheter Motion for Input to a Robotic Catheter Navigation System

Objective: Commercial robotic catheter navigation systems (RCNS), used for many types of cardiac ablation therapy, enable the interventionalist to remotely manipulate a catheter’s position. Typically, the interventionalist operates the robotic systems unnaturally with a provided user interface that is not instinctive, often including a joystick-based controller. Specialized training is required to operate these systems, which may lead to future dependence on this technology. An intuitive solution was previously developed to facilitate translation form conventional to robotic intervention [1]. This device detects axial and rotational changes of a master-side catheter and although inherent to the interventionalist, its use in contemporary RCNSs is limited because modern interventional catheters are steerable, permitting catheter tip deflection. To address this, we have developed a master-side input device that detects motion changes in all three positional degrees-of-freedom.

Methods: The input device enables direct manipulation of an ergonomic master-side catheter handle. A shell of a recycled steerable
Y. Thakur et al., precision and dexterity. The catheter handle assembly is then mounted on a custom linear motion stage whereby a rack and pinion mechanism coupled to another encoder detects axial motion. A dedicated electronic system with a powerful microcontroller provides quadrature encoding and robotic motion scaling to enable higher levels of precision. A wireless module provides position streaming to a slave robot. The design of the input device provides a calculated axial resolution of 13 μm and both rotational and deflection resolution of 0.18°. The accuracy of the input device was evaluated using an optical tracking system. Five 30-second motion profiles were manually imposed on each degree-of-freedom. Position data provided by the embedded system and the tracking system, were then compared for their mean error.

**Results:** The input device, depicted in the image below, shown to have an absolute mean error in the axial direction to be 0.44 ± 0.33 mm, rotary direction to be 0.41 ± 0.15°, and tip deflection to be 0.54 ± 0.43°. The on-board embedded system enables reliable, high-speed data transmission for optimal master-slave robotic control and permits selectable motion scaling.

**Conclusion:** We have developed and evaluated an instinctive master-side input device that can be used with an RCNS to fully manipulate a slave-side steerable interventional catheter with high precision and dexterity.


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**SP111.4 - Pulse Wave Velocity as a Function of Cuff Pressure – Extra Information About the Cardiovascular System**

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High blood pressure (BP) is one of the biggest global health risks. Non-invasive methods determine only the momentary value of systolic- and diastolic BP. Knowing arterial rigidity would provide cardiologists with invaluable extra information.

A Home Health Monitoring Device, HHMD, was developed at the Dept. Measurement and Information Systems, Budapest University of Technology and Economics. HHMD inflates and deflates the cuff slowly (6 mmHg/s) and records also ECG and photoplethysmographic signal (PPG) at both index fingertips. Among other parameters the pulse wave transit time, PWTT is calculated. Measured from a healthy senior person, Figure 1 shows a typical PWTT – cuff pressure (CP) curve. Occlusion with the cuff causes temporary alteration in the dynamic properties of the brachial artery. The alteration can be characterized by the change of PWTT.

**Fig. 1.**

The slope of the PWTT – CP curve is characteristic for the cardiovascular system. We determined the CP belonging to the steepest change. During inflation it is denoted by *dup*. PWTT was averaged for 8 s with CP=0 before (PWTTbefore) and after (PWTTafter) inflation and deflation. The ratio of the two PWTT values is ΔT Ratio=PWTTbefore/PWTTafter.

170 were selected and analyzed from more than 1500 recordings taken from patients who underwent open-chest cardiac surgery and also from young- and senior healthy control persons. The results confirm that the PWTT – CP function provides extra information about the state of the brachial artery. Based on our research we suggest three parameters to quantify this information.

The difference between *dup* and DBP: For all the three tested group *dup* correlates with DBP. The difference is smallest for the young healthy group. Values for the senior healthy persons and for the patients are similar.

The change of PWTT: In most cases PWTT is greater after than before occlusion, thus ΔT Ratio < 1. It can be interpreted that occlusion temporarily increases the elasticity of the brachial artery. For patients ΔT Ratio can exceed 1. The value of ΔT Ratio is an indicator of arterial rigidity; it correlates neither with SBP nor with DBP.

Slope of increase of PWTT during inflation: There is almost no difference among tested persons regarding the slope of increase of PWTT during inflation when CP exceeds *dup*. However, there are two patients who sometimes produced much higher values than the maximum of all other tests (6 s/mmHg). This indicates momentary increased rigidity of the arterial wall.

**SP111.5 - Cardiac Output estimation through Impedance Cardiography using reconfigurable hardware.**

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Impedance Cardiography allows the noninvasive determination of cardiac output quickly and continuously. Cardiac output provides vital information for evaluating and analyzing the hemodynamic information in patients who are in critical medical conditions. A distribution of current-injection electrodes is used to sense changes to pulsed voltage changes that are proportional to the thorax bioimpedance. The acquired signal combines basal impedance component with dynamic tissue components. It is the resulting product of an amplitude modulation with frequency components located on either side of the frequency component of the injection signal. A quadrature demodulation stage is used for translation to baseband of the signal in order to preserve amplitude and phase information. Digital signal processing is implemented on FPGA, allowing high flexibility during the research process.

**SP111.6 - Microfluorimetry System Instrumentation for Ca^{2+}−**
Associated Fluorescence Imaging of Cardiomyocytes in Response to High Electric Fields

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The defibrillation is the only effective therapy against ventricular fibrillation. Although a common clinical procedure, this technique also harms healthy cells by means of electroporation, possibly re-introducing arrhythmias. In order to study how myocytes respond to high electric fields (E), scientists commonly use fluorescent dyes in sophisticated and expensive microscopes. These devices produce high quality data, but they are sometimes financially unreachable. We have developed an artisanal microfluorimetry system employing some pieces from deactivated medical equipments. The system proved successful as we could generate quality fluorescence images of isolated adult rat cardiac myocytes loaded with Ca²⁺-associated fluorescent dye Fluo-3 and subjected to monophasic high intensity E. Cells with major axis parallel to E direction were selected. Using regions of interest (ROIs) analysis, we verified that fluorescence variations in ROIs facing the electrodes are bigger and asymmetric, with higher variations at the side towards the anode.

SP111.7 - A practical device to warn on impending syncopal episodes

Author(s): Michael Cheng¹, Venkatesh Thiruganasambandamoorthy¹, Hilmi R. Dajani², Miodrag Bolic³
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Syncope (fainting) can lead not only to serious personal injury but also can endanger public health as when the sufferer is driving a car. An electronic monitoring device can help to minimize syncopal events due to cardiac rhythm changes. This kind of devices will greatly enhance the ability of the patient to take immediate action to safeguard personal and public health.

On the current consumer market, there are numerous heart rate monitoring devices catering for sports use with sophisticated software support; however such devices are not specific to individual patient’s needs. On the other hand, ample devices are available to monitor and record various patient data to be analyzed by proprietary clinical software catered for physician use; but such devices are relatively expensive, sold only to physicians, and the data are interpreted “off line” (by the physician).

This paper proposes a simple device to be worn by sufferers of cardiac arrhythmia to provide online (instant) warning signals directly to the wearer on impending fainting. The sufferer could act immediately to stop physical activities, sit, lie down, or stop the car etc. and so help prevent potential injury to the sufferer or to others. The device concept is based on physiological findings that when the time interval between successive heart beats (the RR interval) is

SP111.8 - Robust Blood Pressure Monitoring in Atrial Fibrillation Patients

Author(s): Saif Ahmad¹, Izmail Batkin¹, Miodrag Bolic², Hilmi R. Dajani¹, Voicu Z. Groza¹, Sanjeev Chander³
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Background Blood pressure (BP) is an important vital sign characterizing cardiovascular health. Therefore, hypertension/hypotension diagnosis and management through accurate monitoring is critical for reducing risk of life-threatening conditions like stroke. Automated non-invasive BP (NIBP) devices are increasingly recommended in clinical practice. However, these devices tend to be unreliable in patients with chronic conditions like atrial fibrillation (AF) and obesity [1] – resulting in inefficient BP management and hence increased risk [2]. Unreliability arises because NIBP monitors estimate BP by analyzing arterial pulses alone and these patients may present weak, erratic, and/or unpredictable arterial pulses.

Method/Results Health Parametrics Inc. (HPI), a University of Ottawa spinoff, is investigating novel technology for increasing the accuracy of automatic NIBP estimation. Briefly, we have developed a novel yet simple method for simultaneous acquisition of electrocardiogram
SP112 - Instrumentation

SP112.1 - Adaptation of Surgical Instruments for the Removal of Bladder Tumours

Author(s): Spencer C. Barnes¹, Duncan E.T. Shepherd¹, Daniel M. Espino¹, Richard Viney², Prashant Patel², Richard T. Bryan²

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Background: Transurethral resection of bladder tumour (TURBT) is the gold standard in non-muscle invasive bladder cancer removal. The tumours are removed piecemeal and this is thought to be a key reason for the high recurrence rate of up to 78% at 5 years.

Aims: A novel device has been designed to facilitate a decrease in this high recurrence rate by creating a sealed environment in which the surgeon can resect a tumour. This device aims to arrest the spread of cancer cells to the rest of the bladder wall.

Methods: Shape memory metal (Nitinol), 3D printing and latex have been used to create an actuating cone which can press against the bladder wall, surrounding the tumour. This design, in the open state, can be seen in figure 1 around a resectoscope, the device currently used for removing bladder tumours. Shape memory alloys (SMAs) such as Nitinol exhibit the property of solid phase change when heated and as such are able to move to a pre-trained shape. Nitinol wires were ‘trained’ at 550 °C in a steel jig at 30°. These wires were then sequentially placed in a 3D printed housing and soldered together in a series configuration. Subsequently, liquid latex was painted onto the wires using a mould, and allowed to dry. After being initially deformed to a closed state the device was then able to open when heated.

Testing: The device was actuated successfully using a 2.6 ampere 10 volt supply in liquid environments at 37 °C using custom made testing apparatus. Despite the extra heat loss due to the liquid environment the device was still able to open. The ability of the device to seal was also successfully tested with blue dye.

References
SP112.2 - A compact gantry based on pulse powered magnets for a laser-based proton radiotherapy

**Author(s):** Leonhard Karsch1, Thomas Hermannsdörfer2, Florian Kroif3, Umar Masood2, Michael Schürer1, Jörg Pawelke2

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**Purpose:** The new approach of particle acceleration by high intensity lasers may provide size and cost reduction for proton facilities. However, laser-driven proton beams are characterized by intense and short (few picoseconds) pulses with low repetition rates, high energy spread and large beam divergence. In addition to more compact accelerators due to the short acceleration length of few micrometers, also more compact beam transport systems are possible. The beam pulse structure enables more compact gantries by the use of pulse powered magnets without iron core, but much higher magnetic field strengths. Using pulsed magnets, the magnetic field is only generated for a short time period but still sufficient long for the transport of a proton pulse.

**Method:** First, a gantry was designed regarding laser accelerator specific requirements like a proton capturing element and an energy selection system. Secondly, prototypes for every type of pulsed magnets necessary for the gantry - solenoid, dipole and quadrupole - were designed and realized. Thirdly, these prototypes were experimentally characterized at a pulsed 10 MeV proton beam of a tandem accelerator. This beam is well defined in energy and intensity, the pulse duration is arbitrary adjustable down to 1 microsecond which is still longer than the pulse duration of laser driven beams. Therefore, it allows to test the ion optical behavior at low electrical risks, i.e. at reduced magnet current.

**Result:** A gantry for laser driven proton therapy was designed being much smaller than existing devices. A radius of 2.5 m and a length of 3 m is achieved by deploying high magnetic fields of up to 40 T inside the solenoid, up to 10 T inside the dipole and a magnetic field gradient of up to 300 T/m in the quadrupole. The achieved magnetic pulse durations with these prototypes are approximately 1 ms. The duration during which the field is constant is about 100 microseconds. Each of the individual magnets, as well as their combination to a pulsed beamline, show the expected ion optical properties like focussing and bending.

**Outlook:** After an adaptation of the setup, further experiments at clinical relevant proton beam energies (up to 230 MeV) will follow. For this purpose, the proton beam from the conventional cyclotron at a facility in Dresden recently put into patient treatment, has been adapted to deliver pulsed beams to an experimental bunker. The work is supported by the german government BMBF (no. 03Z1NS11).

SP112.3 - Developing a pH Responsive Mesh as a Smart Skin Wafer in Ostomy Appliances

**Author(s):** Anna McIlstr, James Davis

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**Purpose:** Despite notable advancements in the management and treatment of ostomies over the past number of years, one problem still persists; peristomal skin complications (PSCs). The erosion of the skin directly underneath the skin wafer as a consequence of exposure to stoma fluid can lead to debilitating irritation and ulceration and is one of the most common post surgical complications. In the US alone, it is estimated that over one million patients deal with the routine of ostomy care, the majority of which will have, at some point, suffered from a PSC. Despite requisite pre and post-operative education for new patients, PSCs continue to be a perennial issue with incident rates ranging from 10-70%.

**The present communication outlines progress towards the design of a smart wafer system that can actively monitor the skin condition and respond accordingly to minimize the onset of irritation dermatitis. A conductive, mechanically flexible mesh incorporating poly-L-tryptophan is detailed and its modification to yield a pH sensitive diagnostic layer is outlined. The system has been characterized and its potential integration and application in stoma appliances is critically appraised.**

SP112.4 - Development of a smart needle integrated with a micro-structured impedance sensor for the detection of breast cancer

**Author(s):** Niall T.P. Savage1, Brian D. O’Donnell2, Martin J. O’Sullivan3, Eric J. Moore1

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**The aim of this research is to develop a novel medical device for the detection of breast cancer within the clinical setting. Breast cancer is the second most common cancer in women worldwide and the use of population-based screening programmes has increased the demand for more sensitive and specific detection tools to limit the number of patients being misdiagnosed or over-treated. This research will focus on the development of a minimally invasive diagnostic probe for the determination and localisation of cancerous tissue within the structure of the breast. Gold microelectrodes fabricated on a silicon substrate were developed in Tyndall National Institute and used to obtain electrical impedance recordings from ex vivo tissue samples of both animal and human origin. Functional prototype devices have been produced using both photolithogra-
Chronic obstructive pulmonary disease is the 4th leading cause of death worldwide. Extracorporeal lung assist devices that promote oxygenation and/or CO2 removal, like the Novalung interventional lung assist device (iLA®), can improve lung protection and increase quality of life [1]. As a drawback these systems limit patient mobility. In addition, longterm use is frequently accompanied by thromboembolic complications and device fouling due to inappropriate material characteristics of the blood contacting surfaces. Our goal is to develop the first wearable miniaturized lung assist device with improved surface properties [2].

Methods

We developed prototypes of new miniaturized hard- and software components, as well as a suitable carrying system. We also designed a new, disposable gasexchange unit with optimized geometry to minimize hemolysis and thrombogenicity. Hemolysis and gas exchange performance tests were carried out in vitro and validated in a porcine model.

To improve the hemocomaptibility of the gas exchange material Polymethylpentene (PMP), we seeded human dermal endothelial cells onto PMP hollow fibers, either coated with heparin/albumin, or covalently functionalized with heparin/RGD. Seeding efficiency and cell coverage were analyzed microscopically using live/dead staining and staining for van Willebrand factor.

Results

We successfully miniaturized all hardware components and developed a new design of the gas exchanger to improve blood distribution, while maintaining adequate gas exchange in vitro and in vivo. Following seeding of stacked PMP fiber mats, the endothelial cells formed a confluent monolayer on the fibers, which was preferentially retained for 5 days on the heparin/RGD coated fibers under both static and dynamic in vitro testing conditions in a new bioreactor system.

Conclusion

We successfully designed and implemented a miniaturized wearable lung assist device, which is currently being tested in a porcine model. Importantly the gas exchange property of the miniaturized device are adequate to provide significant respiratory support. Future studies will test these devices in a first in man trial.

References


Acknowledgements

We acknowledge productive collaboration with our consortium partners from Imperial College London and the University of Florence and thank the EU for the financial support under the 7th framework program through the key action “medical technology for transplantation and bioartificial organs”.

SP112.5 - Towards development of a wearable, miniaturized, bioartificial lung

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Introduction

Cough, obstructive pulmonary disease is the 4th leading cause of death worldwide. Extracorporeal lung assist devices that promote oxygenation and/or CO2 removal, like the Novalung interventional lung assist device (iLA®), can improve lung protection and increase quality of life [1]. As a drawback these systems limit patient mobility. In addition, longterm use is frequently accompanied by thromboembolic complications and device fouling due to inappropriate material characteristics of the blood contacting surfaces. Our goal is to develop the first wearable miniaturized lung assist device with improved surface properties [2].

Methods

We developed prototypes of new miniaturized hard- and software components, as well as a suitable carrying system. We also designed a new, disposable gas exchange unit with optimized geometry to minimize hemolysis and thrombogenicity. Hemolysis and gas exchange performance tests were carried out in vitro and validated in a porcine model.

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Results

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Conclusion

We successfully designed and implemented a miniaturized wearable lung assist device, which is currently being tested in a porcine model. Importantly the gas exchange property of the miniaturized device are adequate to provide significant respiratory support. Future studies will test these devices in a first in man trial.

References


Acknowledgements

We acknowledge productive collaboration with our consortium partners from Imperial College London and the University of Florence and thank the EU for the financial support under the 7th framework program through the key action “medical technology for transplantation and bioartificial organs”.

SP112.6 - Development of a Low Cost Spectrometer for Studies of Diffuse Reflectance with Dermatological Science and Applications

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From an optical perspective, skin with all its layers and surfaces are made from different tissues that have different or unique pattern of reflectance, which could help to differentiate normal or healthy tissues from those with a presence of any type of injury or pathology. The application of optical tool for the characterization of bio- tissues have gained importance due to its noninvasive nature.

In this work it is proposed to conduct a study to develop an inexpensive spectrometer and a light source of broad spectrum; as well as the protocol that would allow the exploration of diffuse reflectance of colloids with the intention of develop a tool that could be used to identify any type of pathology. In this paper, the preliminary results of the study, involving the development of the light source, a low-cost spectrometer and the measurement and analysis protocol to explore the feasibility of implementation in areas of biomedical science areas are discussed.

Beside the development of the system, agar and dyed gelatintis-
sue phantoms were used in order to study the performance of the system.

Results show a good consistency in the performance of the developed spectrometer, in its capability to acquire the diffuse reflection from the tissue samples. As well, in accordance to the irradiated wavelength and the amount of dispersion induced in the tissue phantom. Still, results cannot be conclusive in order to determine significate differences that could lead to the application of this technology in health applications, it is expected to obtain a better specificity with future work.

**SP112.7 - Correctness of bioimpedance data for body composition obtained by BIA approach in various external conditions**

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This paper presents our ongoing research in a field of body composition obtained by body impedance analysis. In this work we were focused on changes in bioimpedance in dependence on change of measurement external conditions. This paper also deals with question if data obtained from this method are enough informative with ought any information about the performed measurement. We discovered that it is crucial to have information about the whole measurement procedure and that operator that is performing such measurement should know exact type of device that is used for measurements. Influence of specific conditions did not statistically changed results of calculated values. However in directly measured values resistance and reactance at high frequencies (250 kHz and 500 kHz) were found statistically significant changes (P=0.05) for highly conductive gel. Overall was concluded that external conditions that can be normally encountered at laboratories do not have effect on obtained values. However it is important to know which device was used so the set of used equations are comparable.

**SP113 - Information Technologies in Healthcare Delivery and Management: Part 1**

**SP113.1 - Technologies for Patient Self-Care of Chronic Illness: Development and Evidence.**

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The global plight of chronic illness has affected healthcare systems around the world. The delivery of care for those who need it most is not sustainable without a re-evaluation of enabling patients and their informal caregivers with the ability to perform self-care. Technological innovation in this area is showing great promise with the advent of mobile devices and wearables, but is not without the challenges of design, implementation, and a lack of clinical evidence. The keynote will outline addressing these challenges and the emerging evidence that shows the untapped potential of patients when given the opportunity for self-care facilitated through technology.

**SP113.2 - A mobile monitoring tool for the automatic activity recognition and its application for Parkinson’s disease rehabilitation**

**Author(s):** Jorge Cancela, Matteo Pastorio, Eugenio Moreno, Maria T. Arredondo Waldmeyer

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In order to perform a continuous monitoring of patients in their daily lives, it is the need to contextualize the collected data coming from the patients. In this sense, the identification of the Activities of the Daily Life (ADL) carried out by the subjects is essential to understand and to put in context other data linked to the monitoring disease itself. This work was aimed at using the accelerometers integrated in most of the current available smartphones to build an automatic activity recognizer based on the signal coming from this sort of sensors. The validation carried out showed the impact of the frequency sampling in the classifier performance as well as the impact in the battery usage. Finally, it suggested that the use of one second as sampling period is a fair trade-off between accuracy in the classification and power saving.

**SP113.3 - My Patient: An Electronic Patient Information Management System**

**Author(s):** Satish Jaywant¹, Qaiser Muhammad²

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Princess Margaret Cancer Center/University Health Network (UHN), Toronto, was approached to improve cancer services over a period of five years at the Kuwait Cancer Control Center (KCCC), Kuwait. As an integral component of this project, a computerized appointment scheduling system was implemented to reduce patient wait times, improve patient satisfaction and efficiency. It also provided an opportunity for data collection, tracking and management of resources. For this purpose, an electronic patient management system called “My Patient” was developed that will allow users to
become familiar with the basic steps and processes of creating, accessing and updating patient records. UHN Kuwait Information Management/Information Technology teams performed the gap analysis and requirements for the KCCC outpatient department workflows. It then worked closely with KCPC clinicians to finalize the clinical engagement, project governance and implementation plan. An in-house outpatient department scheduling module for KCCC was built. The pilot was launched May 2014 for 2 months in the gastro-intestinal site and has now been implemented for Radiation Oncology.

The tasks and functions in My Patient cover four distinct areas: Registration: Staff within the Medical Records Department has access to register patients, create new patient files and modify patient demographic information. Other users must contact Medical Records to have these functions performed.

Scheduling: This functionality is available within the outpatient departments to staff with appointment booking access. Any other My Patient users can only view schedules whereas booking, updating and cancelling appointments is limited to scheduling users only.

Laboratory Ordering: The cytology laboratory staff has access to the laboratory management tool for laboratory order entry, specimen number generation and specimen label printing.

Administrative: The supervisory staff within each department has administrative access to correct entry errors within their department.

Various safety and patient confidentiality features are in place in this tool. As an example, every staff member accessing My Patient for clinical or administrative purposes has a unique user name and password. This presentation highlights the application of My Patient to Radiation Oncology.

SP113.4 - Hom-e-call – An enhanced fall detection system based on accelerometer and optical sensors applicable in domestic environment

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A reliable detection of falls is an important challenge for applications of ambient assisted living. Especially for elderly people living autonomously at their home, such a system would help to treat possible injuries faster. Most of the currently used systems are only based on the analysis of the movement data recorded by a wearable device. In this study an automatic fall detection system is developed that can be installed in domestic environment. Based on an accelerometer fixed to the body and optical sensors mounted on the wall, the fusion unit analyses the actual posture of the patient and detects fall events. By means of simulated fall scenarios performed by young athletes, the overall system performance is tested. To identify the false alarm rate of the fall detection system elderly people have performed activities of daily living in a furnished test flat. The combined system approach can be used to improve conventional fall detection algorithms.

SP113.5 - An Algorithm Based on Voice Description of Meal for Insulin Dose Calculation to Compensate Food Intake

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Diabetes may lead to serious complications when blood glucose levels are not maintained in safe ranges. Proper insulin dosing is crucial in good metabolic control, however it is not easy for all patients. There are some computer applications supporting insulin bolus calculation based on the meal composition, but they may be difficult to use for some patients. Our team decided to developed a voice-driven system helping patients in calculation of the proper insulin dose for food intake compensation. The system consists of several software applications (on smartphone and MS Windows server) working with developed language dictionaries and with nutrient database. The speech recognition software was trained with sets of words from meal descriptions. The algorithm for transition from the text description is based on language dictionaries with variety of food item descriptions related to one product in nutrient database. The system calculates the number of insulin units for patients using insulin pen or delivery time and number of insulin units for patients with insulin pump. The algorithm for insulin dosage works not only on the basis of the amount of carbohydrates, but also takes into consideration protein and fat content in the meal. The system was successfully tested on the group of 34 subjects achieving 92.3% of correctly recognized food descriptions in the first try. The overall percentage of fails in recognition was 1.5%.

SP113.6 - Building neuroscientific evidence and best practices in active and healthy aging

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Supporting the elderly by means of technology has recently taken the form of monitoring the elderly in an unobtrusive way. The latter is linked with the task of installing various devices inside the home as well as requesting the elders to wear specific garments (e.g. watches, bracelets etc) or being trained by means of cognitive and physical exercise games (serious gaming: exergaming). The latter forms a contemporary trend within the field of Active and Healthy Aging (AHA). Serious games for elderly healthcare provide a promising and novel way to promote the well-being of senior citizens. However, to fully understand the underlying mechanisms as well as to accumulate scientific evidence for such approaches, we argue that one needs carefully designed neuroscientific experiments, along the usual batteries of neuropsychological tests and subjective measures like quality of life questionnaires.

In the past 6 years we have been using a comprehensive protocol of EEG recordings pre- and post any game enriched intervention. This allows for a much stronger analysis of the effects but also a deeper analysis and requirements for the KCCC outpatient department. In this paper, we demonstrate how functional neuroimaging analysis of these dense EEG measurements can reveal brain sources/areas responsible for the de-noising of the elderly brain after the intervention. What is more, functional connectivity network analysis can reveal a reorganisation of the default mode network due to combined physical and cognitive training. Our results refer to a wide pilot deployment involving more than 150 senior subjects over an intensive training protocol of 2 months.

Besides this, recent emergence of motion capture technology has enabled acceptable unobtrusiveness as well as other features of making the game challenging and seniors being motivated. A key
step towards this direction would require using emotional queues in the midst of the game-flow and within the gaming environment, so as to allow for suitable embodiment of real-time mental (cognitive and emotional), and physical data. To properly study the above, one needs ecologically valid but yet controlled set-up, in the form of home-like environments. We have designed and implemented such an Active and Healthy Aging Living Lab/e-home within our Assistive Technologies and Silver Science Lab to facilitate such simulation as well as experiments and recordings with real elderly users. A vast amount of “daily-living” data is therefore created. These are then analysed with intelligent methods enabling early symptom identification and allowing decision support for early disease diagnosis. Emphasis is given on interlinking robust scientific methods and tools of studying emotions, as well as, age-related cognitive decline within the gaming environment and in-game metrics.

ACKNOWLEDGMENTS

This work was funded by the Operational Program “Education and Lifelong Learning” of the Greek Ministry of Education and Religious Affairs, Culture and Sports (Project STHENOS, www.sthenos.gr, ref. number 2012EE24580284).

SP113.7 - Intelligent System for Identification of patients in Healthcare

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The Inadequate identification of patients in health care centers remains as a common problem that has brought incidents and adverse event to this kind of facilities. This work present a system design to deal with this situation. To develop this proposal different identification systems and patient monitoring systems in health centers was studied, and a comparative study was conducted between existing technologies to develop this proposal. The NFC technology was chosen to develop a system solution because of its availability in mobile phones, its feature of information security, speed, low cost and simplicity in data exchange. Confidentiality of the patient information is guaranteed through authentication profiles for system access and data security through SSL and HTTPS protocols. The purpose of the proposed system is to provide correct information transfer, keeping track on patients and facilitate control of them by the health care center staff, in order to minimize accidents and mistakes of identification and to improve the healthcare facilities’ quality.

SP114 - Dosimetry and Radiation Protection

SP114.1 - Development of Object Simulator for Evaluation Periapical Radiographs

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This study aimed to develop a dental phantom with cysts for evaluation of periapical radiographs that was tested in private dental offices in the city of Maraba, northern Brazil. Through some tests with the object simulator (phantom) were obtained 12 periapical radiographs (one in each of the offices visited) that waking up to the standards of Ordinance N. 453 were visually evaluated by observing the physical parameters of exposure (kVp and mA), time, and the quality of radiographic film, later the other radiographs were visually compared with C6 ray set as the default. Among the results, it was found that only two of the twelve rays cysts could not be viewed and, therefore, these two images were deemed unsuitable for accurate diagnosis in the 10 images the cysts could be displayed, however according the images have different qualities comparisons. In addition, it can be concluded that the performance of the phantom was highly satisfactory showing to be efficient for use in quality control testing of dental X-rays, the quality control of radiographs and continuing education of dental professionals for a price much more accessible.

SP114.2 - Impact Created by Medical Physicist from Regulatory Quality Assurance Controls in Developing Country

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Background: The use of Ionizing Radiation in medicine has been increasing rapidly over the years in Countries in general and Cameroon in particular. Individual occupational exposure and patient safety varies widely among those involved in medical care. There are certain medical procedures that might give substantial doses to medical staff, normal tissues of patients and the education of medical professionals in radiation protection and quality control issues are continuing problems. Regulatory bodies are mandated through laws and regulations to regulate all ionizing radiation sources as well as the protection of people and environment against ionizing radiation hazards.

Objectives: Improvement of regulatory framework by Medical Physics Quality Assurance Controls.

Methodology: National Radiation Protection Agency (NRPA) of Cameroon activities started with inventory program in 2009, which was completed in July 2010. Over 500 occupationally exposed workers were recorded with about 12 % being monitored 5% of quality assurance undertaken. There was no national dosimetry service provider, all were monitored from abroad. Regulatory Technical control started in 2011. A medical physicist was employed by NRPA in 2010 to coordinate Quality Control and dosimetry activities as
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regulatory aspect. There were a lot of discrepancies recorded at the level of occupational monitoring and state of equipment to produce quality images. NRPA acquired dosimetric monitoring and quality control kits in 2010 and 2011 respectively. These are widely used in quality control, radiation protection and safety, offer a number of potential advantages for medical applications (diagnostic and radiation therapy).

Results: As of 2014, remarkable improvement has been noticed in the dose reduction of workers, patients and the quality of the machines used in then controlled medical facilities. In this, the results of occupational exposure from 2011 to 2014 is shown and the results of the quality control executed from 2011 and 2014 compared are illustrated in tables.

Recommendation: Recommendations are ditched out to competent authorities at various levels for the continuous improvement of quality assurance programme and occupational monitoring to safeguards radiation protection/safety culture.

Conclusions: Radiation Principles are being applied by using national and international standards for the benefits of both patients and workers in radiological practices. This can never be sustainable without the creation of the awareness of Medical Physicist policy and roles in developing countries.

SP114.3 - Evaluation of Dental X-rays equipment in Sobral-CE, Brazil

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The ionizing radiation has important application in dental diagnosis. In Brazil, the National Ordinance No. 453/1998 of the Ministry of Health regulates the operation of medical and odontological diagnostic radiology services. However, the inspection of periapical dental X-ray equipment is not carried out by some Sanitary Surveillance. This study intended to determine the suitability to the ordinance of the dental offices of Sobral-CE, Northeast of Brazil, and to compare the results with literature data for other cities of Brazil. It was performed tests of radiation field and image quality, and it was applied questionnaires to the professionals. For the image quality test, it was used a dental phantom and the processing of the films was performed in the clinics and at the laboratory (standard). The questionnaire assessed physical parameters that interfere on the radiation protection and on the quality of images. The results show that the ordinance is not being properly followed and that it is necessary to inspect the periapical X-ray equipments. Moreover, in general, it is observed that dental professionals should have better training on ionizing radiation and on radiation protection.

SP114.4 - Effect of static magnetic field exposure on human blood electrolyte levels in vitro

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This proposed paper presents a study of effect of strong static magnetic field (SMF) exposure on electrolytes in human blood in-vitro. There have been major concerns of safety from magnetic fields (static and dynamic magnetic fields) to life and their effects on physiology. It is noteworthy that magnetic fields are listed as ‘Potentially carcinogenic’ by W.H.O. There are evidences of SMF causing special sensations in humans and animals like bizarre behavior and magnetophosphenes, these are probably attributed to cell membrane property changes.

Magnetic therapy is a treatment modality being used since ages, the claimed mechanism of action being the presence of iron in the blood and the alteration in blood viscosity, which is mostly doubted by the modern science.

Here, the effect of SMF exposure on blood electrolytes was studied. A Case - Control study was carried out, collecting blood samples from healthy young volunteers. The samples were divided into 6 equal parts in 3 pairs of Case and Control, and exposed in vitro for 20 minutes to SMF strengths of 500 Gauss (G), 5000 Gauss and 1 Tesla respectively one after the other. Here case sample was exposed to 500G SMF generated by a coil electromagnet between 2 soft iron cores and the control samples shielded by placing in an iron box. After 20 minutes of exposure and shielding, both samples were estimated for electrolytes: K+, Ca++, Na+, CI and pH by indirect Ion Selective Electrodes method on a Combiline® blood gas analyzer machine. The process was repeated for the other pairs of samples with cases on 5000G and 1 Tesla (1 Tesla = 10000 Gauss) SMF one after the other and shielding controls to match the effects of the time lapse. The data acquired was analyzed by applying paired T test on the case and control samples for each ion parameter at each SMF strengths exposed, the P value was taken to be significant at p<0.05. Here, no statistically significant changes in the ion concentrations of the case and control samples were found. The results indicate that the SMF of 500 Gauss, 5000 Gauss and 1 Tesla did not result in any significant change in the electrolyte concentration in the samples, possibly inferring to no significant change in leakiness of the red blood cell (RBC) membrane.

This study suggests that very strong SMF of up to 1 Tesla, as used in this experiment, do not affect the electrolytes and possibly the leakiness of the RBC membrane in vitro. In this study it was also found that the SMF of around 500 Gauss, the strength of the magneto-therapy magnets also did not show any change in electrolyte concentration, hence no change in membrane leakiness of the RBCs. This study, hence points towards the safety of the magnetic field exposure on the red blood cell membrane leakiness.
SP115 - CT Image Quality and Dose Optimization

SP115.1 - Towards Image Quality Analysis of Small and Full Field of View Dental Cone Beam CT Systems

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Cone-beam CT (CBCT) systems have been used for dentomaxillofacial surgery applications. Different dental CBCT devices are being developed and released, with a wide variability of exposure parameters and fields of view. Although they have sufficient diagnostic quality, a quantitative analysis of image quality and radiation dose is required to enable their optimal use. The aim of this study was to develop and implement a feasible methodology for image quality analysis for different dental CBCT devices. The methodology was based on conventional CT quality control procedures and adapted to overcome the limitations of dental CBCT. A prototype phantom was specially designed to allow the acquisition of image quality parameters relevant to dental imaging. Equipments were divided into categories, related to their field of view: Small Field of View (SFOV) and Full Field of View (FFOV). The following image quality parameters were evaluated: uniformity, noise, contrast-to-noise ratio, CT number accuracy, artifacts, spatial resolution and geometric distortion. Applicability of the methodology was assessed using one SFOV and four FFOV CBCT devices. Results from preliminary analyses of the prototype phantom showed its potential for routine quality assurance on dental CBCT. Large differences in image quality performance were seen between the devices.

SP115.2 - Rapid non-invasive spatially varying HVL measurements for CT sources

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Purpose: A method is presented to generate spatially varying half value layers (HVLs) that can be used to construct of computed tomography (CT) x-ray source models for CT dose computations.

Methods: To measure the spatially varying HVLs, we combined a cylindrical HVL measurement technique with the characterization of bowtie filter relative attenuation (COBRA) geometry. An apparatus (HVL-Jig) was fabricated to position a real-time dosimeter off-isocenter while surrounded by concentric cylindrical aluminum filters (CAFs). Data was acquired using axial CT protocols filters to investigate the energies of 80, 100, and 120 kVp on a single CT scanner (GE Optima CT580). In this geometry, each projection of the rotating x-ray tube is filtered by an identical amount of high-purity aluminum while the stationary detector records an air kerma rate versus time waveform. The CAFs were progressively nested to acquire exposure data at increasing filtrations to calculate the HVL. Using dose waveforms and scanner geometry, each timestamp was related to its corresponding fan angle. These measurements were validated against the more laborious conventional step-and-shoot approach.

Results: At each energy, HVL data from the COBRA-cylinder technique was fit to a trendline and compared with the conventional approach. The average relative difference in HVL between the two techniques was 1.3%. A systematic overestimation in HVL was observed due to scatter contamination, but by applying a 1% downward shift to all measurements, all differences lie within a 0.2 mm Al threshold needed to generate spectra for accurate Monte Carlo CT dose computations.

Conclusion: The rapid, accurate, and non-invasive approach described allows one to acquire the spatially varying fluence and HVL data using a single experimental setup and three scans. These measurements can be used to characterize the CT beam fluence and energy spectra along the BT filter direction, which can serve as input for CT dose computations.
SP115.4 - Evaluation of automatic exposure control systems in computed tomography

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Introduction: The greatest and relatively new advance in CT to lower the patient dose is the automatic exposure control (AEC) systems [1]. These systems modulate the dose distribution along the patient taking into account their size and tissue densities [2]. AEC-systems are complex and their functioning is not fully understood [3]. This work aims to evaluate the performance and susceptibilities of AEC-systems.

Methods: The approach was the extraction of tube current modulation (TCM) data from DICOM image sequences and analysis of the image noise of those images [4]. The TCM of each CT scanner provides the performance of the AEC-system. Dose measurements with the AEC-system ON and OFF were made to verify if the tube current was consistent regarding the dose distribution behavior.

Results and Discussion: Figure 1 shows the TCM, and the corresponding noise for a Philips Brilliance 16 longitudinal AEC mode, Z-DOM, and the longitudinal AEC mode with the DoseRight ACS option ON. This example shows that this option causes a great increase on tube current, with a lower image noise and it doubles the dose compared to Z-DOM with this option OFF and the image noise decreases about 25%.

Conclusions: The results attained give rise to optimizations on the AEC-systems applications and, by consequence, decreases the patient dose without compromising the diagnostic image quality.

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SP115.5 - Development of a Software for Image Quality Assessment in Computed Tomography using the Catphan500® Phantom

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Introduction: A software for image quality assessment in computed tomography (CT) was written using MatLab® language. This software intends to improve CT scanners quality control programs, evaluating quantitatively the Catphan500® images. The software can identify the images from each section of the phantom and calculate the physical quantities of interest in these images. This process is performed with minimal direct user interference.

Methods: The software was written in modules. The MTF module uses images of the beads of the Catphan section CTP528 and subtracts the background, obtaining the PSF. The MTF is calculated from the resulting PSF. Due to the system symmetry, the two-dimensional MTF can be averaged over the azimuthal angle to obtain a radial MTF, MTFrad, in function of the spatial frequency fr. The uncertainty is also evaluated by averaging the MTFrad of multiple bead images.

The noise module uses images acquired from the section CTP486, and evaluates the noise and the NPS of the CT system. Noise is calculated taking the pixel mean and standard deviation in a central region of interest (ROI) and other four peripheral ROI's, as recommended by the Catphan user manual[i]. The two-dimensional NPS, NPS2D, in function of the spatial frequencies fx and fy is calculated by the method proposed by the ICRU Report nº 87[ii]. The NPS2D of multiple image pairs are then averaged to lower the uncertainty.

Results: Figure 1 illustrates the mean NPS2D and MTFrad calculated by the software, using 49 noise image pairs and 82 bead images respectively, selected from a set of 868 images in total. The images were acquired in a GE Discovery 690 PET/CT scanner. These results are consistent with previous qualitative results obtained from the quality control program implemented in the same equipment.

Figure 1: NPS2D (left) and radial MTFrad (right) of the GE Discovery scanner.

Conclusions: The preliminary results from the software agree with the expected from previous works. Without such software, the calculations of NPS and MTF is not always done, as it takes many hours; this software greatly reduces this time. Also it makes the analysis less subjective, more quantitative, and improves reproducibility.

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SP115.7 - A software tool for automated artifact detection in scans of the CT daily water phantom

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Purpose: The objective of this work was to develop a software tool for automated artifact detection in scans of the daily CT water phantom.

Methods: The artifact detection algorithm developed in this work uses a uniformity map created from convolution of the water phantom image with a small region of interest (ROI). Non-uniformities in the image are detected by looking for connected objects with CT numbers outside of an acceptable range inside the uniformity map. A pilot study was conducted to test the artifact detection algorithm on water phantom images acquired on a Siemens Sensation 64. This pilot study was split into two phases. First, a training dataset consisting of one month of daily water phantom images was collected for tuning the parameters of the artifact detection algorithm. Parameters to tune included the size of the ROI used in the convolution to generate the uniformity map, an acceptable CT number range in an artifact free image, and the minimum size of a connected region to count as a non-uniformity. Histograms summarizing how often connected objects of varying sizes occur for different CT number ranges were used to tune the parameters of interest. In the second phase, the software was used to monitor daily water phantom images for five more months.

Results: The training dataset revealed several important characteristics of the water phantom images. These characteristics included: a normal image (artifact-free) might not be uniform, there can be variation in "normal" non-uniformities between slices, and there are fluctuations in mean CT numbers from day-to-day as well as drift in average CT number over time. The artifact detection algorithm was modified to deal with these characteristics as follows. First, a normal image acquired on a previous date and known to be artifact-free is subtracted from the current water phantom image under investigation. This subtraction is performed slice-by-slice to deal with the variation observed between slices. Second, the average CT number of each water phantom image is subtracted from each pixel in the image to address the fluctuation in CT numbers from day-to-day. The histograms that were plotted to show the frequency of connected objects of various sizes with different settings for the acceptable CT number range demonstrated that a reasonable set of parameters for detecting artifacts was to classify a connected object as an artifact if it was larger than 200 pixels in size and had a CT number greater than +2 HU or less than -2 HU. Using these parameters for the second phase of the study, no artifacts were detected by the software over the five month period. No artifacts were reported by a technologist during this same period. When the software was used to analyze water phantom images with known artifacts from other scanners, these artifacts were correctly identified.

Conclusion: A general method for detecting non-uniformities in water phantom images was developed. This software should not be used to replace the human observer, but can serve as an added daily check for scanner issues.

SP115.8 - Monte Carlo Simulation of X-ray Spectra in Computed Tomography Scanner using GATE

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Introduction: X-ray spectrum modeling has an important role in medical imaging and many of researchers are still trying to find a simple and accurate method for simulation of x-ray spectrum. Monte Carlo simulation is a powerful tool in prediction of the x-ray spectrum. In this study, the x-ray spectra of the computed tomography system simulated using GATE Monet Carlo code. After validation the effect of the anode angle, tube voltage and thickness of filter on x-ray spectrum was investigated by using of Monte Carlo (MC) simulation. The simulated results were compared with MCNP4C MC simulated x-ray spectra and the spectra calculated by IPEM report No.78.

Materials and Methods: The GATE and MCNP4C MC packages were used for accurate modeling of the x-ray tube. The geometry of the x-ray tube in both codes was implemented precisely the same. The tungsten target with 7 degree and focal spot size 1.2x1.2 mm² was simulated. The x-ray spectra simulated using various tube voltages and different anode and variable thickness of Cupper filter. The IPEM report No.78 was used as a reference to compare with the results from simulation codes.

Results: The changes in quality and quantity of the spectrum for four different tube voltages 60, 80, 100, and 120 kVp were investigated and the results indicated that by increasing the voltage, the average of spectrum reached to the higher energy level. The x-ray spectra simulated for 4 different anode angle 7, 9, 11, and 13 degree. The simulated spectrum by using GATE was compared with two spectra from MCNP4C and IPEM report No.78 and in general there was good agreement between the results.

Conclusion: The effect of different variables on the spectrum was investigated. Good agreement between the simulated spectra by using GATE, MCNP4C and IPEM report No.78 were observed, although there are systematic differences between the simulated and reference spectra especially in the K-characteristic x-rays intensity. The results indicate that the GATE MC package is a useful tool for generating x-ray spectra of CT.
SP116.2 - Using Gamma Maps of Anatomy to Highlight Changes in Anatomy During Image-Guided Adaptive Radiotherapy: Head and neck example

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In recent years, technology has allowed radiation therapy of increasing complexity to be delivered to cancer patients, with the goal of improving tumour control and reducing toxicity. In adaptive radiotherapy (ART), imaging information acquired during treatment is used to adjust the treatment plan if necessary. During treatment of head and neck cancer, anatomical changes (e.g., weight loss) may occur and patients are flagged for re-CT simulation if the changes are substantial. But, how do we know when to flag patients for treatment replanning? The goal of this abstract is to demonstrate a graphic tool to aid in assessing changes in patient anatomy using the gamma comparison.

In the past, gamma function calculations have been used for quality assurance of the dose delivered to phantoms by the treatment machine compared with the planned computed dose. We propose using this function to highlight changes in patient anatomy, instead of dose, as a tool (an alarm) to aid the therapist and oncologist in deciding whether to flag the patient for re-CT simulation. Implementing this function in 3-D is computationally intensive; but, recent advances in graphics processing units (GPUs), and associated software, have greatly accelerated this calculation. With GPU hardware (costing under $1,000) the gamma function comparing two full-size 3-D CT data sets (512x512x60) can be calculated in one minute. This result could be displayed at the treatment console to determine if a treatment adjustment merits consideration. We will demonstrate a sample application of this approach to head and neck cancer.

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SP116.1 - Automated segmentation of whole-slide histology for vessel morphology comparison

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Introduction: Characteristics of microvasculature can be revealed by immunohistochemical tissue staining, but manual quantification of these characteristics on whole-slide images containing potentially hundreds of vessels on each is tedious and subject to operator variability. Conventionally, manual quantification is performed for selected regions of the whole tissue section where the regions may not be representative of the pathology. Major challenges to automated segmentation include the irregularity of staining of vessel walls and artefactual appearance of DAB stain on structures other than vessel walls. Our objective was to develop and validate a fully automated segmentation of the vascular smooth muscle layer on whole-section histology of normal and regenerated post-ischemia mouse hind limb microvasculature, stained for smooth muscle using 3,3-diaminobenzidine (DAB) immunostain.

Methods: Our approach accounts for irregularity of vessel wall staining using colour deconvolution to isolate the DAB stain, and joining the morphological skeletons of the vessel wall fragments disjointed by inconsistent staining. Artefactual fragments were removed on incoherence of neighbouring tissue in an accurate 3D histology reconstruction (Y Xu, SPIE Medical Imaging 2014). The vessel wall thickness, vessel density, area, and perimeter were quantified.

Results/Discussion: For segmentation validation, vessels were manually delineated and compared to the automated segmentation approach on a normal mouse, resulting in a Dice similarity coefficient of 0.84 (Figure 1). Differences in the vessel measurements observed between the normal and ischemic mice were concordant with the known effects of regeneration of vasculature in ischemic mice (p < 0.05, Table 1). Fully automatic and accurate measures of the vascular morphology are feasible with the automated segmentation of the vascular smooth muscle. With refinement and validation of this method on a larger data set, we aim to provide a valuable tool for scientists requiring high-throughput vascular segmentations and morphological measures for the analysis of vasculature for disease state comparisons.

![Figure 1: Contours of automatically segmented (a) and manually delineated (b) vessel walls in the normal mouse hind limb stained with DAB for smooth muscle.](image)

Table 1: Automatic vessel/smooth muscle morphological measures

<table>
<thead>
<tr>
<th></th>
<th>Area (µm²)</th>
<th>Perimeter (µm)</th>
<th>Thickness (µm)</th>
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<tr>
<td></td>
<td>Median</td>
<td>IQR Median</td>
<td>IQR 5th Percentile</td>
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<tr>
<td>Normal 1 (n = 2598)</td>
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<td>4.3</td>
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<td>5.8</td>
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<td></td>
<td>0.5</td>
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<tr>
<td>Post-ischemic (n = 1508)</td>
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<td>8.2</td>
<td>19.1</td>
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<td></td>
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<tr>
<td></td>
<td>1.6</td>
<td>1.6</td>
<td>2.8</td>
</tr>
</tbody>
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Figure 1: Gamma function on pairs of CBCT data sets of the head and neck region. ΔHU: 30 (absolute) Δr: 5 mm
SP116.4 - Inter-operator variability of 3D prostate magnetic resonance image segmentation using manual and semi-automatic approaches

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Purpose: To measure accuracy and inter-operator variability of a semi-automatic prostate segmentation method for T2-weighted endorectal magnetic resonance (MR) imaging.

Materials and Methods: MR images from 42 prostate cancer patients were acquired. Manual border delineation was performed by one observer on all the images and by two other observers on a subset of 10 images. Simultaneous truth and performance level estimation (STAPLE) segmentation was calculated from all three segmentations. Our algorithm calculated inter-subject prostate shape and local boundary appearance similarity during its training phase. To initiate the segmentation, the operator indicated the anteroposterior prostate orientation and selected the prostate centre on the most-superior, mid-gland, and the most-inferior slices. These inputs were used to identify candidate prostate boundary points using learned appearance characteristics, which were regularized according to learned prostate shape information to produce the final segmentation. On all subjects, we evaluated our method against the manual reference segmentations using complementary boundary-, region- and volume-based metrics: mean absolute distance (MAD), Dice similarity coefficient (DSC), recall rate, precision rate, and volume difference (ΔV). On 10 cases, we measured the inter-operator variability of manual segmentation by comparing the reference segmentations to the STAPLE segmentation, and conducted a multi-operator study to measure inter-operator variability of the semi-automatic algorithm.

Results: Table 1 shows our results on our 42 subjects with a single operator. Table 2 compares the consistency of manual and semi-automatic segmentations on 10 cases. The variability of all of the metrics resulting from the semi-automatic segmentation was reduced, compared to the manual segmentation.

Conclusions: We observed substantial inter-operator variability in manual segmentation and reduced variability in semi-automatic segmentation. In studies evaluating prostate segmentation algorithm accuracy using a single-operator reference standard, it is important to consider the measured errors in the context of inter-operator manual segmentation variability.
SP116.5 - Derivation of Residual Noise of Filtered Poisson and Gaussian Series

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Residual noise analysis is useful in designing optimal filters for noise reduction. To begin we derived the variance of residual noise $\sigma_r^2$ from Poisson and Gaussian series after filtered by a Gaussian filter. For Poisson series, we have $\sigma_r^2 = \sqrt{2\pi} I^*/4\sigma_0$, and for Gaussian series, $\sigma_r^2 = \sqrt{2\pi} \sigma^2 / (4\sigma_0)$, where $I^*$ is the noiseless signal in the Poisson series, $\sigma$ and $\sigma_0$ are the standard deviations of the Gaussian series and the Gaussian filter, respectively.

The figures below compare the analytically derived $\sigma_r^2$ , noted as «ana2» in the legends, with the numerically simulated ones, noted as «num». The first figure is for Gaussian noise sequences $\eta$, with standard deviations 2 and 4, respectively, and the second figure is for Poisson noise sequences $I^* + \eta$ with noiseless $I^*=40$ and 80 respectively. The discrepancy is mainly due to pixelation of the Gaussian filter. If one uses the shape of the pixelated filter in the analytical derivation, the results, noted by “ana1” were much improved.

By utilizing these results, we designed an optimal filter with the aim of minimizing the local noise-to-signal ratio in a Poisson series with $I^* = 40 + A \sin(kx)$, which can represent the change of contrast and resolution of an image with $A$ and $k$, respectively. Given $A$ and $k$, the optimal standard deviation in the Gaussian filter was analytically obtained, and excellently agreed with that from numerical simulations. See our full paper for the details, Thus the analytical form of the variance of residual noise can be utilized to design filters and determine the optimal values of the filter parameters.
SP116.6 - Fast Registration of Intraoperative Ultrasound and Preoperative MR Images Based on Calibrations of 2D and 3D Ultrasound Probes

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During the intraoperative-ultrasound-guided intervention, ultrasound (US) is often registered with other high-quality preoperative images like computed tomography (CT) or magnetic resonance (MR) to improve the navigation accuracy. However, real-time registration is difficult to achieve due to the difference of image modality and dimensionality. To solve this problem, we apply preoperative 3D US image collected with a 3D calibrated probe to simplify 2D US and 3D MR image registration into two easy-achieved steps: 2D-3D US intra-modal registration and 3D US 3D MR pre-operative registration. To achieve fast intraoperative 2D US and preoperative 3D US registration, we take advantage of effective 2D and 3D US probes' calibration results and get a near optimal registration transform. Then intraoperatively we just need to do an automatic local adjustment, which will make real-time registration become possible. To achieve effective calibrations, we design an improved calibration phantom and propose a warm-start iterative closest points (ICP) method.

SP116.7 - Development of digital subtraction angiography for coronary artery without motion artifacts enabling read-time processing

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Purpose: The purpose of this study is to develop a new method of digital subtraction angiography (DSA) for coronary artery reducing motion artifacts caused by heart beat and by the periodic motion in the lung field.

Methods: In this study, the mask image is produced by the density difference image. That is made by subtracting plain mask image from contrast-enhanced live image. Our approach employed fluctuation of pixel value at the same position. First, the pixel value for the mask image is selected from the plain mask image, when the density difference value is larger than a threshold level. The search area for the maximum pixel value was selected from two volume areas using the value of the standard deviation (SD) for each pixel from the previous 14 image frames. Next, when the SD value in the 14 frames was greater than a threshold level, the search area of the maximum value was set 1 pixel x 1 pixel x 14 frames. Otherwise, 32 pixels x 32 pixels x 7 frames was selected as the search area mentioned above. Finally, the pixel value in mask image was selected from either volume area. To evaluate images obtained by our method, we used standard deviation of total pixel values in subtraction image sequences as an objective evaluation method. In addition, subjective evaluation was carried out. Cardiologists evaluated the degree of motion artifacts using score (1 to 5: 1 is the most deteriorated by artifacts). Twenty coronary angiograms with various occlusion severities in vessels were used. We employed the PC (CPU: 2.4GHz, 4 GB memory) to produce DSA image process by our method.

Results: As results of objective evaluation, standard deviations of total pixel value of subtraction images were 33% lower than that of normal DSA, in 20 cases of coronary arteriogram. In subjective evaluation, average score of motion artifacts was 4.2 whereas 2.6 for normal DSA images. These results showed that the motion artifacts were extremely decreased by our method. Coronary artery and carotid artery and vein were clearly enhanced. The calculation time to produce one subtraction image by our method was 0.085 sec/image. This result shows this method will be able to use in a real-time in the clinical situation.

Conclusions: In conclusion, we proposed this new method where using standard deviation of pixel value and searching the highest value in the volume area. The results showed that the motion artifacts were extremely decreased and will be able to use in a real-time. Coronary artery, carotid artery and vein were clearly enhanced. This method would be very helpful for the diagnosis of angiography with motion.

SP116.8 - Real-time measurement of cardiomyocyte contraction and calcium transients using fast image processing algorithms

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An improved technique for recording of contraction of heart cells simultaneously with recording of calcium transients by fluorescence method is introduced. The technique aims to quantify contractions under conditions including low image quality caused by reduced transmitted light. The proposed methods allow more accurate detection, lower error rate using the up-to-date image processing, and automation of the process comparing to recent approaches.
The technique is compared with direct optical measurement method using processing of two-dimensional digital images of the cardiac cell. The technique is improved to be fast enough to be included in the system for real-time measurements.
couch rotation $0^\circ$. In some cranial SRT cases, the planning target volume (PTV) is in very close proximity to vital organs-at-risk (OARs), and these cases require additional modification of patient treatment couch position due to this anatomical arrangement. Using six previously delivered cranial stereotactic radiotherapy plans for acoustic neuromas treated at the NSCC, we have redesigned the treatment arrangement to find the optimal couch rotation position based on the reduction of overlap between OARs and PTV. Maintaining the arc lengths from the delivered treatment, the couch position was determined based on a cost function analysis of accumulation of overlap score from an equation developed by Yang et al[2] and refined by MacDonald et al[1]. The algorithm incorporates factors for depth of OARs and PTV volumes and radiation dose sensitivities of each OAR.

Results: In a six patient population with application of this optimization technique, maximum and mean doses to the OARs were reduced by approximately 35.48% ± 5.38% and 36.60% ± 4.68% respectively, as compared to the original delivered plans. In addition, PTV coverage was maintained during optimization. The average homogeneity index [3] was 7.53 ± 1.46 for conventional plans and 4.89 ± 0.38. The conformity number [4] was 0.76 ± 0.05 for conventional plans and 0.76 ± 0.05 for optimized plans.

Conclusion: The reduction in OAR doses is a substantial improvement in plan quality. The modification of the existing delivery technique with guidance from a PTV-OAR overlap cost-function analysis technique can yield significant dosimetric improvements with no increase to delivery or planning time. This technology is immediately implementable on any linear accelerator capable of basic stereotactic radiotherapy.

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SP117.3 - Automated Dose Map Prediction Through Radiomics and Regression on the Patient Manifold

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Technical innovations in RT have improved the quality of RT plans at the cost of increased complexity. Therefore, automated planning methods have been suggested to improve the highly manual, iterative and complex RT planning process. To date, treatment planning has focused on optimizing volume-based objectives (e.g. <30% of the right lung volume should receive <50% of the prescribed radiation dose) which are derived from a template and manually adjusted at each planning iteration or selected from a database in the case of automated planning approaches. These objectives neglect fundamental spatial information and only represent surrogates of the actual clinical treatment intent with the resulting RT plans limited in their capacity to tailor dose for each patient. We propose a paradigm shift in automated RT planning. By explicitly modelling the relationship between patient anatomy and radiation dose, this research is the first to generate automated RT plans that directly specify the spatial distribution of the radiation dose to the patient.

Our method uses a novel machine learning (i.e. customized regression) algorithm based on thousands of previous RT plans deemed to be of high quality, to learn relationships and patterns in the data (i.e. how radiomic features describing patient organ/target appearance and geometry correlate with radiation dose to ensure a clinically acceptable RT plan). For a new patient, the algorithm computes relevant radiomic features, to be correlated with features in the database. Machine learning uses the radiomic features to predict a probabilistic dose for each voxel in the image, based on features at both the voxel and whole image level.

Our preliminary results have focused on three distinct RT treatment sites using intensity modulated RT (IMRT) and volumetric modulated arc therapy (VMAT): whole breast (tangent IMRT), breast cavity (non-coplanar IMRT), and prostate bed (VMAT). We used 336 training patients, 143 testing patients, and measured automated planning accuracy via Gamma analysis comparison with each patient’s clinically delivered treatment plan. Our overall accuracy rates were 88.2%, 74.9%, and 86.1% respectively, with 50.6%, 20.0%, and 25.7% having a Gamma over 90%. An example image is shown below with fully automated planning results from two breast cavity, and one prostate bed plan.

Our method will enhance the existing RT process by reducing RT planning times, promoting simplification and standardization, and improving the quality of personalized RT. The research will realize a novel clinically implementable framework and provide a training knowledge base for RT.

SP117.5 - Models for Predicting Objective Function Weights in Prostate Cancer IMRT

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Purpose: To develop and evaluate the clinical applicability of advanced machine learning models that simultaneously predict multiple optimization objective function weights from patient geometry for intensity-modulated radiation therapy (IMRT) of prostate cancer. Methods: A previously developed inverse optimization method (IOM) was applied retrospectively to determine optimal objective function weights for 315 treated patients. We used...
an overlap volume ratio (OV) of bladder and rectum for different PTV expansions and overlap volume histogram slopes as explanatory variables that quantify patient geometry. Using the optimal weights as ground truth, we trained and applied three prediction models: logistic regression (LR), multinomial logistic regression (MLR), and weighted K-nearest neighbor (KNN). The population average of the optimal objective function weights was also calculated. **Results:** The OV at 0.4 cm feature was found to be the most predictive of the objective function weights (Figure 1). We observed comparable performance (i.e., no statistically significant difference) between LR, MLR, and KNN methodologies, with LR appearing to perform the best. All three machine learning models outperformed the population average by a statistically significant amount over a range of clinical metrics including bladder/rectum V53Gy, bladder/rectum V70Gy, and dose to the bladder, rectum, CTV, and PTV.

When comparing the weights directly, the LR model predicted bladder and rectum weights that had, on average, a 73% and 74% relative improvement over the population average weights, respectively (Figure 2). The treatment plans resulting from the LR weights had, on average, a rectum V70Gy that was 35% closer to the clinical plan and a bladder V70Gy that was 29% closer, compared to the population average weights. **Conclusion:** We demonstrated that the KNN and MLR weight prediction methodologies perform comparably to the LR model and can produce clinical quality treatment plans by simultaneously predicting multiple weights that capture trade-offs associated with sparing multiple OARs.

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**SP118 - Diagnostic Radiology: Dosimetry and Quality Control**

**SP118.1 - Measuring absorbed-dose to cardiac implantable electronic device using OSL.**

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**Purpose/Objectives**

The American Association of Physicists in Medicine (AAPM) Task Group 34 and more recently 203 raised the issue about the management of radiation oncology patients with a cardiac pacemaker or an implantable cardioverter-defibrillator (ICD). Clear guidance about dose limits are given in these reference works. However, most dose levels reported in the literature and used clinically to evaluate the absorbed-dose are based on calculated values and not on direct measurements. In this study, direct measurements using optically stimulated luminescent (OSL) detectors placed directly inside a pacemaker were performed for planning CT scan, positioning CBCT scan and external beam radiation therapy treatment in order to compare with the planned dose.

**Materials/Methods**

Output measurements of the CT scan at 140 kVp and of the CBCT X-ray tube were performed at 100 kVp and 120 kVp. Measurements were based on the AAPM Task Group 61 protocol using a Farmer-type ionization chamber calibrated for the corresponding beam quality. Once the outputs were determined at the reference point, the correlation between OSL's number of counts and the resultant dose was achieved for both imaging methods. However, most dose levels reported in the literature and used clinically to evaluate the absorbed-dose are based on calculated values and not on direct measurements. In this study, direct measurements using optically stimulated luminescent (OSL) detectors placed directly inside a pacemaker were performed for planning CT scan, positioning CBCT scan and external beam radiation therapy treatment in order to compare with the planned dose.

**Results**

Direct exposition of the pacemaker could give a maximum reading of 4 cGy for a CT scan acquisition and 3 cGy for a CBCT scan acquisition with our in-house protocols.

**Conclusions**

Knowing the measured absorbed-dose to the cardiac implantable electronic device (CIED) from our different planning and positioning imaging protocols, adequate classification of risk group of patients with (CIED) could be done. Therefore, dosimetric decisions regarding the planning can be performed under a sounder basis.

**SP118.2 - Organ dose estimation in computed tomography based on Monte Carlo simulation**

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Due to the significant rise of computed tomography (CT) exams in the past few years and the increase of the collective dose due to medical exams, dose estimation in CT imaging has become a
major public health issue. However, in clinical practice, dose is still estimated by empirical index such as CT air kerma indices and air kerma-length product. Protocols can hardly be optimised with such information. On this basis, we decided to develop an organ dose estimator providing dosimetric information for DICOM patient images and/or numerical standard phantoms. In this paper, developments and validations of the Monte Carlo (MC) dose simulator are mainly discussed. A MC tool, based on the 2006 release of the PENEOLE PRO code, has been adapted to enable CT exams simulations in a voxel-ified numerical phantom mimicking the human anatomy.

For that purpose, the GE Lightspeed VCT 64 CT tube was modelled by adapting the method proposed by Turner et al. (Med. Phys. 36: 2154-2164). First of all, equivalent spectra were determined for 100 kVp and 120 kVp by using experimental half-value layers (HVL). Measurements were performed is static mode with a CdTe detector associated with a method developed by the French national laboratory of metrology for ionizing radiations (LNHB) to achieve experimental spectra (X-ray Spectrometry 43(5): 298-304) and validate the tube model. Equivalent bowtie filter shapes were then established by using dosimetric profiles. Furthermore, axial and helical rotations of the X-ray tube were implemented in the MC tool. To improve the efficiency of the simulation, two variance reduction techniques were used: a circular and a translational splitting. The splitting algorithms allow a uniform particle distribution along the gantry path to simulate the continuous gantry motion in a discrete way. To validate the calculation, simulated sinograms are compared with the expected ones and the particle distribution along the gantry path is checked.

First validations were then performed in homogeneous conditions using a house-made phantom and the well-known CTDI phantoms. Comparisons between measured and simulated values are in good agreement with less than 10% deviation for several cases. Then, validations were performed in CIRS ATOM anthropomorphic phantoms using both optically stimulated luminescence dosimeters for point doses and XR-QA Gafchromic® films for relative dose maps. Last results are very encouraging with less than 20% deviation for punctual doses.

Organ Doses for several acquisition parameters into the ICRP male and female phantoms (ICRP, 2009. Adult Reference Computational Phantoms. ICRP Publication 110. Ann. ICRP 39 (2)) should soon be provided by the simulator in order to build a dosimetric data base which could be used in clinical practice.

**SP118.3 - Comparative study of Average Glandular Doses of three different digital mammography units in three Ministry of Health Hospitals in Oman: An analysis**

**Author(s):** Arun Kumar I. S., Rashid Al-Hajri, Saeed Al-Kalbani Medical Physics, Ministry of Health, Muscat/OMAN

Breast cancer accounts about 12% of all new cancers worldwide (WHO, World Cancer Report 2014) and this is about 25% in the Sultanate of Oman (2013) which is also the highest among all cancers in Oman. Breast screening by mammography can reduce mortality by about 25% and hence we follow a comprehensive radiation acceptance & quality assurance protocol for the testing of mammographic units installed in ministry of health (MOH), before handing over for routine patient care work. Of the many radiation parameters measured, the average glandular doses (AGD) of three different digital mammographic units from three manufacturers installed in three different hospitals was analysed in this study so as to make sure that the mammographic units meet WHO/IAEA standards as the Sultanate does not have currently a national protocol for acceptance of mammographic units.

The Average Glandular Dose (AGD) of three different digital mammography units was estimated by using a 4.5 cm polymethyl methacrylate (PMMA) phantom along with a calibrated 3.0 cc mammography chamber. Of the three mammography units, the first two had identical x-ray spectral features - W/Rh, Mo/Mo & Mo/Rh where as the third unit had W/Rh & W/Ag spectrum. The phantom used is assumed to have a glandularity of 50:50. The Entrance Surface Air Kerma (ESAK) and half value layer (HVL) of the beam was measured by the mammography chamber. The paddle is made in contact with the ion chamber and arranged the phantom & chamber side by side such that ESAK is measured without backscatter. From the measured ESAK and HVL values, AGD was estimated as per the European Guidelines (2003) by the formalism of Dance et. al. (2000 and 2009), i.e., AGD = Kgcs where K - is the ESAK without backscatter and g, c & s are correction factors. The phantom was compressed to the same breast thickness in all the three hospitals so that compressed breast thickness remained the same. ESAK and HVL for all available spectral qualities were measured in the three units and AGD’s were estimated for each spectral quality.

Also, AGD’s were estimated for phantom thicknesses of 3cm, 6cm and 8cm in the three units for the above spectral qualities. The results showed that AGD’s increased with the increase in thickness as expected. The system/mammo unit estimated/displayed entrance surface dose & organ dose (AGD) were noted and compared with the measured values of ESAK & the estimated values of AGD of the corresponding setting. Of the three hospitals, the estimated AGD’s were quite comparable in two hospitals where as the third hospital shown a variation of about 18% from the other two. However, in all the three hospitals, AGD’s were within the recommended value of 3 mGy for each projection.

Surveys shown that mammography units operating at optimal parameters have increased detection rates for smaller lesions with optimal dose to the breast. A well performed QA programme in mammography will yield good quality mammograms which in turn delivers an optimal dose to the patients undergoing mammographic investigations.

**SP118.4 - First Data on Quality Control Test done in Diagnostic X-ray facility at Major Public Hospitals in Kathmandu Valley, Nepal.**

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One of the most important goals of good medical practice in the use of X-ray is to diagnose the disease and its extent to minimize an adverse effect. During any action taken in diagnostic X-ray, there is an important issue of quality of the image and dose to the patient. Hence, regular practice of quality control in diagnostic X-ray is essential to provide a good quality images and less hazard to the patients and its checking on regular basis enhances the appropriate diagnosis with minimum side effects.

The quality control tests were carried out at thirteen X-ray units at seven different government hospitals in Kathmandu valley. The parameter like kV, kVp, dose, dose rate, HVL and mAs were measured with the acceptance limits. In this study, beam alignment test, radiation leakage test and focal spot test were also done.

During the study, we found that there is not any established proper method for the installment of diagnostic X-ray equipment and acceptance testing procedure in Nepal. Actions were not taken to improve the old X-ray machine and for restoring it to a proper working condition. The study shows that the need for quality assurance of diagnostic X-ray to be taken to avert detrimental effects to patients and staffs. Radiographers should provide sufficient training to ensure proper condition of X-ray machine. Radiation regulation now is essential for such programs to be introduced. Any program to manage patient dose in radiology should provide a high priority in the country like Nepal. Dose given in diagnostic X-ray should be...
SP118.7 - Radiation Dose Assessment for Retrospectively ECG-Gated Coronary Computed Tomography Angiography (CCTA) Examination

**Author(s):** T S Tuan Muda¹, C H Yeong¹, Sock Keow Tan¹, Kwan Hoong Ng¹, Yang Faridah Abdul Aziz¹, Zhonghua Sun²

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**Purpose:**

Coronary computed tomography angiography (CCTA) has been recognised as a reliable diagnostic technique for the assessment of coronary artery disease since the introduction of 64-slice CT. However the radiation dose received by the patients from CCTA is still high compared to other examinations, thus raising concerns in the medical field. This study aimed to assess the entrance skin dose (ESD) and organ absorbed dose measured in both patients and phantom during retrospectively ECG-gated CCTA examination.

**Methods:**

ESD for 30 patients (15 males, 15 females, 58±10 year-old) who underwent CCTA using a dual-source CT scanner (Siemens Definition DS, Germany) were compared with standard reference level on regular basis to identify the condition of the X-ray. Institute must introduce a mandatory system for acceptance test of X-ray when installed and regular quality control program.

**Keywords**— X-ray, acceptance test, quality control, radiation regulation
using optically stimulated luminescence dosimeters (OSLD). The measurement was extended to organ absorbed dose in an anthropomorphic phantom (Atom702G, CIRS, Virginia) with OSLD placed within the respective organs. Effective dose was then calculated using the CT Expo V2.3.1 software (Hannover, Germany).

Results:
The ESD measured on both male and female patients are presented in Figure 1. Figure 2 shows the absorbed dose measured within the selected organs of the ATOM phantom. The effective doses calculated from the CT Expo software showed that female patients received significantly higher effective dose than the male patients (14.70±4.35 vs. 10.40±5.94 mSv; p<0.05). The ESD of the breasts was about 8-9 times higher than the ESD reported from a typical mammogram of a breast of 5 cm compressed thickness.

Conclusion:
Due to the high radiation dose delivered to the patients, serious attention should be given to CCTA examination for dose reduction. Optimisation of the CCTA protocols should be carried out to minimise radiation dose to the patients.

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**SP119.2 - CT overexposure as a consequence of scan length**

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**Background**

The diagnostic benefits of CT scans with appropriate clinical reasoning far outweigh the potential radiation risks and this has seen an increased number of CTs ordered yearly in Australia. In saying that, effort must be made to lower radiation dose to the patients to ensure that the risk is kept as low as reasonably achievable.

A simple method of dose optimization is ensuring the correct scan length is chosen for the corresponding scan type, i.e. imaging only the anatomy that is required and nothing more. Initially, a scout image is obtained to ensure the patient is set up correctly for their scan. Adjustments to scan lengths based on anatomical landmarks and radiologist protocol should be made on the scout image before executing the CT scan on the patient.

**Aim**

This study aims to quantify the increased effective dose as scan length were chosen that deviated from standard protocol.

**Methods**

This study was performed using Monte Carlo software and a mathematical phantom to represent real patient data. The software package used in this study was CT-Expo V2.2. The software was validated by comparing the calculated CTDIvol and DLP to the CT-DIVol and DLP given on the CT scanner.

A reference scan was obtained for each scan protocol and the scan parameters, including kV, mA, rotation time, collimation width, table feed and slice thickness, were entered into CT-Expo to calculate the effective dose. The reference scan was acquired using CTU-41 CT Torso Phantom and the correct scan length for each simulation was validated by comparing the calculated CTDIvol and DLP given on the CT scanner.

A simple method of dose optimization is ensuring the correct scan length is chosen for the corresponding scan type, i.e. imaging only the anatomy that is required and nothing more. Initially, a scout image is obtained to ensure the patient is set up correctly for their scan. Adjustments to scan lengths based on anatomical landmarks and radiologist protocol should be made on the scout image before executing the CT scan on the patient.

**Results**

The results of this study show that for scans with a high CTDIvol the patient is exposed to an extra 1 mSv within 6 cm of overscan. Protocols that investigated large scan areas may not see a significant relative dose reduction, however radiation exposure should be kept as low as reasonably achievable.

**Conclusions**

The main emphasis of CT dose optimisation has been focused on new scanner technologies, however the operator can still play a key role in reducing patient dose. Ensuring the correct scan length is chosen by the radiologist and selected by the radiographer can potentially reduce the effective dose of each scan by up to 2 mSv. High dose protocols, such as head and spine, can benefit significantly in dose reduction with more stringent adherence to the anatomical region to be imaged.

**SP119.3 - Regional survey of pediatric patient doses from CT examinations in Tehran, Iran**

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**Objectives:** To establish regional diagnostic reference levels (RDRRLs) for typical paediatric CT examinations in Tehran, Iran and compare them with established international data. In addition, the aim was to develop a method of analyzing local scan parameters for further optimization.

**Methods:** The dose assessment was performed in terms of weighted CT dose index (CTDIw) and dose length product (DLP) for head, sinus, chest and abdomen-pelvis CT examinations using standard methods. CTDI were measured in a polymethyl methacrylate (PMMA) Head and Body phantoms. RDRRLs were derived from mean survey values for different age categories in 19 CT facilities in Tehran, Iran.

**Results:** The mean range of CTDIw for all age categories were 41.77-53.04, 24.37-26.55, 12.45-13.48 and 13.18-18.25 for Brain, Sinus, Chest and Abdomen-pelvis, respectively. Related DLPs were 325.5-495, 181.5-222.7, 143.2-250.6 and 186.5-488.4, respectively.

**Conclusion:** Many hospitals were incorporating adult scanning parameters for children, resulting in very high effective doses. The great variations of CTDIw and DLP observed among hospitals and relatively high values of DLP in some centers are evidence that radiation doses of Paediatric patients from CT examinations need to be optimized.

**SP119.4 - Dose Reduction Efforts in PET/CT: the Quebec Experience**

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**Problematic and objective:** The province of Quebec (Canada) has 15 publicly funded PET/CT center for a population of 8.2 million. This relatively large per capita ratio makes PET an accessible technology that significantly contributes to the collective radiation dose of medical origin in the province. In this context, the province of Quebec has created and mandated the Center for clinical expertise in radiation safety (CECR) to proceed with a province-wide tour of PET/CT installations with the objective of establishing good radiation protection practices for patients and caregivers.

**Methods:** The CECR first conducted a province-wide survey to establish a snapshot of the current practice in 2014. This survey was followed by on-site visits by a team composed of a medical physicist, a nuclear medicine technologist and a CT imaging technologist. The 2-day visit consisted, on day 1, in 1) quality controls and performance evaluation of the CT, PET and dose calibrator, 2) verification that the procedures used to perform the PET/CT studies (preparation and execution) are defined and observed. Furthermore, 15 whole-body and 4 high-resolution (fine CT slice thickness) head and neck 18F-FDG PET/CT studies were analyzed. Specifically, the signal to noise ratio (SNR) for both PET and CT images were obtained for the liver (whole-body studies) while the CTDI, the DLP, the injected activity and the injection/acquisition interval were retrieved from images or their DICOM header. The team also verified all aspects of radiation protection practices in the visited center.
On day 2, the team presented their observations to the local team of technologists, physicians and managers and made recom-

mendations for improving the radiation protection practices. For adult studies, the amount of 18F-FDG recommended was based on both EANM guidelines for tumor imaging and on the Japanese guidelines. The measured performance of the PET system was also taken into account for the determination of the optimal injected dose. With the approval of local physicians, PET/CT studies scheduled for the second day were performed using the proposed protocols. Prompt feedback from the physician on image quality allowed the CECR expert to fine-tune the protocol parameters in order to reach optimal quality with the minimal dose.

Results: Survey results showed that PET examinations vary considerably across centers, with dose varying from 8 to 30 mSv for 18F-FDG whole-body protocols, which account for 99% of all PET studies. Recurring visit recommendations for adult protocols include: 1) using automatic tube current modulation for CT, resulting typically in 20% dose savings, 2) reducing the tube current by 20% for high-resolution head and neck CT protocols, 3) reducing by 30% the amount of injected activity, 4) complying with the prescribed injection/acquisition interval.

Conclusion: The approach used by CECR to optimize PET/CT protocols takes into account the performances of devices and EANM/Japanese guidelines. It is based on the active participation of all stakeholders in the process: nuclear medicine physicians, biomed-

Results: A small fraction (0.27%) of forty-one patients were identified (63% male, mean age 62, range 24-83, mean weight 82 kg). These patients received 347 CTs in total. The median of the received number of CTs was 7.0 (range 3-20) with 3.5 series per scan within a time frame of 166 days (median: range 8-320). Median cumulative effective dose was 117 mSv (range 100-301). A positive correlation was found between the number of CTs and the received effective dose (Figure 1). Most frequent scan indications were: oncology, abdomi-

nal imaging for abscess and drainage as well as complications after surgery. The most frequently selected scan region was the abdo-

men (n=150) with a median effective dose of 11 mSv (range 2.5-49), followed by combined thorax/abdomen protocols (n=39, median 17 mSv, range 6.4-57).

Conclusion: Very high cumulative doses (>100mSv) only occur in a fraction of patients. As clinical indications justify each examination and the average radiation dose per scan was acceptable, these cumulative doses may represent common clinical practice in severely ill patients.

Figure 1 The cumulative effective dose per patient as a function of the number of CTs a patient received. The solid line indicates a linear fit (R^2 = 0.46), the dashed line the 100 mSv inclusion criterion.

SP119.5 - Assessment of high cumulative patient doses of repetitive CT examinations

Author(s): Cecilie R. Jeukens, Roald S. Schnerr, Sandra Niesen, Joachim E. Wildberger, Marco Das

Maastricht University Medical Centre+, Maastricht/NETHERLANDS

Purpose

In daily routine patients often undergo multiple CT examinations within a short time frame, which may lead to a high radiation exposure. Our purpose was to evaluate patients who received a cumulative effective dose of more than 100 mSv within one year with repeat CT examinations.

Methods and Materials

15,000 consecutive CT examinations were systematically analyzed using dedicated dose monitoring software (RadimetricsTM, Bayer Healthcare) within the time period 08/2013-08/2014. The effective dose (according to ICRP 103) is calculated from the technical and dose related parameters retrieved from the CT scanners, using an incorporated Monte Carlo module. All patients with a cumulative effective dose above 100 mSv were identified. Besides patient specific parameters (sex, age, weight), patients were analyzed with respect to cumulative effective dose, number of CT scans and scan series, dose per CT scan, time interval of the scans, clinical scan indications and anatomical scan regions.

Results

A small fraction (0.27%) of forty-one patients were identified (63% male, mean age 62, range 24-83, mean weight 82 kg). These patients received 347 CTs in total. The median of the received number of CTs was 7.0 (range 3-20) with 3.5 series per scan within a time frame of 166 days (median: range 8-320). Median cumulative effective dose was 117 mSv (range 100-301). A positive correlation was found between the number of CTs and the received effective dose (Figure 1). Most frequent scan indications were: oncology, abdomi-
**SP119.7 - Occupational Dose Measurement in an Interventional Radiology Facility in Jakarta**  
**Author(s):** Lukmanda Evan Lubis, Nur Aida, Nurdina G. Pratiwi, Kristina Tri Wigati, Supriyanto Ardio Pawiro, Djawarini Soeharso Soejoko  
Department Of Physics, Faculty Of Mathematics And Natural Sciences, University of Indonesia, Depok/INDONESIA

The increasing use of ionizing radiation for diagnostic aims increases the alert on radiation protection. Whereas high standard and awareness are typically possessed by workers on Diagnostic Radiology facilities, personnel of Interventional Radiology departments are of higher need of attention. The works in Interventional Radiology the procedures are done with a long time fluoroscopy and the personnel being inside the imaging room. Two studies were performed on occupational dose measurement in Cardiac Interventional Radiology. The first study was done by measuring exposure levels on working staffs during a single interventional procedure, with the efficacy of available shielding being evaluated also. Second study was carried on by measuring scattered dose levels in various positions during a range of varied cardiac interventional procedures. On the whole, resulting remarks served as an input for the workers on the feasibility of their equipment, and scattered radiation during Cardiac Interventional Radiology procedures.

**SP119.8 - Evaluation of the Comparative Effectiveness of Various Jurisdictional Computed Tomography Radiation Dose Reduction Models**  
**Author(s):** Anne Li¹, Mark Fan², Anthony Easty²  
¹Institute Of Biomaterials And Biomedical Engineering, University of Toronto, Toronto/ON/CANADA, ²Humanera, Techna Research Institute, University Health Network, Toronto/CANADA

**Background:** High reliance on computed tomography (CT) worldwide results in high levels of radiation exposure to patients, which translates into increased cancer risks. Efforts to manage radiation dose are progressing, but the approach has not been standardized. It was, therefore, the aim of this study to systematically assess and compare jurisdictional policies that have been developed to optimize CT radiation dose.

**Methods:** Six jurisdictions (British Columbia, Ontario, Texas, California, Germany, Ireland) that contain institutions with dose tracking systems were selected to account for several possible approaches to radiation dose management. Each policy was reviewed and indexed for recurring themes. Five themes (technical requirements, operating requirements, radiation safety committee/quality assurance programs, radiation dose reporting, diagnostic reference levels) emerged. An assessment instrument was formulated by identifying 3 domains of related constructs (executability, comprehensiveness, rigor) that would negate common knowledge translation barriers. Two reviewers performed independent policy evaluations using the assessment framework until inter-rater reliability was judged to be sufficient (κ <0.75). Inter-rater reliability was calculated using Weighted Cohen’s kappa. Final scores were achieved through consensus once κ was satisfactory. Statistical analyses were performed using Pearson correlations.

**Results:** Two rounds of independent evaluations were necessary to achieve sufficient inter-rater reliability. Inter-rater reliability was high (κ=0.830) for the assessments after discussion occurred to clarify the definition and application of the domains. Final domain and theme scores for each jurisdiction are presented in Table 1. There was strong positive correlation for the domains, but not themes.

**Conclusions:** The assessment instrument may be useful for relative comparisons of knowledge translation potential in regulatory policies. Positive correlations between the domains suggest that carryover effects may be present if policymakers focus intensively on developing any one domain. The evaluations revealed that precise accreditation standards (such as those in British Columbia and California) exhibited the most executable, comprehensive and rigorous model for managing radiation dose. California’s efforts in mandating CT facility accreditation and dose reporting achieved the highest score overall (51 out of 72). Ireland and Germany achieved comparable scores, despite developing different interpretations of the same regulatory framework (Euratom’s Directive 97/43) that resulted in varying approaches to dose management. The framework can be further enhanced to account for these critical differences. Our goal is to improve patient safety globally, by encouraging translatable jurisdictional models for radiation dose management. Further evaluations will need to validate the relationship between jurisdictional policies and radiation dose reduction over time.

<table>
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<tr>
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<th>British Columbia</th>
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Obstructive sleep apnea (OSA) is a public health problem with severe health consequences. The current OSA severity estimation is based on the average number of breathing cessation and desaturation events per hour of sleep, neglecting the individual event characteristics. The aim of the current study was to evaluate desaturation event morphology in deceased and matched control patients with severe OSA.

12 deceased and 12 AHl, age, BMI and follow-up time matched alive control patients with severe OSA were analyzed. Desaturation event durations, depths, and areas of the deceased and alive control patients were compared. Also the effect of different baseline level selection in the desaturation depth analysis was investigated.

Patient demographics, apnea-hypopnea-index (AHI) and oxygendesaturation-index (ODI) did not differ statistically significantly between the groups. The average oxygen saturation levels were statistically significantly lower 89.8% vs. 93.2% ($p=0.002$) in the deceased patients compared to the alive controls. The median desaturation event duration 31.8s vs. 25.9s ($p=0.017$, depth 15.0% vs. 9.5% ($p=0.006$) and area 349.9% vs. 201.4% ($p=0.001$) were statistically significantly greater in the deceased patients compared to the alive control patients when using 100% saturation as baseline level for desaturation events. When the first point before desaturation onset was used as baseline no statistically significant differences ($p=0.089$) were found between the deceased and alive control patients in desaturation depths. Based on quantitative inspection of the distributions of individual desaturation event characteristics the desaturation events were more severe in the deceased group.

Patients with similar AHI and ODI can have different individual desaturation event characteristics. Selection of the baseline for desaturation event depth analysis can affect the estimation of the event severity. The analysis of the individual desaturation event characteristics can provide supplementary information on the severity estimation of OSA and support the individual mortality risk estimation in severe OSA patients.

**SP120.2 - Static Posturography of Elderly Fallers and Non-Fallers with Eyes Open and Closed**

**Author(s):** Jennifer Howcroft1, Jonathan Kofman2, Edward D. Lemaire3, William E. McIlroy4

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Static posturography can be used to assess postural balance, which is important for activities of daily living. For older adults, poor postural balance can indicate increased fall risk. This study investigated eyes open and eyes closed static posturography assessments of 100 elderly participants (≥ 65 years) in two-foot stance. Twenty-four of these people had fallen in the previous six months. Range in anterior-posterior (AP) and medial-lateral (ML) motion; center of pressure (CoP) root mean square distance from mean; AP, ML, and resultant CoP velocity; and percent body weight on left and right feet were calculated from Wii Balance Board vertical force data. All AP measures and resultant CoP velocity were significantly greater with eyes closed than eyes open for fallers and non-fallers. ML CoP velocity was significantly greater with eyes closed than open for fallers. The largest percent increase from eyes open to eyes closed was for AP velocity, followed by 2D velocity for both fallers and non-fallers. Therefore, AP-based center of pressure-derived posturography measures appear to be sensitive to changes in postural control due to elimination of visual input. Significant differences were not found between fallers and non-fallers.

**Results:** Table 1 shows that for the group with accelerated HR (HR≥90 bpm), several indexes were different before VT/VF (faster HR, more ectopy, shorter and more fixed CI) versus control. In contrast, the group with HR<90 bpm had similar indexes before VT/VF versus control. Although the group with HR<90 bpm was characterized with faster HR and shorter CI than the group with HR≥90 bpm, both groups had similar ectopy.

**Conclusions:** Several quantitative characteristics of PVCs evaluated with the heartprint method in short-time HRV series obtained from ICDs are potential markers of imminent tachyarrhythmia (VT/VF). The interaction between accelerated HR and high ectopy (previously known risk factors of tachyarrhythmia) should be considered in future evaluation of CI indexes as risk indicators for VT/VF.
SP120.4 - An evaluation of Arterial Stiffness Index in Relation to the State of the Cardiovascular System

Author(s): Jan Havlík1, Jakub David2, Jan Dvořák3, Lenka Lhotská4
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The study deals with an evaluation of correlation between an Arterial Stiffness Index and a state of the cardiovascular system. The main goal of the research is to show whether theASI is an appropriate parameter for CVS state classification. The statistical evaluation of the dependency of the ASI on the CVS state and other parameters has been done using the linear regression analysis and the t-test of mean values. The ASI has been correlated with the age of the patient, the blood pressure (low/normal/high), the mean arterial pressure and the presence both of the cardiovascular diseases and diabetes mellitus in the study. Only the correlation between the ASI and blood pressure (low/normal/high) has not been directly proved. Although the results are statistically significant, the study shows the limitations of ASI as a CVS status marker. The ASI is a suitable parameter for primary screening, but it should be complemented by additional parameters for increased reliability.

SP120.5 - Investigating a Novel Non-invasive Measure to Assess the Upper Airway Narrowing during Sleep

Author(s): Ying Xuan Zhu1, Elma Zola2, Milos Popovic2, Azadeh Yadollahi2
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Introduction: Previous studies from our team have shown that upper airway (UA) narrowing during sleep could increase its resistance. Increased UA resistance and the associated inspiratory flow limitation are important means of assessing both the cause and the consequences of breathing disorders during sleep. While gold standard assessment of the UA resistance requires invasive measurement of pharyngeal pressure, previous studies have shown that the contour of nasal airflow could be used as a non-invasive technique to detect increased UA resistance during sleep. However, these studies have not investigated whether the non-invasive estimation of the UA resistance is associated with physiological variations such as the narrowing in UA cross-sectional area (UA-XSA). The objective of this study is to evaluate the sensitivity of the non-invasive measures of the UA resistance to estimate the changes in the UA-XSA during sleep.

Methods: Subjects attended a regular sleep study in our sleep laboratory. The nasal airflow was collected non-invasively using a nasal cannula. The sleep apnea severity was assessed by the apnea-hypopnea index (AHI). Before and after sleep, UA-XSA was measured by acoustic pharyngometry. For each inspiration, different temporal features such as the number and location of peaks and the plateau in the airflow contour were extracted. Those features were used to manually annotate the inspirations, which correspond to severe flow limitation in the UA and increased UA resistance. The correlation between changes in UA-XSA due to sleep and the percentage of the flow-limited breaths were examined.

Results: 10 non-obese men, age 31.8±26.7 years and AHI of 41.4±12 completed the protocol. After sleep, UA narrowed by -11.87±10.38% (P<0.001). From each subjects, 244±80 episodes of inspiratory airflow signal were randomly selected from their stage 2 of sleep, and annotated by two experts with consistent agreement. We found that there was a second-order significant correlation between the narrowing in UA-XSA and the percentage of flow-limited inspirations (r=0.73, p=0.017).

Conclusions: Our results show that non-invasive assessment of the UA resistance, obtained by measuring the contour of nasal airflow, can be used as a sensitive measure to assess the severity of UA narrowing during sleep.

Acknowledgement: This study was supported by Toronto Rehabilitation Institute and the University of Toronto.
Conclusion: These promising results demonstrate that non-invasive measurements of bioimpedance can be used to develop a novel biomarker to assess patients at high risk of fluid overloading and developing OSA.

Introduction: Obstructive sleep apnea (OSA) is common in 10% of adults and is characterized by repetitive collapse of the pharynx. OSA prevalence increases in fluid retaining patients such as those with heart or renal failure. It is shown that OSA severity worsens with overnight fluid accumulation in the neck. The objective of this study is to develop a new biomarker to assess fluid accumulation in the neck which can be used to determine patients at high risk of developing OSA due to fluid overload.

Methods: This study was part of a double cross-over study to investigate the effects of experimentally induced fluid overloading during sleep on OSA severity. During the control arm saline was infused at a minimal rate to keep the vein open, while during the intervention approximately 2L of saline was infused intravenously during sleep. OSA severity was assessed using polysomnography to estimate obstructive apnea-hypopnea index (OAHI). Before and after sleep, neck fluid volume was measured using bioelectrical impedance at 50kHz. For each subject, resistance and reactance was extracted from the impedance measurements. Neck impedance can be modeled as a resistor (extracellular fluid, RE) in parallel with a capacitor (cell membrane, Cm) and resistor (intracellular fluid, Ri). Increase in intracellular fluid could swell the cell and increase Cm. The recorded reactance and resistance from bioimpedance measurements can be expressed in terms of Ri, RE, ω(2πf) and τ (Cm[Ri+Ro]). Assuming that $\omega^2\tau^2 << 1$, the recorded resistance and reactance can be simplified to $R = R_o$, and $X_c = -\omega C_m R_o^2$, respectively. Using these relations, the bioimpedance recording of neck can be used to estimate Cm, which could represent the intracellular fluid of the neck.

Results: Subjects who had an increase in OAHI from the control to saline infusion arm were investigated. 12 non-obese men, age 44±13, with OAHI 18±23 were included. Our results show that subjects with a larger Cm before sleep during the control arm had a larger increase in OAHI from control to intervention (P=0.008). This indicates that those with a larger estimated capacitance and intracellular fluid were more susceptible to the adverse effects of fluid overload on OSA severity.
SP121 - Deep Brain Stimulation

SP121.1 - A 16-bit High-Voltage Digital Charge-Control Electrical Stimulator

Author(s): Soheil Mottaghi1, Richard Pinnell1, Ulrich G. Hofmann2
1Neuro Surgery, Neuro Electronics Systems, University Hospital Freiburg, Freiburg/GERMANY, 2Neuro Surgery, neuro Electronic Systems, University Hospital Freiburg, Freiburg/GERMANY

Research on the effects of electrical stimulation, needs an accurate system able to generate any arbitrary waveforms with different frequencies and interphase delays. Some applications such as Deep Brain Stimulation (DBS) turn to smaller electrodes resulting in higher impedances, causing obstacles to deploy the same amount of charge to the tissue. In this paper a 16-bit digital charge-control current stimulator is presented which can produce up to +/- 35V output swing voltages. Platinum flexible electrodes have been used to compare the performance of the developed with two commercial stimulators.

SP121.2 - A method for side effect analysis based on electric field simulations for intraoperative test stimulation in deep brain stimulation surgery

Author(s): Daniela Pison1, Fabiola Alonso2, Karin Wårdell2, Ashesh Shah1, Jérôme Coste1, Jean-Jacques Lemaire1, Erik Schkommom�au1, Simone Hemm-Ode1
1Institute For Medical And Analytical Technologies, School of Life Sciences, Muttenz/SWITZERLAND, 2Department Of Biomedical Engineering, Linköping University, Linköping/SWEDE, 3Image-guided Clinical Neurosciences And Connectomics (ea 7282, Centre Hospitalier Universitaire de Clermont-Ferrand, Clermont-Ferrand/FRANCE

Despite an increasing use of deep brain stimulation (DBS) the fundamental mechanisms underlying therapeutic and adverse effects remain largely unknown. The simulations of electric entities are increasingly used to evaluate stimulation effects. So far no group has considered such simulations combined with a side effect analysis of data obtained during intraoperative test stimulations. The aim of the present paper is to introduce a method allowing patient-specific electric field simulations for stimulation amplitudes inducing side effects during DBS-surgery.

Two female patients presenting essential tremor, both bilaterally implanted in the ventral intermediate nucleus (VIM) region (Clermont-Ferrand University Hospital, France) were included in the study. Intraoperative test stimulations were performed on central and posterior trajectories in each hemisphere. At each position, in addition to the evaluation of the therapeutic effects, side effects such as pyramidal symptoms and paresthesia without localization indicator or paresthesia with localization indicated by the patient (in the hand or in the fingers) were noted. The anatomical structures such as VIM and its neighbors were preoperatively manually outlined using the iPlan software (Brainlab, Feldkirchen, Germany) according to spontaneous MRI contrasts [1]. The so identified structures were exported via a specifically designed interface (VLLink, Brainlab, Feldkirchen, Germany). Whenever side effects occurred the inducing stimulation amplitude was chosen for electric field simulations. A finite element method [2] was applied to calculate the electric field distribution. Conductivity values were deduced from the patient's T1 weighted MRI. An isofield level of 0.2W/mm was chosen and the points of the isosurface were exported. They were visualized together with the extracted anatomical structures and the trajectories. The different structures presented inside the volume defined by the isofield level and their appearances were determined. Combinations of structures always appearing together for a specific side effect were identified.

For both patients, eight electric field simulations were performed. A first analysis showed that pyramidal effects appear when parts of the ventro-oral nucleus (VO) and the VIM were present inside the isosurface. The ventrocaudal lateral nucleus (VCL), the ventrocaudal medial nucleus (VCM) and the VIM were among the identified structures in hand paresthesia (VCL, VIM), finger paresthesia (VCL, VCM, VIM) and paresthesia with location not formally identified by the patient (VCM, VIM).

The application of our method to two patients has shown its feasibility. Our results are consistent with anatomical knowledge that stimulation of VCL and VCM induce paresthesia in the body and the face respectively. Nevertheless, more patient data have to be analysed to draw any conclusions. The present method will allow an optimised data exploration compared to existing methods only taking into account the anatomical position of the center of the measurement electrode.

References

SP121.3 - Comparison of Three Deep Brain Stimulation Lead Designs under Voltage and Current Modes

Author(s): Fabiola Alonso1, Malcolm A. Latorre2, Karin Wårdell1 Department Of Biomedical Engineering, Linköping University, Linköping/SWEDE

Since the introduction of deep brain stimulation (DBS) the technique has been dominated by Medtronic systems. In recent years, new DBS systems have become available for patients, and some are in clinical trials. The present study aims to evaluate three DBS leads operated in either voltage or current mode. 3D finite element method (FEM) models were built in combination with a neuron model for this purpose. The axon diameter was set to D = 5 μm and simulations performed in both voltage (0.5-5 V) and current (0.5-5 mA) mode. The evaluation was achieved based on the distance from the lead for neural activation and the electric field (EF) extension at 0.1 V/mm. The results showed that the neural activation distance agrees well between the leads with an activation distance difference less than 0.5 mm. The shape of the field at the 0.1 V/mm isopotential surface in 3D is mostly spherical in shape around the activated section of the steering lead.
SP121.4 - Effect of closed-loop and open-loop deep brain stimulation on chronic seizures control

Author(s): E. Muhammad T. Salam, Roman Genov, Jose Luis Perez Velazquez

1Electrical Engineering, University of Toronto, Toronto/ON/CANADA, 2Electrical Engineering, University of Toronto, Toronto/ON/CANADA, 3Neuroscience & Mental Health Programme And Division Of Neurology, Hospital for Sick Children, Toronto/ON/CANADA

Objective: To investigate the effects of closed-loop and open-loop neurostimulation of the hippocampus on the suppression of spontaneous seizures in a rodent model of epilepsy. Method: Chronic seizures in ten rats were induced by intraperitoneal kainic acid injection. Two bipolar electrodes were implanted into the CA1 regions of both hippocampi. The electrodes were connected to the custom-built programmable therapeutic neuromodulation device that can trigger an electrical stimulation either in a periodic manner or upon detection of the intracerebral electroencephalographic (iEEG) seizure onset. This device has a microchip consisting of a 265-channel iEEG recording system and a 64-channel stimulator, and a programmable seizure detector built in a field-programmable gate array (FPGA). This device was used to evaluate seizure suppression efficacy in the epileptic rats for 240 days (5760 hours). For this purpose, all rats were randomly divided into two groups: the non-stimulation and the stimulation group. The non-stimulation group did not receive stimulation; whereas the treatment group received closed-loop stimulation and later, open-loop stimulation. Result: The non-stimulation and stimulation groups had a similar seizure frequency baseline, average 5 seizures per day, but the closed-loop stimulation reduced seizure frequency by 90% and the open loop stimulation reduced by 17% in the stimulation group. Significance: In this study, this closed-loop stimulation strategy proved superior to the open-loop stimulation in the seizure suppression using the optimal number of stimulations. Therefore, an effective alternative to the open-loop neurostimulator is the closed-loop neurostimulator, in which the involvement of the deep brain stimulation is minimal. Such a system would be able to sense the upcoming seizure in real time, and deliver the proper stimulation. The new era of deep brain stimulation strategies based on closed-loop paradigms may be able to target different pathological aspects of brain activity for the treatment of various neurological disorders.

SP121.5 - Clinical validation of a precise tremor assessment system to aid deep brain stimulation parameter optimisation

Author(s): Thushara Perera, Shivanthan A.C. Yohanandan, Mary Jones, Richard Peppard, Wesley Thaveethasan, Andrew H. Evans, Joy L. Tan, Colette M. McKay, Hugh J. Mcderrmot

1Neurobionics, Bionics Institute, East Melbourne/AUSTRALIA, 2Electrical And Electronic Engineering, The University of Melbourne, Melbourne/AUSTRALIA, 3Department Of Neurology, St Vincent’s Hospital, Melbourne/AUSTRALIA, 4Department Of Neurology, The Royal Melbourne Hospital, Melbourne/AUSTRALIA

Introduction

Deep brain stimulation (DBS) is an established therapy for Parkinson’s disease and Essential Tremor. Yet finding the most efficacious stimulation amplitude, pulse duration and frequency is difficult due to the numerous parameter permutations. The therapeutic outcomes are measured using a variety of clinical assessments including subjective rating scales. These measures lack sufficient sensitivity to inform DBS parameter optimisation, thus justifying our aim to develop a more precise and objective measure.

Methods

The Tremor Biomechanics Analysis Laboratory (TREMBAL) system, developed at the Bionics Institute, provides real-time tremor severity measurements for clinicians using an electromagnetic motion tracker (Ascension, Vermont, US) to acquire absolute displacements and rotations of the tremulous body part. TREMBAL automatically computes tremor amplitude, velocity, peak frequency and peak power spectral density (PSD) for both translational and rotational components of motion.

We placed two sensors on each hand at the proximal phalanges of the middle fingers and approximately 5 cm above the olecranon of the elbows to measure proximal and distal tremors of nine participants with existing DBS therapy. Four trials were performed where DBS level was systematically reduced from 100% (clinically optimal level) to 75%, 50% and finally 0% (DBS off). In each trial, after waiting 12 minutes for adaptation, the participant held their hands outstretched for 10 seconds and performed the finger-nose exercise. These were video recorded and presented to three blinded experts (W.T., A.H.E., J.L.T.) for clinical rating using the Bain Tremor Rating Scale. Linear regression analysis between the average expert tremor ratings and computed tremor metrics were used to validate TREMBAL. Pearson’s correlations were also performed to confirm any associations.

Results

Sixty-four clinical ratings were included in the analysis. One patient was excluded because they presented with dystonia. Results were deemed significant if p < 0.0063 (Bonferroni correction for multiple comparisons). Objective measures of translational amplitude and velocity had the strongest ability to predict clinical ratings (table 1).

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<td>Translation</td>
<td>Amplitude</td>
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<td>0.53</td>
<td>0.90</td>
<td>&lt;0.001</td>
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<td>Velocity</td>
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<td>Rotation</td>
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<td>0.20</td>
<td>0.01</td>
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Table 1. The coefficient of determination (R²) and standard error (SE) indicated the goodness-of-fit of the linear regression between clinical ratings and TREMBAL metrics for distal tremor of the worst affected hand. Pearson’s correlations indicated strength (r) and statistical significance (p) of the association. PSD = Power Spectral Density.

Discussion

Tremor frequency and PSD in addition to all angular measures showed weaker agreement with clinical ratings. We believe that clinicians rely mostly on displacement and speed to assess tremor severity thus accounting for the high concordance with translational TREMBAL data. Further work will aim to determine the test-retest reliability of the system and the optimal combination of metrics to reduce TREMBAL’s output to a single measure based on machine learning algorithms.

Acknowledgements

Colonial Foundation and the Victorian Government Operational Infrastructure Support Program.
SP121.6 - The Role of Microelectrode Recording (MER) in STN DBS Electrode Implantation

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1Biomedical Eng & Neurology & Neurosurgery And, Nizam’s Inst of Medical Sciences (NIMS) University & Hospital, HYDERABAD/INDIA, 2Neurology, Nizam’s Inst of Medical Sciences, Hyderabad/INDIA

The purpose of this paper is to study the correlation of microelectrode recording with the final tract chosen during bilateral STN DBS performed at a specialized centre in South India. Deep brain stimulation (DBS) of bilateral subthalamic nuclei (STN) is an efficient method of rehabilitation in subjects (diseased conditions—patients) with advanced idiopathic Parkinson disease (PD). Accurate targeting of STN neurons and placement of microelectrodes are paramount importance for optimal results after STN-DBS. Stereotactic assessment, intra-operative microelectrode recording and intra-operative stimulation effects have all been used in targeting, albeit the individual role of each modality is still not known. Microelectrode recordings (MER) of STN were detected in a mean of 3.5 ±1.1 channels on right hemisphere and 3.6 ±1.04 on left hemisphere. Final channel selected were most commonly central seen in 42.3% followed by anterior in 33.7%. Concordance of final tract with the channel having the highest recording was 58.7%, with the channel showing maximum-depth-of-recording was 48% and with either was 64%. Absence of any recording in the final tract chosen was seen in 6.52%, in these subjects the tract was chosen based on stimulation results. The depths of microelectrodes were detected by MER in 75.6%.

Conclusion: Microelectrode-recording (MER) is useful to identify and confirm the tract in which DBS electrodes are placed and is most-useful in determining depth-of-electrodes placement but has to be taken in consideration with effects seen on macrostimulation.

SP121.7 - Effectiveness of Micro-Electrode-Recording (MER) in Determining Subthalamic-Nuclei Deep Brain Stimulation (STN-DBS) Lead Position in PD Conditions

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Biomedical Eng & Neurology & Neurosurgery And, Nizam’s Inst of Medical Sciences (NIMS) University & Hospital, HYDERABAD/INDIA

Objectives: To study the effectiveness of microelectrode-recording in determining final tract for placing DBS-electrode during bilateral STN-DBS

Background: Deep-brain-stimulation of bilateral subthalamic-nuclei is an effective mode-of-therapy in subjects with idiopathic Parkinson’s-diseased-conditions (PD patients). Accurate targeting and placement of microelectrodes are paramount importance for optimal results after STN-DBS. Stereotactic-assessment, intra-operative microelectrode-recording and intra-operative stimulation effects have all been used in targeting, though the individual role of each modality is still unknown.

Methods: 52PD subjects were included in the study. Subjects with advanced PD of >5 years with good response to levodopa and H and Y score of <4 with normal cognition were eligible for surgery. Functional surgery was planned using a CRW frame with an MRI protocol using Framelink software with 5 channels. Microelectrode recording was performed in all subjects extending from 10mm above target to 10mm below STN. Final target-selection was based on the effects and side effects of macrostimulation and confirmed by post op MRI.

Results: 52PD subjects with their mean age of 58.1 ±9.1 years, mean disease duration of 8.8 ±3.64 years were included. Prior to implantation, mean UPDRS score in ‘off’ state was 52.7 ±10.6 and in ‘on’ state was 13.4 ±5.0. STN microelectrode recordings were detected in a mean of 3.5 ±1.1 channels on right hemisphere and 3.6 ±1.04 on left hemisphere. Final channel selected were most commonly central seen in 42.3% followed by anterior in 33.7%. Concordance of final tract with the channel having highest recording was 58.7%, with the channel showing maximum-depth-of-recording was 48% and with either was 64%. Absence of any recording in the final tract chosen was seen in 6.52%, in these subjects the tract was chosen based on stimulation results. The depth of microelectrodes was identified by microelectrode recording in 75.6%.

Conclusion: Microelectrode-recording (MER) is useful to identify and confirm the tract in which DBS electrodes are placed and is most-useful in determining depth-of-electrodes placement but has to be taken in consideration with effects seen on macrostimulation.
**Methods**

We applied both data mining and microarray analysis in this study to identify genes that differentially express (fold-change > 2, p-value < 0.05) in synovial tissues between OA and the control patients. To further study the biological roles of these differentially expressed genes (DEGs), they were analyzed using DAVID. In addition, TargetScan was used to predict the conserved miRNAs that target the interested genes.

**Results**

The microarray data series were first downloaded from GEO, and then analyzed to obtain OA-related gene expression profile. We have identified 2,602 and 1,556 DEGs from series GSE29746 and GSE55235, respectively. The subsequent gene function annotation revealed that a number of pathways in which the DEGs may be involved, including cytokine-cytokine receptor interaction, MAPK signaling pathway, Hematopoietic cell lineage and cell adhesion molecules, might be associated with OA pathogenesis. Among them, 5 DEGs may be the potential molecular targets of OA (Table 1). MiRNAs have been reported to regulate genes expression in joint disease. So conserved miRNAs that target these genes were also predicted. However, the biological functions of these genes in OA, as well as their regulation by miRNAs, need further elucidation.

**Conclusion**

We have studied the expression of genes between OA and healthy controls, and identified a number of DEGs that may be putative molecular signatures of OA. miRNA regulators of five distinct DEGs were also predicted. **TIPARP** may be targeted by miR-221/222. And we found that **TIPARP** expression was significantly reduced in OA patients. Taken together with the fact that miR-221/222 is significantly over-expressed in rheumatoid arthritis synovial fibroblasts, **TIPARP** may play a role in OA pathogenesis via negative regulation by miR-221/222. The newly identified dysregulated genes and their miRNA regulators in OA may act as genetic markers for OA diagnosis and treatment in the future.

**Table 1:** miRNA regulators and GO functional annotation of five putative osteoarthritis-associated genes

<table>
<thead>
<tr>
<th>Gene1</th>
<th>miRNA2</th>
<th>GOTERM_BP_FAT3</th>
<th>GOTERM_MF_FAT4</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADH1C</td>
<td>miR-3978/1273e/1290</td>
<td>ethanol metabolic process</td>
<td>transcription regulator activity, ion binding</td>
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<td>ETS2</td>
<td>miR-33ab</td>
<td>skeletal system development, regulation of transcription</td>
<td>DNA binding, transcription regulator activity</td>
</tr>
<tr>
<td>RORA</td>
<td>miR-302abcde/372/373/520be/520acd-3p</td>
<td>positive regulation of biosynthetic process, regulation of transcription</td>
<td>DNA binding, transcription regulator activity, ion binding</td>
</tr>
<tr>
<td>STXB6</td>
<td>miR-133ab</td>
<td>vesicle-mediated transport</td>
<td></td>
</tr>
<tr>
<td>TIPARP</td>
<td>miR-221/222</td>
<td>skeletal system development, cell surface receptor linked signal transduction</td>
<td>ion binding</td>
</tr>
</tbody>
</table>

1 fold-change > 2, false discovery rate-adjusted p-value < 0.05; 2 Predicted conserved miRNA regulators; 3 GO Biological Process term; 4 GO Molecular Function term
Identifying regulatory relationships between genes is a central and challenging problem in the field of genetics. One classical approach is epistasis analysis (Avery & Wasserman, Trends in Genetics, 1992). Broadly speaking, epistasis between a pair of genes in a pathway, X and Y, happens when the phenotypic consequence of deleting genes X and Y is “unexpected” based on the results of deleting each gene individually. By following the rules of epistasis, one can sometimes infer which of X or Y is upstream of the other, and whether the relationship between them is activating or repressing. However, different pathway structures can result in identical phenotypes upon gene deletion. Thus, it is not always possible to infer the relationship between X and Y.

We propose dynamic epistasis analysis, which extends the classical approach by assuming that we can drive the pathway with a time-varying input signal. Intuitively, the time-varying input may help us discriminate between alternative pathway structures that are otherwise indiscriminable—for instance, because of how quickly the signal propagates to the phenotypic output, or because of transient changes in the output. Moreover, the approach is feasible in practice, because robotic flow cytometry and microfluidics devices make it relatively easy to interrogate cells with time-varying signals such as drug dosages or nutrient concentrations. Here, however, we report on a theoretical investigation of the limits and benefits of dynamic epistasis analysis.

First, we computationally enumerated all possible acyclic network topologies on two genes X and Y, which regulate the state of a third “output” gene Z, and which are themselves influenced by an “input” signal S. (Epistasis analysis is generally restricted to studying feedforward pathways, hence the limitation to acyclic networks. However, we impose no other limitations.) We adopted a discrete-time Boolean model for all variables, S, X, Y, and Z. When there is a regulatory link between a pair of variables, we assumed it can be activating or repressing. When a variable takes input from more than one other variable, we assume it adopts either the AND or the OR of its inputs (or their negations, in the case of repressive links). We found a total of 4608 possible networks that differ either by structure or regulatory functions. We then studied how many of those could be uniquely identified based on classic epistasis analysis, which looks at Z under different knockout conditions and static signal states S=0 or S=1, and dynamic epistasis analysis, which looks at Z under different knockout conditions and arbitrary time-varying S. We found that no network had unique patterns of phenotype Z in the classical approach, whereas 7.3% do under dynamic epistasis. If we allow gene knock-ins, which force X or Y to be on, classical epistasis can still only identify 0.7% of pathways, whereas dynamic epistasis identifies 19.4%. Thus, we conclude that dynamic information is potentially a very powerful addition to epistasis analysis.

Many transcription factors (TFs) initiate transcription only in specific sequence contexts, providing the means for sequence specificity of transcriptional control. A four-letter DNA alphabet only partially describes the possible diversity of nucleobases, a TF might encounter. Cytosine is often present in the modified forms 5-methylcytosine (5mC), 5-hydroxymethylcytosine (5hmC), 5-formylcytosine (5fC), and 5-carboxy-cytosine (5caC). TFs have been shown to distinguish unmodified from modified bases. Modification-sensitive TFs provide a mechanism by which widespread changes in DNA methylation and hydroxymethylation found in many cancers can dramatically shift active gene expression programs.

To understand the effect of modified nucleobases on gene regulation, we developed methods to discover motifs and identify TF binding sites in DNA with covalent modifications. Our models expand the standard A/C/G/T alphabet, adding m (5mC), h (5hmC), f (5fC), and c (5caC). We adapted the well-established position weight matrix (PWM) formulation of TF binding affinity to this expanded alphabet.

We engineered several tools for expanded-alphabet sequence and PWMs. We developed a program, Cytomod, to create the sequence using data from bisulfite sequencing. Cytomod decides between multiple modifications at a single position using a configurable evidence model. We also developed new versions of MEME (Multiple EM for Motif Elicitation) and FIMO (Find Individual Motif Occurrences) that enable de novo discovery of modification-sensitive motifs and identification of modification-sensitive binding sites.

We created an expanded-alphabet genome sequence using mouse embryonic stem cell data, and identified cis-regulatory modules that we believe are active only in the presence of cytosine modifications. We found new binding sites for known methylation-sensitive TFs, such as Klf4 and the c-Jun/c-Fos heterodimer. Using ChIP-seq data on TF binding locations, we discovered novel expanded-alphabet motifs.
with the immune system, p53 pathway, and other pathways involved in cell cycle regulation (Figure 2A). Eleven modules were significantly associated with clinical factors ($P < 0.05$, Figure 2B). We further observed strong predictive power for pathway activation status; the areas under the receiver operating characteristic curves (AUCs) of the strongest predictions of every module ranged from 0.62 ($P = 0.03$) to 0.72 ($P < 1E-6$). In addition, combining radiomic data with clinical factors and genomic information resulted in consistent increases in power to predict overall survival in the validation dataset (concordance index max 0.73, $P < 1E-9$). In conclusion, we show that radiomic approaches permit a non-invasive assessment of molecular and clinical characteristics of tumors, and therefore have the potential to support clinical decision-making and advance therapeutic strategies using routinely acquired, standard-of-care imaging data.
SP122.6 - A machine learning method to build multi-SNP predictive models of clinical radiosensitivity

**Author(s):** Jung Hun Oh¹, Sarah Kerns², Harry Ostrer³, Barry Rosenblatt⁴, Joseph O. Deasy¹

¹Memorial Sloan Kettering Cancer Center, New York/NY/UNITED STATES OF AMERICA, ²University of Rochester Medical Center, Rochester/NY/UNITED STATES OF AMERICA, ³Albert Einstein College of Medicine, New York/NY/UNITED STATES OF AMERICA, ⁴Mount Sinai School of Medicine, New York/NY/UNITED STATES OF AMERICA

**Purpose:** Genome-wide association studies (GWAS) have become a vital method to identify single nucleotide polymorphisms (SNPs) associated with common complex diseases. Many current GWAS analyses have used single-SNP models by individual association test. However, these methods suffer from multiple-testing correction due to a large number of SNPs being evaluated, which may cause some potentially important SNPs to fail to achieve genome-wide significance. Moreover, single-SNP models do not take into account correlations or interactions among significant SNPs.

**Materials/Methods:** To overcome these weaknesses of the single-SNP approaches, we propose a machine learning-based multi-SNP model for predicting radiation-induced late rectal bleeding toxicity in prostate cancer patients. Our method consists of the supervised principal component analysis (SPCA) and least absolute shrinkage and selection operator (LASSO). Using SPCA, many irrelevant SNPs are filtered out and redundant SNPs are further removed via sparse regression models in the LASSO process.

In this radiosensitivity study, 365 prostate cancer patients who received radiotherapy were analyzed. For these patients, germline DNA extracted from lymphocytes was genotyped using the Affymetrix genome wide array (v6.0). To build a predictive model, we coded the status of rectal bleeding as 0 (grade 0 or 1; n=291) or 1 (grade 2+; n=74) using the Radiation Therapy Oncology Group (RTOG) late radiation morbidity scoring schema.

For an unbiased assessment, the dataset was split once and for all into two groups: a training dataset (2/3 of samples) and a validation dataset (1/3 of samples). In the modelling process, only the training dataset was used and the validation dataset was used to validate final predictive models.

**Results:** With the training dataset, univariate analysis was performed using Chi-square test. Based on the p-value, with an increasing number of top ranked SNPs (from 200 to 1000 SNPs), the model building process was conducted. Figure (A) shows the best AUC results obtained using the validation dataset with a different number of SNPs that were fed into the model building process. Figure (B) shows the number of SNPs that entered into the LASSO models after irrelevant and redundant SNPs were removed. When 700 SNPs were input into the model, an AUC of 0.74 was obtained with 573 SNPs that entered into the LASSO models.

**Conclusions:** Our proposed machine learning-based method was used to build a predictive model of late rectal bleeding toxicity for prostate cancer patients. We demonstrated that the proposed method has the potential to improve the prediction power in GWAS.
SP123.1 - Incident reporting and learning systems improving quality and safety in radiation oncology

Author(s): Mary Coffey
Radiation Therapy, Trinity College Dublin, Dublin/IRELAND

The publication of a number of fatal incidents in radiotherapy globally has led to an increased emphasis on openness and transparency and underpins the importance of reporting and learning from minor incidents and near misses in the prevention of further major incidents. Incidents and near incidents are a fact of life and cannot be eliminated completely, what is important is to learn from these and to share that learning with the wider radiotherapy community.

Reporting as part of the cycle of investigation, analysis, feedback and learning is one method of improving the safety of radiotherapy. Reporting can be mandatory or voluntary, internal or external depending on the requirements of the individual country. In the last decades a number of initiatives at country or professional organization level have resulted in the development of comprehensive reporting systems. One of the most recent systems to be put in place, the RO-ILS, was launched at ASTRO in 2014. Canada are currently piloting a national system, the ASN in France, the United Kingdom and The Netherlands have well established national systems and two voluntary international systems are in place: the Radiation Oncology Safety Information System (ROSIS) and the International Atomic Energy System: Safety in Radiation Oncology (SAFRON).

The Radiation Oncology Safety Information System (ROSIS) was established in 2001 and went live online in 2004. The IAEA Safety in Radiation Oncology (SAFRON) went live in December 2012. ROSIS and SAFRON share information with each other and SAFRON is currently developing further links with other national systems. In 2013/14 as part of a project supported by Varian and Elekta the taxonomy of ROSIS was revised to be consistent, as far as possible, with SAFRON, the AAPM system and RO-ILS.

The European Society for Radiotherapy and Oncology has established a Risk Management Committee with reporting and learning in the context of the recent European legislation a key focus.

SP123.2 - Applying an Evidence-based Approach to Managing Alarm Safety: A University Health Network Case Study

Author(s): Anne Li1, Dave Gretzinger2
1Institute Of Biomaterials And Biomedical Engineering, University of Toronto, Toronto/ON/CANADA, 2Department Of Medical Engineering, University Health Network and Mount Sinai Hospital, Toronto/ON/CANADA

Background: High reliance on medical technologies to perform a myriad of tasks, ranging from surveillance to delivery of therapies, in modern medicine has resulted in excessive number of alarms on clinical units. This translates into an increased risk of alarm fatigue amongst caregivers, lowered quality of care and interrupted patient recovery. Technologies (such as alarm communication management systems and smart algorithms) have been developed to address alarm safety, but there are inherent limitations to every technology. It was, therefore, the aim of this case study to develop an evidence-based approach to alarm safety management that can be applied across clinical units.

Methodology: Two intensive care units, a Level 3 (Medical Surgical Neurological Intensive Care Unit (MSNICU)) and a Level 2, at the Toronto Western Hospital were investigated. A recommended alarms management program by the ECRI Institute was modified to include only steps that were applicable to the investigational units and their associated workplace cultures. A multi-disciplinary team consisting of clinical engineers, nursing educators, and allied health professionals assembled bi-weekly to steer the direction of this initiative. Observations in the clinical units, nursing alarm surveys for MSNICU staff and review of incident reports from April 2012 to September 2014 were used to determine the areas of greatest vulnerability and establish priorities. Recurring themes in the textual data were indexed and refined.

Discussion: Thematic analysis revealed that alarm safety concerns center around three themes of related constructs (alarm noise, alarm desensitization and alarm workflow). However, the relative contribution of each theme to alarm concerns varied due to differences in workflow and patient population. A universal management option, therefore, does not exist. The negative impact of continuous noise on patient recovery was unanimous amongst the surveyed nurses. High number of false positive and/or clinically irrelevant alarms resulted in caregiver apathy and desensitization, which caused true monitor events to be neglected. Non-standardized workflows (such as procedure for coverage of breaks and physiological parameter adjustments) also contributed to alarm safety issues.

Conclusions: Observations revealed that institution-wide procedural changes, such as mandatory physiological patient parameter adjustments and implementation of a standardized procedure to temporarily pause alarms when continuous monitoring is not required, may reduce excessive noise and false positive alarms. Frustrations often arose due to incomplete knowledge of the medical technologies. Information sessions and easily accessible answers to frequently asked questions (FAQ) could lessen this aspect of concern. Cultural changes are anticipated to provide a good first step to alarm safety management, however, qualitative data alone is insufficient to drive alarm safety initiatives. Since there is no “one size fits all” solution, future studies will require analysis of alarm data (number per bed, type and duration) to identify high-priority areas per clinical unit. Alarm data collection systems provide a safe process to monitor and evaluate the effectiveness of interventions. Sustainable improvements in alarm safety will require long-term commitment from all levels of institution.

SP123.3 - Using infusion pump logs to recreate a patient safety event: considerations for smart pump improvement

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The authors describe the reconstruction of a unique event involving a nurse’s response to an error with an infusion pump in a critical care environment, and subsequent learning opportunity. The authors propose further considerations for smart pump improvement.

A 75-year-old male patient presented in July 2013 to a major teaching hospital with a massive gastrointestinal bleed and myocardial infarction, and was admitted to the intensive care unit. Although in tenuous health, the patient’s condition stabilized with multiple infusion lines providing life-sustaining medication. At some point during the patient’s care, the pump alarmed a “Communication Error” message. The nurse attempted to clear the alarm but the pump
appeared unresponsive. She disconnected the module to reprogram the pump, causing an interruption in the DOPamine infusion. This caused the patient’s blood pressure to plunge, resulting in a cardiac arrest. The pump was subsequently quarantined and sent to Biomedical Engineering for analysis.

The smart pump was a modular infusion pump with one central PC unit (PCU) and up to four large volume pump modules. Pump logs and the server database were mined and discovered that three PCUs and eight modules were connected to the patient at the time of the error. All equipment was functional and operated within the manufacturer’s specification. The inter-unit interface connecting the PCU and module infusing DOPamine had corrosion and white “fluff” on the contacts, which is believed to be the cause of the “communication error”.

During the investigation, the manufacturer explained that the pump’s fail safe mechanism is to continue to infuse the drug at the prescribed rate during a “communication error” message. The pump gave no explicit instructions to resolve the issue, and resolution was not intuitive. Learning yielded a nursing practice alert to clarify how a nurse should resolve a “communication error”.

The authors believe that infusion pump logs are not designed with any forethought as to how they will be used in an incident investigation. Pump logs are awkward and the data extracted is often heavily coded and not easily interpretable in plain English. Vendor software lacks meaningful tools to easily analyze the data, leaving the investigator to make sense of raw data.

Modern smart pump technology does not operate as a patient focused system. Instead, each PCU operates independently, lacking the ability to allow soft warnings or hard stops for a combination of contraindicated drugs (e.g. additive, potentiation or antagonistic) in the drug library that are infusing on separate channels of a PCU. Similarly, if 2 or more PCUs are connected to the patient, none of the PCUs know what is being infused on the other PCU channels. Pumps should be able to be daisy chained together so that they can communicate and record information as a cohesive system per patient.

Smart pumps have succeeded mitigating bedside medication errors. Secondary uses for incident investigations and multiple pumps to operate as a cohesive system on a patient should be considered for future enhancements.

**Conclusion:** The proposed engine is organized in three basic phases: the phase of preprocessing and parsing, the phase of entity extraction and the phase of ontology population. The phase of preprocessing and parsing is responsible for recognizing and separating the interesting section of the vigilance report related to the medical devices. The phase of entity extraction is the core process of our approach. During this stage, the entities of interest from each vigilance report are extracted. In our case, terms of interest among others include the manufacturer, model, serial number, etc. The phase of ontology population includes the mapping of the previous phase outputs into ontology individuals.

**Results & Conclusion:** For evaluating purposes we fed the NLP engine with 30 reports (in html format) from FDA which were also manually annotated. In order to test our NLP engine we examine two aspects. Firstly, we assess the efficiency of preprocessing and parsing and its capacity to dissociate the areas of the report which are related to product description (PD), code description (CD), reason description (RD) and recalling firm description (RFD). The second examined aspect is the ability to extract the entities Manufacturer, Model, Serial, Product Metric (PM) and Product Amount (PA) from the respective sections.

Based on the results, it is expected that the proposed engine through the design, development and implementation of modern ICT tools, will create a prototype system, which will provide critical, on time and customized information to health care institutions with regard to MD adverse events.

**Acknowledgements:** The presented work was carried out in the framework of the project “EIPAS”, funded under the THALES programme, co-financed by the European Union (European Social Fund-ESF) and Greek national funds through the Ministry of Education, Lifelong Learning and Religious Affairs and the Operational Program “Education and Lifelong Learning” of the National Strategic Reference Framework (NSRF).
Methods: We modified DOSXYZnrc (version V4-2.4.0) to optionally output a 4D IAEA phase space during a source 20 simulation, in order to collect particles exiting the patient during a VMAT treatment. This phase space can be used for further synchronized simulations of EPID dose using the MU index associated with each particle. We have also modified DOSXYZnrc to output a new file in which this time-like variable is binned in a user-defined manner (e.g. consistent with the EPID cine-mode acquisition), and associated with each bin is the amount and location of energy deposited by particles whose MU indices fall within that bin.

Results: Evaluation of the new technique was done with an anthropomorphic phantom for a 2-arc head-and-neck VMAT plan. Comparison of the EPID cine-mode images with the corresponding MC calculated distributions, via the Gamma metric (3%, 3mm), showed greater than 96% agreement (see Figure). Total simulation times were not increased and the time-integrated dose was identical to that from a standard 3ddose file.

Conclusions: Our method allows for comparisons of the 4D MC phase space EPID prediction with the actual EPID data acquired with the patient on treatment. This technique also allows for creation of a dose rate map within a phantom or patient. We demonstrated the feasibility of including transit EPID cine-mode MC simulations as part of a comprehensive patient-specific VMAT quality assurance process.

Figure. EPID dose images (a, d) compared with MC distributions (b, e), using 3%/3mm Gamma metric (c, f). Upper row corresponds to a segment of one arc; bottom row corresponds to full treatment (2 arcs).
SP123.6 - Development of an interactive training tool to help reduce error rate associated with shared infusion volume management tasks

Authors: Kyle Tsang¹, Patricia Trbovich², Sonia Pinkney³
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Background Medication administration errors in a hospital pose a serious threat to patients. Several types of medical technologies (e.g. smart pumps, alarms) have been introduced into the hospital environment, yet despite their numerous benefits, preventable medication administration errors still exist. Analysis reveals that inadequate training is a primary reason for these preventable errors. In the context of intravenous (IV) infusion systems, a clinician’s training is mainly associated with the specifics of “how” to use certain equipment, but a fundamental understanding regarding IV infusion principles (e.g. hydrostatic pressure) is often missing. In particular, the concept of shared infusion volume, which refers to the common volume shared by 2 or more infusions in the IV tubing between the patient’s vein and the point of medication delivery, is often incorrectly accounted for, which can result in unpredictable and hard to detect medication errors (e.g. delays in therapy, medication incompatibilities). Nurses often do not understand nor consider the presence of shared infusion volume in their practice and there are currently no explicit training methods to address this issue. This research aims to design and test an interactive training tool (ITT), in the form of a computer based e-learning module, to help improve a clinician’s ability to deal with shared infusion volume management.

Objective The purpose of this research is to understand the different mental processes (e.g. decision making) associated with shared infusion volume using a cognitive task analysis method. Once a critical decision model is formed, the knowledge gained will be applied to the refinement of an ITT. This ITT will help train nurses to better understand multiple IV infusions by supporting the cognitive processes required and removing identified barriers associated with shared infusion volume.

Design A cognitive task analysis method consisting of semi-structured interviews with experienced clinicians will help determine the cognitive processes (e.g. specific critical cues) required to successfully manage the problem of shared infusion volume. Based on the processes discovered, an ITT will be refined, which will focus on improving the performance of IV infusion tasks. An experimental study using nurse participants from intensive care units will then be conducted. The number of errors in the high-fidelity simulated clinical care environment will help assess the effectiveness of the newly developed ITT compared to a baseline condition of no training.

Conclusions It is expected that the use of an ITT can help reduce the error rate related to medication administration when dealing with multiple IV infusions. When designing an ITT for a complex task (e.g. shared infusion volume management), it is important to perform a suitable cognitive task analysis method to better understand the mental processes associated with the procedure. It is expected that a well-designed ITT that encompasses a proper knowledge framework can better train critical care nurses to effectively tackle complex medication administration tasks by making the invisible features of shared infusion volume visible. Improving patient safety by reducing the number of preventable human-related errors through ITTs may potentially reduce the number of preventable adverse events related to IV infusions.

SP124 - Medical Physics in Developing Countries

SP124.1 - Medical Physics Training Resources for Developing Countries

Authors: Muthana Al-Ghazi
Radiation Oncology, University of California, Irvine, Orange/UNITED STATES OF AMERICA

Purpose: To outline resources available to developing countries for the training of medical physicists

Background: Cancer incidence in developing countries is rising with dearth of resources to combat it. In recent years, there has been a concerted effort on the part of national and international organizations (e.g. IAEA) to provide a framework and resources including complex radiotherapy technologies to address the problem. An important component of this effort is provision of trained personnel. Medical physicists play a leading role in the safe implementation of modern radiation treatment planning and delivery technologies and establishment of cancer care programs.

Methods: The advent of the World Wide Web, internet and social media make possible the use of these media to devise training resources aimed at developing educational and training programs for medical physicists in developing countries with little or no cost. The information is already available. What is required is guidance to colleagues in developing countries to harness these resources in a structured manner. The resources include, by way of example:

- American Association of Physicists in Medicine (AAPM) resources such as task group reports, medical physics graduate and residency program structures, standards of practice, international educational portal and partner-in-physics (PIP) membership category
- International atomic Energy Agency (IAEA) web-based resources
- These do not require special access requirements and are globally available. There are many others based on UK, Canada, European medical physics organizations.

A key component is guidance by an experienced physicist based in a developed country who is specifically interested in education and development of the profession in developing countries to establish contact with a counterpart(s) in developing countries and work with them to tailor the available resources to their specific needs. This will generate interest in the country(ies) concerned and initiate awareness amongst authorities once the advantages of the effort are realized. This communication will develop and lead to the establishment of national medical organizations in developing countries which can then become IOMP members and access the full advantages of IOMP membership.

Results: Based on the author’s experience, the approach described above led to the promotion and establishment of several national medical physics organizations in developing countries. All started from a single encounter.

Summary: Modern communication methods based on the availability of the internet can assist in promoting the field of medical physics and the training of medical physicists in developing countries who will contribute to the safe implementation of radiation treatment planning and delivery. This contributes positively to the global effort of combating cancer.
SP124.2 - Medical Physics in Indonesia: Current Status and Plans
Author(s): Djawani Soeharso Soejoeko, Supriyanto Arjio Pawiro, Lukmanda Evan Lubis
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Since the nation-wide introduction of medical physics profession in 1980s, Indonesia continuously seeks a way to improve physics services in clinical environments in response to the rapidly-enhancing devices coming into use. It begun with efforts to primarily enhance educational aspect, to be followed by the work of making equipment and legal instruments available. Major hold-back is caused by inadequate number of master-degree holders in medical physics due to limited number of universities offering relevant degrees. Physics Department, Faculty of Mathematics and Natural Sciences, University of Indonesia has started to contribute on Medical Physics enhancement since 1996. Since then, nation-wide developments and changes has taken place involving our department, with more efforts to approach international standard still in place. This paper serves to share Indonesia’s Medical Physics status and plans of enhancements.

SP124.3 - Surveying Trends in Radiation Oncology Medical Physics in the Asia Pacific Region
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Aim
Medical Physicists are important contributors to patient care in radiation oncology. However, their work is often less visible than that of clinicians or allied health staff which could affect their status as members of the health care team. It is the objective of our study to assess and track the work load, working conditions and professional recognition of radiation oncology medical physicists (ROMPs) in the Asia Pacific Region over time.

Methods
Since 2008 we have been conducting surveys on profession and practice of ROMPs in the Asia Pacific Region. A structured questionnaire was mailed in 2008, 2011 and 2014 to approximately 20 senior medical physicists representing 23 countries. The questionnaire covers 7 themes: 1. Education and training, 2. Staffing, 3. Typical tasks, 4. Professional organisations, 5. Resources, 6. Research and teaching, and 7. Job satisfaction.

Results
Across all three surveys the response rate was >90% with the replies representing practice affecting more than half of the world’s population. The expectation of ROMP qualifications has not changed much over the years and typically requires a master degree and between 1 and 3 years of clinical experience. This is in line with the policy documents of IOMP; however, formal professional certification is only available in a small number of countries. Compared to 2008, the number of medical physicists in many countries has doubled. However, the number of experienced ROMPs compared to the overall workforce is still small in particular in low and middle income countries. The increase in staff is matched by a similar increase in the number of treatment units over the years. Furthermore, the number of countries using complex techniques (IMRT, IGRT) or installing high end equipment (tomotherapy, robotic linear accelerators) is increasing.

A trend towards increasing quality assurance activities over treatment planning can be observed and most ROMPs are required to work overtime, usually not fully remunerated. The number of ROMPs who find time for research is still small and typically only 10% or less of the workforce have academic appointments, even if more are required to teach other professions. Resource availability has only improved marginally; however, better opportunities exist now than 6 years ago as nearly all medical physicists have access to the internet. Overall, ROMPs still feel generally overworked and the professional recognition, while varying widely, appears to be improving slightly.

Conclusion
Radiation Oncology Medical Physics practice has not changed significantly over the last 6 years in the Asia Pacific Region. However, both the number of physicists and the number and complexity of treatment techniques and technologies have increased dramatically. It is important to increase our effort now to improve the quality of the workforce and its professional recognition.

Acknowledgement: We would like to acknowledge the support of our colleagues in the Asia Pacific Region.

SP124.4 - The Status of Medical Physics in Iraq
Author(s): Muthana Al-Ghazi
Radiation Oncology, University of California, Irvine, Orange/UNITED STATES OF AMERICA

Purpose: To provide an overview of the status of medical physics in Iraq

Background: Iraq is a Middle Eastern country with a population of approximately 30 million. It has a history of excellent educational and healthcare systems in the Middle East. In the past three decades these suffered greatly due to wars, sanctions and civil strife. Despite these challenges, steps are being taken to advance the field of medical physics concurrent with developments in cancer care and attention that is being directed towards establishment of modern radiotherapy facilities where medical physicists play a critical role.

Medical Physics Practice: Most medical physicists are graduates of main stream academic physics programs and receive on the job training upon employment. There is one university that offers graduate medical physics studies at M.Sc./Ph.D. levels. Courses in radiation dosimetry, medical imaging, anatomy and physiology, radiobiology and radiation safety are included in the curriculum. This program has been re-structured recently to follow modern recommendations (e.g. AAPM report #197). This development is a result of improved communication between educators in Iraq and their counterparts in the West.

Professional Activities and Organization: The Iraqi Medical Physics Society (IMPS) was established in 2010. It has the usual structure (constitution and officers). It is a member organization of IOMP through the Middle East Federation of Organizations of Medical Physics (MEFOMP), the latter being the regional chapter of IOMP. IMPS has 40 members.

The majority of IMPS members are employed in cancer hospitals. There are three such hospitals in the capital and one each in 6 of the major provinces. The physicists’ main responsibilities are in radiotherapy physics. Some collaborate with biomedical engineers in diagnostic imaging departments. There is a national radiation protection agency that monitors radiation safety in the country. The major cancer hospital in Baghdad has 70 oncology beds and serves as the Oncology teaching hospital for the University of Baghdad. This hospital takes advantage of the radiotherapy quality assurance program offered by the IAEA through the latter’s TLD service for monitoring linear accelerators’ output.
Discussion: There are 11 megavoltage units, 9 treatment planning systems, 9 CT-simulators and one Gamma knife, with another 10 linear accelerators planned, along with associated imaging and treatment planning systems. In the past 7 years, radiotherapy practice has advanced to include 3DCRT. One center has started using IMRT, with others expecting to follow. While these are encouraging developments, recent surveys indicate that only one third of the population has access to cancer care. This is because of shortage of centers within reach of majority of the population and travel challenges in a war zone.

Cancer incidence in the country is higher than that in developed countries and most patients present with advanced disease making their outcome poorer than their counterparts in the developed world.

Summary: Medical physics in Iraq is developing in the right direction by establishing a medical physics society, modernizing educational programs and acquiring new technologies to establish imaging and cancer treatment programs befitting modern clinical practices. Detailed numerical data will be presented.

SP124.5 - Evaluation and Adaptation of Medical Physics Practicum for Nicaraguan Students at a Canadian Cancer Centre
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1Medical Physics, Tom Baker Cancer Centre, Calgary/ CANADA, 2Physics And Astronomy, University of Calgary, Calgary/ AB/ CANADA, 3Oncology, Tom Baker Cancer Centre, Calgary/ AB/ CANADA

On-the-job training is paramount to success in any career and must be particularly rigorous in medical professions. Unfortunately, practicum or residency-type clinical opportunities for medical physicists from low-income countries are in short supply, often requiring new graduates to transition to clinical work without the necessary knowledge, exposure, and experience. Inadequate training programs can lead to sub-optimal and even unsafe treatment conditions. This is especially true in cases where countries are preparing to transition to more modern radiation therapy technologies, and local knowledge from more senior medical physicists is limited. In order to help bridge this gap in practical training, our cancer centre in Canada hosted two medical physics students from Nicaragua in a three-month practicum towards the end of their studies. The practicum had students rotate through clinical and QA areas including simulation, treatment planning, treatment delivery, HDR brachytherapy, radiation safety, and nuclear medicine. The primary goal of this practicum was to provide fundamental medical physics knowledge and hands-on experience for treatment techniques currently used in Nicaragua (simulator, Cobalt RT, simple treatment planning and delivery). The other major goal was to provide exposure to linac-based treatments in preparation for the purchase of a new linac in the Nicaraguan clinic in the upcoming years.

Benchmarking [Brown et al., 2014, IAEA, 2007] has been previously highlighted as a top priority for implementing new technologies in low-income countries. A similar concept was applied to this practicum. Upon arrival, the students were asked to give presentations on their educational background, and their expectations for the practicum, and details about cancer treatment in Nicaragua. A short written survey was also implemented to assess these factors and their basic medical physics knowledge. These written and oral evaluations allowed us to evaluate both the level of education and previous training, and English language proficiency. The evaluations were crucial in personalizing the training to meet their specific needs. Benchmarking surveys/quizzes were given before each rotation. Based on the student responses, appropriate learning objectives were then set. Students were re-evaluated again after each rotation to determine if the learning objectives were met. Any shortcomings were noted and added to the schedule. At the end of each rotation, the students were given feedback evaluations in order to address both individual concerns and interests that could be added to the final month of the schedule. Ideally, the practicum would get a final evaluation in one year once the students have spent time practicing medical physics in Nicaragua.

We are using this practicum hosting experience as a guide to determine ‘what works best’ and the feasibility of hosting more students in the future at our centre, and at other Canadian centres.

In addition to evaluating the practicum on a functional level, we also looked at it from a staffing and resource level by tracking the amount of dedicated time spent with the Nicaraguan students by medical physicists and clinical staff. In this way we can provide detailed information to other institutions interested in supporting this type of program.

SP124.6 - Coordination of AAPM Educational Courses for Developing Countries with Major International and Regional Organizations of Medical Physicists
Author(s): Eugene P. Lief
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American Association of Physicists in Medicine (AAPM) has had an active program of arranging two educational courses a year in developing countries since 1992. Typically, AAPM reimburses travel expenses for five AAPM members who volunteer their time for teaching practical topics in diagnostic and therapy medical physics for physicists from developing countries.

As a result of joint meetings of AAPM, IOMP, and EFOMP officials in 2013, these educational courses are now organized in close collaboration with International Organization for Medical Physics (IOMP), International Atomic Energy Agency (IAEA), and regional Medical Physics organizations, such as EFOMP, ALFIM, and others. While choosing a place, time, and topic of such an education event, it is extremely important to avoid duplication of efforts by excluding regions that recently had a benefit of a similar educational course conducted by IAEA, IOMP, EFOMP, ESTRO, ALFIM, or some other international or regional organization.

A recent example was a course in Radiation Therapy organized in Estonia last year. The course was developed in the framework of AAPM International Scientific Exchange Programs Committee (ISEP) and IOMP on 16-20th of June 2014 in the capital of Estonia-Tallinn. The course was endorsed by EFOMP and IAEA. These agencies also provided financial assistance and sponsored some participants and speakers bringing the total number of lecturers to 10.

The meeting was attended by 62 clinical physicists and 10 company representatives. Third of participants were from the Baltic States (Estonia, Latvia, Lithuania), another third from the former Commonwealth of Independent States countries (Russia, Ukraine, Belarus, Azerbaijan, Kazakhstan), and the remaining third from other Eastern European countries (Poland, Romania, Serbia, Montenegro, Croatia, Czech Republic, Slovenia, Bulgaria, etc.). Altogether, the participants represented 25 countries. By all measures, the course was a success and was highly evaluated by the attendees.

Conclusion: To be really efficient, future educational efforts in developing countries should be organized in close coordination and collaboration with the major international and regional organizations.
SP125 - Technology Enhanced Education

SP125.1 - e-Learning in Medical Physics – pioneering and future trends

Author(s): Slavik Tabakov
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Medical Physics was one of the first professions in the world to develop its own original e-learning materials. The projects EMERALD and EMINTE (1994-2004) developed extensive e-learning materials – training tasks, image databases (including 4000+ images), simulations, and one of the first e-learning web sites (www.emerald2.eu). Further, the project EMITEL (2005-2013) developed the first e-Encyclopaedia of Medical Physics (3100+ articles) with Multilingual Dictionary of terms (translated in 29 languages) – both major reference materials for the profession (www.emitele2.eu). These materials are used by thousands of colleagues all over the world. The success and impact of Medical Physics e-learning through these projects was recognised with the first educational award of the European Union – the Leonardo da Vinci Award.

The projects, initially including specialists from UK, Sweden, Italy, Portugal, Ireland, France, Czech Republic and Bulgaria, expanded rapidly through EFOMP and IOMP to include more than 320 senior colleagues from 36 countries. The unique experience of the profession led to further expansion through other e-Learning projects and web sites delivering quick educational and professional information to the whole medical physics community.

This development was extremely useful for a dynamic profession like medical physics, characterised by constant development of new methods/equipment and their implementation in medicine. Our experience and surveys showed strong involvement in e-learning development of all different sub-fields of the profession. At the same time we noticed an increased ratio of the time of development to the time of use of e-learning simulations, (mainly due to change of software versions). The web sites above (emerald2 and emitele2) were specifically coded for the purpose, what assures their long uninterrupted life. Their platforms are now available to be used for additional e-learning materials and IOMP is now forming Task Groups to update and expand the existing ones.

In parallel with the above development, we are witnessing expansion of Virtual Learning Environment (VLE) platforms in all Universities – a cost-effective way to supply students with lecture notes and Power Point handouts, as well as handling assessments. These platforms (especially useful for distance education) could further deliver specific “taylor-made” e-learning content, what will increase the effectiveness of the learning process.

In our opinion medical physics, one of the first professions to pioneer e-learning, should concentrate on rapid development of specific e-learning materials, synchronised with the introduction of new methods and equipment. IOMP and its large Regional Organisations include highly experienced specialists, who have all capacity to do this. Such development will significantly increase the speed of delivery of new information to the users. The new IOMP Journal Medical Physics International could facilitate this dissemination. The development of e-learning and its current trends will be described in the presentation (available also in an e-book to be launched at the Congress).

SP125.2 - A Desk-Top Optical Scanner for Teaching the Principles of Computed Tomography (CT)

Author(s): Jerry J. Battista1, Linada Kaci2, Kurtis H. Dekker1, Arvand Barghi1, Colin Versnick2, Michael Peng3, John Miller4, Jennifer Dietrich1, Kevin J. Jordan2
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Medical imaging is widely used for diagnostic and treatment guidance purposes. Students are often faced with difficulties in understanding the concepts of computed tomography (CT) image reconstruction because of the lack of practical demonstrations while learning these concepts. DeskCAT™ is an optical CT system (http://www.deskcat.com/) that has been introduced at 40 universities as a very effective tool for teaching the principles of CT. It is a safe device for classroom or lab demos since it uses visible light instead of x-rays, allowing interactive real-time teaching.

The system offers a dozen lab exercises that introduce different concepts such as: exploring 3D medical imaging by localizing fiducial markers, measuring linearity by scanning materials with known optical attenuation coefficients, assessing spatial resolution by plotting the contrast profiles of line pairs in a phantom, exploring Fourier methods to calculate the Modulation Transfer Function (MTF) and learning the importance of contrast-to-noise ratio in the context of low-dose imaging. More advanced labs also explore artifacts caused by incorrect, incomplete, or inconsistent projections and cone-beam scattering effects, emission CT (SPECT) with attenuation corrections, and Dual Energy CT to discriminate structures according to their absorption at different imaging energies. Artifacts occurring due to organ motion or beam hardening are also observed. Iterative reconstruction is tested as a means of dose and artifact reduction. This presentation will highlight the learning objectives of several of these labs and show sample images and plotted results obtained by DeskCAT™ students.

SP125.3 - Medical Physics e-Encyclopaedia and Multilingual Dictionary – Upgrade and New Developments

Author(s): Slavik Tabakov1, Perry Sprawls2, Franco Milano3, Sven-Erik Strand4, Cornelius Lewis5, Magdalena Stoeva6, Asen Cvetkov6, Vassilka Tabakova1, John Damilakis7
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This is a first attempt to present the Medical Physics community an open online platform for upgrading and improvement of the existing Multilingual Dictionary of Medical Physics (MDP) and the Dictionary of terms (MDT), and to introduce some useful new additions to the existing Materials. The MDP and MDT are used by thousands of colleagues all over the world. The success and impact of the project was recognised with the first educational award of the European Union – the Leonardo da Vinci Award.

The system offers a dozen lab exercises that introduce different concepts such as: exploring 3D medical imaging by localizing fiducial markers, measuring linearity by scanning materials with known optical attenuation coefficients, assessing spatial resolution by plotting the contrast profiles of line pairs in a phantom, exploring Fourier methods to calculate the Modulation Transfer Function (MTF) and learning the importance of contrast-to-noise ratio in the context of low-dose imaging. More advanced labs also explore artifacts caused by incorrect, incomplete, or inconsistent projections and cone-beam scattering effects, emission CT (SPECT) with attenuation corrections, and Dual Energy CT to discriminate structures according to their absorption at different imaging energies. Artifacts occurring due to organ motion or beam hardening are also observed. Iterative reconstruction is tested as a means of dose and artifact reduction. This presentation will highlight the learning objectives of several of these labs and show sample images and plotted results obtained by DeskCAT™ students.
Since its launch at the World Congress in Munich (2009) the EMITEL on-line Encyclopaedia of Medical Physics and Multilingual Dictionary of terms established itself as a very useful reference source for the profession. About 5.3 million searches have been made for its 5 years of existence with approximately of 800 unique users per week. Two more languages were added during this period, thus making the Dictionary with 29 languages in total. The image below shows the number of unique EMITEL users per week for the last 5 years.

EMITEL (www.emitel2.eu) includes about 3100 articles with over 2000 illustrations (with volume about 2100 pages). All these were developed by 7 teams working in parallel (Diagnostic Radiology; Magnetic Resonance; Nuclear Medicine; Radiation Protection; Radiotherapy; Ultrasound; General terms). The overall number of colleagues working on the Encyclopaedia included more than 120 senior specialists, while the 29 groups of translators included another 200+ colleagues. During 2013 it was published on paper by CRC Press. On the next year the EMITEL was prepared to go under IOMP – the largest international medical physics organisation, who will care for its future updates.

A Group was formed under the IOMP Education and Training Committee to deal with the first upgrade including Gerard Boyle, Paola Bregant, Asen Cvetkov, John Damilakis, Mario De Denaro, Charles Deehan, Antonio De Stefano, Peter Dunscombe, Geoffrey Ibbott, Lefteris Livieratos, Renata Longo, Renato Padovani, Magdalena Sto-eva, Vassiliki Tabakova, Sameer Tipins, Slavik Tabakov.

The first task of the group will be to expand the Thesaurus with new terms (methods, equipment, etc). After this, in parallel with the development of the encyclopaedic entries, the Dictionary will be updated. In fact the Dictionary updates were already initiated. The upgrading process uses the existing EMITEL guides, thus providing all new additions similar to the existing materials. Before upload all new materials will be reviewed by members of the EMITEL Editorial Team (S.Tabakov, P.Sprawls, M.Lewis, A.Simmons, S.Keevil, F.Stahlberg, S-E.Strand, B-A.Jonson, M.Peterson, C.Lewis, P.Smith, J.Thurston, F.Milano, I-L.Lamm, C.Deehan, J.Chick, D.Goss, T.Janson, G.Taylor, W.Hendee). The Upgrade Group will continue to expand aiming to have the first updates ready by the WC2015.
SP125.4 - Physics for Medical Students: Technology Enhanced Teaching from the Dipole to the Vectorcardiogram
Author(s): Robert Arnold, Ernst Heller
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Teaching Biophysics of the electrocardiogram (ECG) to first-year medical students is challenging. In research, the origin of cardiac field potentials has been explored in detail with computer simulation programs. Such programs allow ECGs to be computed at any given site of the body with almost arbitrary resolution and complexity. However, in the first year, medical students cannot take advantage of such detailed knowledge as they lack the necessary background in physics, physiology and cardiology. Therefore, the goal of our first semester course is to establish the relevant fundamental laws of physics, apply them in simple qualitative and semi-quantitative models, and explain the origin of the ECG and vectorcardiogram (VCG).

Our course follows a sequence of teaching steps and themes, leading from the electrical dipole to the VCG. Starting with Coulomb’s law, we consider the electric field and potential caused by electric dipoles. We then demonstrate the projection of a dipole vector on to given axes and its reconstruction by back-projection. We introduce the principle of superposition, and use it to explain how a depolarization wavefront generates a dipole-like field, which is represented as the instantaneous heart vector. Students are shown how the spread of excitation can be represented as a sequence of heart vectors describing a vector loop. The relationship of ECG and VCG is demonstrated by an animation of projection and back-projection of the vector loop on standard limb leads I, II and III. Finally, students record their own ECG and VCG and perform exercises demonstrating the role of signal filtering, noise detection and measurement of ECG intervals.

Students are provided with a set of template slides, which are completed during the lecture by the teacher using an interactive pen display in overlay mode. Students can finish their notes on their own tablet or on printed handouts. Animations and interactive simulation tools (Java, Physlets, Flash), both developed in-house and acquired from free and commercial sources, are embedded in the course material. These interactive resources provide the simplest possible models of the physical effects relevant to understanding the VCG.

For practical experiments we developed a 2D-conductor apparatus with a rotatable dipole, whose angle is set by the teacher but remains hidden to the students. Field potential measurements are performed around the hidden dipole using polar, Cartesian and cardiac lead axes. This allows the students to identify the angle of the hidden dipole vector and to verify the law of projection.

Commercially available ECG recorders are closed systems. We therefore developed hardware and software for an open system ECG-VCG recorder, where two arbitrary lead signals can be recorded simultaneously using a standard laptop computer. Students can introduce power-interference noise, experiment with different lead systems, analyze the power spectrum of the ECG, test the impact of various digital filters on noise and on the waveform, and display the vector loop of the subject. With these diverse teaching technologies and methods, we constructed a robust framework for teaching the origin of VCG from simple physical laws.

SP125.5 - matRad: a multimodality open source treatment planning toolkit
Author(s): Eduardo A. Cisternas1, Andrea Mariani2, Peter Ziegenhein3, Oliver Jäkel4, Mark Bangert1
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We present matRad, an open source software for three-dimensional radiation treatment planning supporting intensity-modulated photon, proton, and carbon ion therapy. matRad is entirely written in MATLAB; it is developed for educational and research purposes. The code features high modularity and consequently flexibility. At the same time, matRad allows for an efficient workflow considering realistic patient cases. It comprises descriptive visualizations of the underlying physical aspects. Besides the source code itself, matRad also includes example patient data and appropriate base data for photon, proton, and carbon ion irradiation.

Starting from a segmented patient CT, the toolkit features a set of individual functions modeling the entire treatment planning workflow based on well-established algorithms. The main modules are:

**Dose calculation:** For photons, matRad uses a singular value decomposed pencil beam algorithm. For particles, matRad uses a pencil beam algorithm facilitating a single Gaussian to approximate the lateral dose profile. Base data for the dose calculation algorithms is obtained during measurements at the German Cancer Research Center (photons), analytical computation (protons), and Monte Carlo simulations (carbon ions).

**Ray tracing:** All modalities facilitate an exact three-dimensional ray tracing algorithm for the computation of radiological distances.

**Fluence optimization:** Fluence optimization is performed with pre-computed dose influence data through the minimization of a piece-wise quadratic objective function.

**Sequencing:** For photon IMRT, matRad includes a multileaf collimator sequencing algorithm to translate the continuously optimized fluence weights into deliverable segments.

**Visualization:** The result of matRad’s treatment planning workflow can be visualized via dose volume histograms and two-dimensional dose distributions.

Using a voxel resolution of $3 \times 3 \times 2.5 \, \text{mm}^3$ and a bixel resolution (spot size) of $5 \times 5 \, \text{mm}^2$, we achieve computation times of 60-100s (60-400s) for realistic patient cases including photon (particle) dose calculation and fluence optimization. Memory consumption ranges between 0.2GB and 2.2GB. Figure 1 shows an example photon dose distribution from our benchmarking experiments using AAPM’s TG119 phantom.
SP125.7 - Develop of a Mixed, Haptic and Virtual System to Simulate Radiographic Images

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It has been conceived, designed and built a system, simula-tor of conventional equipment x-ray made to work on technique called two-points ie selecting values of kVp and mAs, with the aim of teaching professionals who must make radiographic pictures of patient, such as Medical Technologist, Biomedical Engineers and others to obtain correct images without the need for an actual equipment emitting X-ray, the system consists of similar technical devices to real in terms Hardware and software, suitable for generating images of different quality depending on the parameters selected and the student learns without generating radiation or spend consumables, advantages that allow manufacture and market a highly innovative system, safe and friendly with environmental.

Figure 1: Transversal dose distribution of a photon treatment plan applying nine equi-distant coplanar fields on AAPM’s TG119 phantom.

matRad is the first open source toolkit supporting treatment planning for intensity-modulated photon, proton, and carbon ion therapy. Both the computational and dosimetric results encourage a future use of matRad in an educational and scientific setting. A first beta release of matRad is available at http://e0404.github.io/matRad/

This work has been supported by the DFG coordinated research program SFB/Transregio 125 Cognition-Guided Surgery.

SP125.6 - Creation of a model for online education of clinical engineering and management of medical technologies to reach professionals worldwide.

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The Institute of Clinical and Biomedical Engineering, SC (ICYB), was created at the end of 2012, to meet the needs of training and updating professionals involved with the performance of: assessment, installation, maintenance, and replacement of medical devices; processes better known as clinical engineering and management of health technologies.

Due to the need of Mexico and Latin American countries to train professionals in order to perform management in benefit of better decision making regarding health technologies, a survey was developed and launched to identify the real need as well as an effective online education model. The survey conducted to the development of an e-learning model that permits the interaction of both experts and professional students from different regions of the world. After almost 3 years of the beginning of the institute, most of our expert teachers are heads of departments in hospitals at Mexico, Canada and Colombia.

Up to date, we have trained 126 chief engineers of biomedical engineering departments. The method of education we use has reported good results and can be taken as a model for developing similar projects in other developing countries.
The discordant alternans formed in the cable of ischemic heart tissue. In fact, there is a range of \([K^+]_o\) in which discordant alternans are initiated, depending on the cable length. The larger the cable length, the window to initiate the discordant alternans is wider. These cases are presented in a bifurcation diagram.

The discordant alternans formed in the cable of ischemic heart tissue present one or multiply nodes, and in some cases block in the conduction was observed.
We introduce a new sophisticated model of the cardiopulmonary system. The model consists of the heart, circulation and respiration systems with emphasis on the cardiopulmonary interaction. Heart and lungs are anatomically and physically coupled through the intra-thoracic pressure since they are both located in the same chest cavity. A novel extended lung model with emphasis on the pleural dynamics was developed. Interactions with the cardiovascular system were modeled using the pleural pressure. This model was implemented in MATLAB Simscape using electrical equivalent circuits. Simulation results for spontaneous breathing show a high agreement with physiological knowledge. Hence, the model could be used to explain many observed phenomena in the physiology.

The genesis and progression of heart diseases are primarily originated from hemodynamic disorders. Among the important hemodynamic parameters to estimate is the blood volume flow rate in coronary arteries. Knowing how the volumetric flow rate is related to geometric and physiologic parameters is challenging. The end product of this paper is a Seven Input Model (SIM) developed to characterize blood volume flow rate in human coronary arteries which can be translated into clinical applications. Several mathematical relations were established relating all primary hemodynamic (pressure and velocity), geometric, and boundary parameters to the volume flow rate. An equation for predicting blood volumetric flow rate was first developed for arterial segments of uniform cross section by solving the set of continuity and momentum equations in cylindrical coordinates. The governing equations were coupled with a total pressure formulation at the inlet and a dynamic pressure-flow lumped model at the outlet to capture in-vivo coronary hemodynamics. The model was then generalized for an artery of variable cross section area and for arteries with low to medium stenosis severities. Two different algorithms were also developed to solve the set of developed equations; (1) a numerical algorithm following Gauss–Seidel method with successive iterative forward and backward substitution; and (2) an alternative analytical approach where an equation of blood volume flow rate was obtained and related to all model parameters, including geometry, inlet and outlet boundary parameters, blood density and viscosity, and normal shear stress at inlet. In the analytical approach, the blood flow rate is directly computed from a single developed model (SIM); local pressure and velocity distributions are then directly obtained. The performance of the developed models and algorithms were tested on (i) an artery with uniform cross section; (ii) an artery of variable cross section; and (iii) an artery with low severity symmetrical stenosis. Predictions were then compared with a full CFD 3D model for validation purposes. An excellent agreement was achieved.

This article shows the estimation of Bergman’s Minimal Model parameters for glucose-insulin interaction in three stages: evolution of the concentration of insulin, evolution of glucose and glucose/insulin interaction itself. First, the dynamics of glucose measured in healthy mice treated with extracts of *Iberovilnia sonorae* root in a range of 100–400 mg/kg; likewise, for mice previously induced with diabetes mellitus type 2 values are determined. The different parameter values obtained are compared showing how they influence the dynamics of Bergman’s Model. The values of the glucose/insulin interaction where obtained in vivo by blood samples of the mice every hour. The evolution and variability of the estimate are shown in graphical form; also the estimation error is quantified by performance curves, which were associated to the energy that is implied in the difference between the values of the parameters obtained and the data obtained in the kinematics of the mice. The results indicate the estimated level reached, where the upper value of the performance curve was 3.0128, while the lower was 0.1978, with standard error values between 1.55% and 10.47%.

Atherosclerosis in the carotid artery is one of the main risk factors for stroke. Arterial compliance, a measure of the elasticity of blood vessels, is a common indicator of vascular disease and is known to decrease in association with other stroke risk factors, including age, diabetes, and hypertension. Decreased local compliance leads to changes in the flow and pressure waves and corresponding changes in the velocity field. Resulting hemodynamic parameters, such as shear stress and turbulence, play a primary role in the process of plaque and clot formation. While it is difficult to accurately extract complex in vivo blood flow structures using clinical techniques, in vitro experimental models can be used to mimic physiological flow systems. Particle image velocimetry (PIV) is an established optical technique for measuring velocity fields with high temporal and spatial resolution that can be applied to study specific aspects of the flow system when used in controlled test models. The aim of this work was to analyze the effect of compliance on carotid artery flow patterns and turbulence intensity experimentally within carotid artery phantoms using PIV. This was accomplished using a custom in vitro flow facility. Two types of polydimethylsiloxane (PDMS) phantoms were used to study compliance, a thin-walled vessel or rigid block phantom model, with identical vessel geometry, 50% eccentric stenosis of the internal carotid artery. Phantoms were perfused using a computer controlled pump to generate a physiologically realistic pulsatile flow rate waveform. A custom blood-mimicking fluid with matching refractive index serves to minimize distortion and model the dynamic viscosity and density of human blood. Downstream flow resistors create a physiological 60:30 flow division at the bifurcation. PIV data were collected using a commercial stereoscopic PIV system (LaVision Inc). Turbulence intensity (TI) was calculated from central plane velocity maps as a metric for quantifying flow disturbances. Slightly higher overall velocity magnitude was observed in a more rigid phantom model compared to the geometrically-matched compliant version, with maximum jet internal carotid artery velocities reaching 1.98 m/s compared with 1.90 m/s.
A stiffer vessel wall resulted in increased maximum average turbulence intensities, 0.41±0.02 m/s in compliant models and 0.48±0.03 m/s in rigid phantom models. The rigid vessel region of maximum turbulence also occurred more proximal to the bifurcation apex (i.e. more upstream). Mean TI over a downstream region of interest at the location of maximum TI was seen to drop off slower with cardiac cycle phase in rigid models suggesting a higher cumulative exposure to disturbed flow over time due to reduced compliance.

### SP127 - Informatics In Health Care And Public Health / Biosensor, Nanotechnology, Biomems And Biophotonics

#### PRESIDENTS CALL

**SP127.1 - A study on the leading cause of immunisation schedule fall up defaulting and early child hood malnutrition sicknesses in developing countries (Uganda in particular) rural areas/villages**

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Uganda is one of the countries that make up east Africa. It’s one of the developing countries in the world, one of the countries on this globe that has been affected by immunizable diseases and child hood malnutrition every year. A study to assess the causes of the rampant immunization schedule fall up defaulting by mothers and early child hood malnutrition in developing countries rural areas was conducted in ten districts of Uganda, (Kampala, Jinja, Wakiso, Kaliro, Iganga, Mayuge, Bugiri, Namutumba, Namayingo, and Kamuli districts) for a period of 12 months. The target population were all babies aged one year who had completed polio, DPT1, DPT2, DPT3 AND Measles vaccinations by one year. A total of 1000 babies were collectively seen. While immunization services were easily available at every health centre from health centre’s one to hospital settings and free of charge, a total of 902 (90.2%) babies had not completed their immunization as scheduled and a total of 780 (78%) babies had been affected by malnutrition. A total of 805 (80.5%) mothers had lost their babies immunization cards by one year and so couldn’t recall when their babies were to be taken back for fall up vaccinations. 15% of the mothers couldn’t find any reason for immunizing their babies since they looked health from day one. I proposed to design a phone application which will keep tracking all registered babies milestones and keep reminding mothers on the next immunization dates of their babies through sending short messages on to their phones two days before as well keep sending mothers nutrition information of their babies per milestone reached.

**SP127.2 - From Smart Phones to Smart Health**

**Author(s):** Melannie Pin1, J Huang1, Diego Zelaya1, Julio Cruz1, Ronald Alvarado1, Ricardo Silva2

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All progress in Telemedicine we has opened new destinations so far only dreamed, allowing use Smartphones as valuable tools for continuous monitoring, recordkeeping, medical alerts, prevention and prediction of various diseases related to our master pump, the human heart. And these devices can do all this without our assistance and in parallel with our recreational, household and daily work. Therefore smart phones are paving the road for smart health. We present the possibilities of smart phone based smart health for cardiovascular patients and our particular approach to this field.

**SP127.3 - Diagnostic Data: a Manifesto**

**Author(s):** Peter Pennafather1, West Suhanic2

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Diagnostic data is the fuel that drives medical information systems by enabling independent input variables to be related to dependent
outcome variables within models of care in ways that can guide medical decision making. By definition, diagnostic data-sets are assembled with specific purposes in mind. The ISO definition of quality is: “the degree to which a set of inherent characteristics fulfills requirements”. Therefore the quality of that data, and of that data’s ability to fulfill requirements, is dependent of the quality of the documentation concerning data generation. We propose as self-evident therefore that for diagnostic value-sets entered into medical information systems to become diagnostic data-sets, then those value-sets must include not only the measured values but also other values that are needed to verify data-quality. The process generating all of those values must be the product of a well documented, replicable and qualified process and must be accompanied by documentation and values that can assist independent evaluators to understand precisely how those value-sets were produced. Our manifesto is that it is the co-location of all values needed to evaluate data quality in addition to those needed to specify value relationships that transforms value-sets into data-sets. This implies that the documentation informing evaluators of why the value-set is a data-set is also in the same data-envelope as the name/value pairs proscribed by that documentation. A complete diagnostic record therefore is one where all steps that led to the generation of the data-set are described and registered in sufficient detail so that those trained in the art can: i) judge the likelihood that each step in the process is within known boundaries of reasonableness, relevance, and reliability, ii) plan how to replicate the process and attempt to acquire similar values and iii) assess the validity of the values. For diagnostic values-sets to be considered diagnostic data-sets, a capacity to support those three steps is both necessary and sufficient. This leads to simplifications of the data-quality management process and flexibility in interpreting the data. For example data-sets entered into medical information systems can support data-analysis, an inferential process aimed at estimating newly derived values from previously recorded data. As with the original data, such data transformations need to be sufficiently documented so as to allow those transformations to be replicated. By meeting that condition the derived value-set can be considered a part of the original diagnostic data-set. Indeed there is no need to distinguish between primary or secondary data or even data and metadata as their meaning should be clear. There is only data. For information systems used to guarantee the quality of medical decision making, there should only be classes of data and not-data. We will describe a diagnostic data-recording method that allow this diagnostic-data manifesto to be respected (see http://www.google.com/patents/US20140122491).

SP127.4 - Comparative analysis of co-expression networks reveals molecular changes during the cancer progression

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Prostate cancer is a serious genetic disease known to be one of the most widespread cancers in men, yet the molecular changes that drive its progression are not fully understood. The availability of high-throughput gene expression data has led to the development of various computational methods for the identification of key processes involved.

In this paper, we show that constructing stage-specific co-expression networks provides a powerful alternative strategy for understanding molecular changes that occur during prostate cancer. In our approach, we constructed independent networks from each cancerous stage using a derivative of current state-of-art reverse engineering approaches. We next highlighted crucial pathways and Gene Ontology (GO) involved in the prostate cancer. We showed that such perturbations in these networks, and the regulatory factors through which they operate, can be efficiently detected by analyzing each network individually and also in comparison with each other.

Using this novel approach, our results led to the detection of 49 critical pathways and GOs related to prostate cancer, many of which were previously shown to be involved in this cancer.

SP127.5 - Copper Meshed Carbon Black PDMS Electrode for Underwater ECG Monitoring

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The traditional method to obtain an electrocardiogram (ECG) in an underwater environment requires the industry standard silver/silver chloride (Ag/AgCl) electrodes to be completely insulated and adhered to the skin with a form of chemical water proof adhesive. However, this can lead, to severe skin irritation with prolonged use and damage to the surrounding area of skin when the covering is removed. To alleviate these discomforts, we developed hydrophobic copper-meshed carbon black/poly-dimethyl siloxane (CB/PDMS) dry bio-potential electrodes that are non-irritating, re-usable, in addition these electrodes do not require wetting, or hydrogel, making them compatible for long term application in more extreme environments. To evaluate the performance of the novel electrodes, we tested them alongside the other various commercially available electrodes (Polar textile, silver coated textile, and carbon rubber electrodes) as well as our previous CB/PDMS design without the embedded copper meshed wire under a submerged use-case scenario.

We found that only the meshed CB/PDMS electrodes provided high-fidelity ECG signal morphologies without any amplitude degradation when collecting ECG data in a freshwater scenario. In fact, based on preliminary data from 5 subjects, the meshed CB/PDMS electrodes provided ECG signal amplification during. The textile electrodes did not fare well as there was significant ECG signal amplitude reduction. Both carbon rubber and non-meshed CB/PDMS electrodes ‘performance in immersed conditions fared better than textile-based electrodes, however, they too had significant ECG signal amplitude reduction.

ECG signal amplitude reduction in water immersion holds a particular significance due to the fact that with body movements, the ECG waveform’s morphologies may not be easily discernible due to motion artifacts. By being able to record an uncorrupted signal the newly developed meshed CB/PDMS electrodes have the potential to be used for a wide variety of application in a various environments where collecting the fine features of a bio-impedance measurement such as an ECG is critical.
A breathing monitor should provide information about the frequency of breathing (respiratory rate, RR) and about the depth of breathing (tidal volume, VT). Clinical devices exist for such tasks, e.g. spirometry or inductance plethysmography, but the need for a portable, accessible to the general population, and low-cost monitoring device still remains. This study employs an optical approach to non-contact estimation of both RR and VT. The algorithm tracks chest wall displacements via the smartphone’s frontal camera and provides a chest movement signal from which the two aforementioned breathing status parameters are estimated. Spirometer-smoothed pseudo Wigner-Ville distribution was employed. The RR estimation, a time-frequency analysis based on the autoregressive model, was used to detrend the spirometer and smartphone signals. Regarding VT previously recorded while the volunteers (N=8) were breathing at VT ranging from 0.3 to 3 L. The Empirical Mode Decomposition was used to detrend the spirometer and smartphone signals. Regarding the RR estimation, a time-frequency analysis based on the smoothed pseudo Wigner-Ville distribution was employed. The smartphone-based RR estimates showed a strong linear relationship with the corresponding reference values from spirometry (r2=0.999 ± 3.85x10^-6, mean ± SD) with a root-mean-square error (RMSE) of 0.338 ± 0.043 bpm. Bland-Altman analysis showed a statistically significant bias of -0.014 bpm, and 95% limits of agreement of -0.675 to 0.647 bpm. Regarding the VT estimation, the relationship between the peak-to-peak amplitude of the smartphone-acquired chest movement signal and the VT from spirometry was analyzed and a strong linear relationship between both quantities was found (r2=0.974 ± 0.016). Therefore, a calibration was performed on a subject-by-subject basis with half of the data randomly selected to obtain the model parameters via least squares linear regression, while the remaining half of the data was used to test the computed model. No statistically significant bias was found (bias=-0.006, p=0.46), the RMSE was 0.219 ± 0.137 L, and the 95% limits of agreement were -0.253 to 0.265 L on the test data set. An example of the VT estimates is shown in Figure 1. Given these results, we foresee the possibility of developing a portable and inexpensive monitor which provides information about both frequency and depth of breathing, when calibrated on an individual basis, and that could be available outside the research and clinical settings due to the increasing ubiquity of smartphones.
These results suggest that cardiac sympathetic nerve function with $^{123}$I-MIBG would be useful supporting diagnostic inpatients with DLB. Furthermore, degree of midportion of the middle and inferior temporal gyrus, amygdala, rectal gyrus, and sylvian vallecula atrophy may be a useful imaging biomarker.

**SP128.2 - Evaluation of probable dementia with Lewy bodies using $^{123}$I-IMP brain perfusion SPECT, $^{123}$I-MIBG myocardial SPECT and voxel-based MRI morphometry**

**Author(s):** Naoki Kodama¹, Yasuhiro Kawase², Hiroshi Takeuchi¹

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Dementia with Lewy bodies (DLB) is the second most common cause of degenerative dementia after Alzheimer's disease. Approximately, 20% of elderly Japanese manifest DLB. The main symptoms of DLB are visual hallucinations, fluctuating cognitive impairment and parkinsonism. Current imaging modalities for DLB are magnetic resonance imaging (MRI), computed tomography (CT), single photon mission computed tomography (SPECT), and positron emission tomography (PET). We evaluated the diagnostic usefulness of studies with statistical methods in $^{123}$I-IMP brain perfusion SPECT, cardiac sympathetic nerve function by $^{123}$I-MIBG, and voxel-based MRI morphometry for patients with probable DLB.

Twenty-six patients with probable DLB (16 male, 10 female; mean age +/- SD, 80.7 +/- 5.7 y; range, 74-90 y) was enrolled this study. Three-dimensional stereotactic surface projections (3D-SSP) were used to analyze the results of $^{123}$I-IMP SPECT. For $^{123}$I-MIBG imaging, we calculated early and delayed heart-to-mediastinum (H/M) uptake ratios. Whole brain T1 weighted three dimensional magnetization prepared rapid acquired echo MPRAGE turbo flash sagittal sequence (slice thickness 1mm) was acquired using a 1.5T Siemens Magnetom Avanto MR imaging system. Using a free software program, the voxel-based specific regional analysis system for Alzheimer's disease (VSRAD) based statistical parametric mapping 8 plus DARTEL.

Qualitative analysis using 3D-SSP demonstrated occipital hypoperfusion in 22 patients (84.6%). Twenty-five patients (96.2%) had decreased cardiac MIBG uptake in the delayed images. Fourteen patients (53.8%) showed z-score of VSRAD exceeded 2.0. We found reduced gray matter in midportion of the middle and inferior temporal gyrus, amygdala, rectal gyrus, and sylvian vallecula in DLB.

**References**


lymphatic and sentinel lymph node (SLN) mapping have yielded mixed clinical results (e.g., low sensitivity and specificity) in GC patients. Lacking in these approaches are mechanisms for resolving microscopic extra-uterine and lymphatic disseminations either pre-or, preferably, intra-operatively in order to accurately identify LNs positive for metastatic disease.

**Problem Statement:** To address this and other issues, we have developed an intravenously administered lymphotropic multimodal contrast agent as a sensitive imaging tool of LN metastasis in GCs. We have previously described an all-organic unilamellar nanovesicle (Porphysome) with intrinsically activatable biophotonic properties. In addition to being biodegradable and biocompatible, Porphysomes can directly and stably chelate radioactive copper-64 ($^{64}$Cu) to serve as a highly accurate and non-invasive PET/CT imaging tool. $^{64}$Cu-Porphysomes functionalized with targeting ligand peptide-folate have been experimentally validated for measurable tumour-specific accumulation lasting 48 hours in primary ovarian cancer xenografts overexpressing folate receptor. We hypothesize that optimising for nanovesicle physicochemical properties including size, surface charge, and targeting ligand, we can anticipate the performance of $^{64}$Cu-radiolabelled Porphysome nanovesicles as selective lymphotropic agents for LNs burdened with metastatic disease in pre-clinical tumour models with reproducible lymphatic dissemination.

**Methodology:** Porphysome nanovesicles are prepared with pyropheophorbide-lipid, cholesterol, and 1,2-distearyl-sn-glycero-3-phosphoethanolamine-N-[methoxy(polyethylene glycol)-2000] (DSPE-mPEG-2000) in molar ratios 55/40/5, respectively. For folate receptor targeting, 1 mol/mol % peptide-folate conjugated DSPE-mPEG-2000-Folate was subrogated into the above formulation. Various sized unilamellar Porphysomes were formed following conventional liposomal preparation. To investigate the lymphotropic performance of optimally sized Porphysomes, four preclinical models of reproducible lymphatic tumour dissemination were developed: a VX2 endometrial carcinoma model with pelvic and retro-peritoneal LN metastasis in rabbits, an intra-prostatic MAT-Ly-Lu tumour and a subcutaneous intra-footpad hyperplasia models in rats, and an intra-uterine VEGF-C overexpressing tumour model with augmented lymphangiogenesis in mice.

**Results:** Radio-pharmaceutical Porphysome kits are manufactured in accordance with good manufacturing practices (GMP); specifically, suitable pharmacopeial grade materials were used throughout manufacture and each production batch is subjected to quality control assays typical of pharmacopeial standards for non-sterile pharmaceutical compounding (e.g., pH, sterility, bacterial endotoxins, etc.) before release. One-step radiolabelling of Porphysome kits with copper-64 prepared parenteral quality injections with high radiochemical purity (> 98%) and specific activity of approximately 2,800 Ci/μmol per nanovesicle. The sensitivity, specificity, and accuracy of optimally sized $^{64}$Cu-Porphysome kits for malignant LNs was quantified for both imaging modalities and correlated with histopathology in our preclinical models.

**Implication:** Our $^{64}$Cu-Porphysomes will permit the synchronous, non-invasive evaluation of GCs for (1) the extent of metastatic tumour spread and LN dissemination by PET/CT (i.e., pre-operative staging), followed by (2) intra-operative fluorescent imaging to detect cancerous LNs in real-time for image-guided lymphadenectomy.

**SP128.4 - Generation of 4-Class Attenuation Map for MRI Based Attenuation Correction of PET Data in the Head Area Using a Novel Combination of STE/DIXON-MRI and FCM Clustering**

**Author(s):** Parisa Khatari1, Hamid Saliheh Rad2, Amir Homayoun Jafari2, Anahita Fathi1, Afshin Akbarzadeh1, Mohnes Shojae Moghadam2, Arvin Aryani3, Pardis Ghafarian3, Mohammad Reza Ay1

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**Purpose:** Despite remarkable advances in positron emission tomography (PET), the effect of photon attenuation still remains unsolved. The act of attenuation correction based on magnetic resonance imaging (MRI) is a challenging issue, since distinguishing between air and bone in adjacent areas is not possible in conventional MRI. In this study, a novel combination of short echo-time (STE) MRI and a dedicated image segmentation method is proposed to derive bone tissue. A four-class attenuation map (μ-map) is proposed based on STE/Dixon-MRI for attenuation correction of positron emission tomography (PET) data of head.

**Methods:** 5 normal volunteers underwent MRI and CT scans. Two consecutive MRI pulse sequences; STE technique (echo-time, 1.1 msec; repetition time, 12 msec; voxel size, 1.2x1.2x2 mm3; acquisition time, 462 sec) and Dixon technique for fat and water decomposition (echo-time 1.2, 2.38 ms; echo-time 2, 4.76 msc; repetition time, 12 msec; voxel size, 1.2x1.2x2 mm3; acquisition time, 462 sec) were applied. Therefore, 3 MRI data sets for each volunteer were available: STE images (from STE technique), in-phase and out-of-phase images (from Dixon technique).

A four-class μ-map including cortical bone, soft tissue, fat tissue, and air regions was derived from MRI images. The image analysis protocol was mainly performed by an in-house-developed software written in MATLAB (The MathWorks, Inc.). Steps for this generation of u-map are illustrated in Figure 1. Tissue attenuation coefficients were calculated using ICRU 44 report.

To assess MRI-based μ-maps, ultra-low dose CT (ULDCT) data were acquired. After registration CT with MRI, CT-based μ-maps were generated. Quantitative assessment was applied to evaluate the MRI-based μ-maps in comparison to CT-based μ-maps. The values of sensitivity, specificity and accuracy were calculated performing a voxel-by-voxel comparison between segmentation results. To assess correlation between MR-based and CT-based μ-maps, joint histogram was plotted and correlation coefficient was calculated.

**Results:** The voxel-by-voxel comparison of the MRI-based and CT-based segmentation results showed that values of accuracy and specificity were more than 95% for classes of cortical bone, soft tissue and air region. The average value of sensitivity was calculated 75% for cortical bone and more than 90% for other classes. Evaluation of correlation between MRI and CT results yielded an overall correlation coefficient of 0.98 and 0.97 for integrated μ-maps over 15 slices.

**Conclusions:** Results indicate that STE/Dixon-MRI data in combination with FCM-based segmentation yields precise MR-based μ-maps for PET attenuation correction in hybrid PET/MRI systems.
The hybrid systems like MRI/PET and MRI/gamma camera, offer advantages, combining the resolution and contrast capability of MRI with the better contrast of nuclear techniques. This work presents, the design of a low field NMR system made up of permanent magnets compatible with a γ radiation detector. The γ detector is based on gel dosimetry. This gel undergoes a T2 relaxation time dependence with the dose. The design is performed using the software ffme for estimation of the magnetic field, and geant4 for the physical process involved in radiation detection and effect of magnetic field.

Low field MRI (lfMRI) is, in one hand, a cheaper and versatile alternative to high field MRI. On the other hand, high field MRI is not easily compatible with other techniques that involve radio frequencies and ferromagnetic materials.

The homogeneity in magnetic field is achieved with an array of NbFeB magnets in a linear configuration with a separation between the magnets, minimizing the effect of Compton back scattering compared with a no-spacing linear configuration. The final magnetic field in the homogeneous zone is ca. mT.

The radiation detector used in this work is a Gel, which is the innovative part. The radiation detectors are expensive and need an electronic set-up, which can interfere with the NMR process or viceversa.

Geant4 and ffme simulation of the hybrid system.

In our hybrid proposal, although the gel detector do not have spatial resolution, it is possible to obtain a dose profile as a function of the x-axis position by using a collimator array. We present two different methods of collimation. The first one uses sheets of lead, and the other one uses the magnets of the lfMRI array as collimator, taking advantage of the high density and atomic mass of its components.

As a result, the system described allows a complete integrated radiation detector within the lfNMR system. Finally we present the better configuration for a hybrid system capable of obtain a 1D image, MRI and gamma dose, simultaneously.
SP129 - Image Quality Assessment (Mammography and Other)

SP129.1 - Kilovoltage-CBCT of a Linear Accelerator as a relative imaging device of a spiral CT scanner - dosimetric results

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Title: kv-CBCT of a Linear Accelerator as a relative imaging device of a spiral CT scanner - dosimetric results

Purpose: Many African countries are in the process of replacing Co-60 equipment with linacs as part of upgrading radiotherapy centers. The purpose of this work is to investigate kv-CBCT of state-of-th-e-art linacs as a relative imaging device of a spiral CT scanner, which may be useful in radiotherapy centers in developing countries, and evaluate the dosimetric accuracy of a simple method of HU-ED calibration on the Truebeam.

Problem Statement: Radiation oncology in developing countries is hindered by numerous factors including availability and choice of equipment. Currently, sub-Saharan Africa depends on Co-60 in most cancer centers, with standard equipment in a typical state-funded radiotherapy center being Co-60, CT scanner, TPS and other dosimetric equipment. However, with the combination of the modern equipment and techniques, cancer care in Africa can see an exponential rise with higher survival rates.

Due to maintenance and service costs, CT scanners frequently breakdown so RT centers rely on external CT scanners operated by individuals for commercial purposes. Clinical images are acquired and eventually sent to the radiotherapy centers for treatment planning. Since each CT scanner has its own calibration curve, it is nearly impossible for the TPS to have all the individual HU-RED calibrations of the commercially available CT scanners. Treatment plans from such CT scanners may therefore be prone to dosimetric errors. CBCT has been reported to provide accurate dosimetric results where they have been used directly to perform treatment plans. Therefore, a simple method to obtain accurate dosimetric results can be useful in radiotherapy centers in developing countries in the event of replanning or the breakdown of a CT. This may be considered as an alternative to relying on commercial CT scanners if dosimetric accuracy is established.

Method: HU-ED calibrations were performed without a bowtie filter. Images for treatment planning were acquired on GE Light Speed CT scanner at 120 kV, 220 mA and 2.5 mm slice thickness. Another set was acquired using the Truebeam using at half fan beam mode and eventually sent to the radiotherapy centers for treatment planing. Since each CT scanner has its own calibration curve, it is nearly impossible for the TPS to have all the individual HU-RED calibrations of the commercially available CT scanners. Treatment plans from such CT scanners may therefore be prone to dosimetric errors. CBCT has been reported to provide accurate dosimetric results where they have been used directly to perform treatment plans. Therefore, a simple method to obtain accurate dosimetric results can be useful in radiotherapy centers in developing countries in the event of replanning or the breakdown of a CT. This may be considered as an alternative to relying on commercial CT scanners if dosimetric accuracy is established.

Results & Conclusion:
Previous results using sophisticated correction methods produced results of ±3% of the prescribed doses. This simple approach produced ±5% of the prescribed doses, but can also produce results with better accuracies. Further modifications to the setup and calibration can improve dose accuracy, and this can be advantageous in situations where the TPS software has limited features.

SP129.2 - Overall performance, image quality and dose in CR mammography systems operating in the Mexican public health sector

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Breast cancer is the first cause of cancer death in Mexican women. Approximately, 20 million women are 40 years old or older; annually, 20,444 new cases (35.4 per 100,000 women) and 5,584 deaths (17.2 per 100,000 women older than 25) are due to this disease. Breast cancer prevention, diagnostics, treatment, control and monitoring is regulated by National-Official-Regulation NOM-041 that recommends a mammogram every 2 years for women 40-69 y.o. NOM-229 establishes technical requirements for mammography equipment. Compliance with these regulations is controlled and monitored by COFEPRIS, a Ministry of Health (SS) commission.

About 2 million mammographic screening studies are performed annually in public services. Public services own 754 mammography units, 351 of these belong to SS. Three technologies are employed: screen/film (33% of SS units), digital flat-panel-detectors-DR (26%) and computed-radiography-CR (41%). An independent 2014 study for 65 CR systems in central Mexico reported that only 6% of services met NOM-041 standards, 79% produced images with artifacts and non-uniformities, and 42% met the minimum score of ACR phantom.

This study, collaboration with CNEGSR-SS, has focused on CR systems operated by SS institutions. The goal was to evaluate overall performance, image quality and dose in 15 CR systems which perform approximately 64,000 studies yearly. 40 evaluation tests, including use of CDMAM phantom and MTF evaluation, were applied in services located in 8 States.

Quality control procedures were those suggested by IAEA QA Programme for Digital-Mammography, Spanish Protocol for Quality Control in Diagnostic Radiology and Spanish Protocol for Quality Control in Digital-Mammography, and those in NOM-229 and -041.

The evaluation was grouped into 7 areas: Electromechanical performance, automatic exposure control, radiation yield, beam quality, dose, image quality and monitor visualization conditions. Systems were combinations of various mammography units with Carestream, Konica or Fujifilm CR plates. Within a month after the evaluation, services received a report with results, description of deficiencies, and strong recommendations to solve problems immediately.

Severe failures in the equipment performance, and general non-compliance with Mexican regulations and international recommendations were found. Percentage of systems complying with recommendations for representative tests were: Mammography unit mechanical evaluation (50%), compression force (64%); AEC thickness compensation (0%); mean-glandular–dose (57%); quantum noise dominance in images (9%); plate homogeneity (0%); spatial resolution (38%); visualization of CDMAM 0.1 mm object (8%); absence of artifacts (0%); 50% of centers had 5 MP interpretation monitors and 30% of rooms presented appropriate visualization.
conditions. On the positive side, 100% of systems showed appropriate half-value-layers, linearity of yield with mAs, and linear (in terms of ln(ESAK)) detector response function. Some positive changes happened after sending the reports: 3 mammography units were replaced, one high-resolution monitor was purchased and conditions in two interpretation rooms were improved. On Dec-2014, after these results, SS informed that CR systems will no longer be purchased for the CNEGSR-Breast Cancer Program, promoting migration to DR systems. It is hoped that this collaboration might result into needed actions, particularly, NOM-229 update.

We thank J Márquez, MJ Villagómez-Casimiro, A Alvarez-Luquin, and grants IAEA RC17683 and PAPIIT-UNAM-IN105813.

SP129.3 - A Catphan attachment for three dimensional measurements of the modulation transfer function

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Commercial image quality phantoms (e.g., Catphan) suffer from two limitations related to the modulation transfer function (MTF). First, the phantoms are suitable for determining the cutoff frequency only, not the full MTF shape. Second, the potential directional dependence of the MTF is ignored, making the quantification of directional blur difficult. In this study, these two limitations are addressed by proposing a Catphan attachment for 3D measurements of the full MTF shape (figure 1). Example results are shown for the Elekta XVI CBCT system. Cylindrical coordinates are chosen because MTF directional dependence is likely along these coordinates – e.g., lag/ghosting blurs the image along the rotating scan direction, thus affecting the azimuthal MTF. The cyclic pattern in each dimension consists of ten groups of line pairs with frequencies from 1.00 to 4.55 lp/cm in increments of 0.4 lp/cm. This frequency range is chosen to capture the sloping portion of the MTF for the XVI system. All lines are 5 mm long and 3 mm deep, and the centers of the line groups in the three coordinates are 36° apart and 5 cm off-center. The MTF is extracted using Fourier analysis of the line profiles along the cyclic patterns to determine the amplitude at the principal frequency. Figure 2 shows example results for the XVI system. For a given set of scan parameters, the longitudinal MTF is superior to the other two directions, and the radial MTF is better than the azimuthal MTF at higher frequencies (ghosting/lag could be a factor). For a given mAs per scan, reducing the scan time from 2 to 1 minute leads to deterioration of the longitudinal MTF and to improvement in the azimuthal MTF. In conclusion, the proposed 3D MTF attachment can be a useful tool to evaluate the overall performance of imaging systems.

SP129.4 - Sensitometric analyses of screen-film systems for mammography exams in Brazil

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A determination of the sensitometric parameters of screen-film systems to evaluate their qualities was performed. The quality control of the automatic film processor was carried out to ensure a high level of efficiency. Based on ISO 9236-3, the following potentials were applied on the X-ray tubes: 25 kV, 28 kV, 30 kV and 35 kV. Four different mammography films from different manufacturers with and without screens were tested for curve shape, speed and average gradient. The results indicated that film 1 exhibited better contrast, film 3 demonstrated the highest energy dependence, and film 4 presented the largest base-fog density. None of the four mammographic films tested achieved satisfactory results in all parameters analyzed. Improvements in the manufacturing process for these films must be completed to avoid losses in the image quality.

SP129.5 - New Line Contrast Figure of Merit for image quality assessment

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A novel Figure of Merit (FoM) is presented which is based on analysis of data extracted from line profiles within the image. This FoM is referred as Line Contrast (LC). In order to evaluate its performance, the proposed FoM along with Contrast to Noise Ratio (CNR), are applied in a simulated phase contrast image and the resulting figures are compared. Phase contrast image is created using the XRAYImagingSimulator an in-house developed software platform for x-ray imaging simulation. A semi-cylindrical phantom especially designed for phase contrast applications that contains materials mimicking the refractive properties (indexes) of breast tissues was used. Images were produced at 20 keV with source to isocenter distance (SID) 23m and object to detector distance (ODD) 400mm and pixel size of 5μm. Results from the application of both FoMs shows that LC comes into full accordance with visual assessment and that it overpass the traditionally used CNR, especially in the ability of detecting the edge enhancement due to phase contrast, of the different structures within the image. The edge detection features make it optimal for phase contrast investigation where the effect on the edge enhancement is of outmost importance.
Image quality of Computed Radiography (CR) systems has been studied, but there have been little effort to evaluate the physical performance of the photostimulable phosphor imaging plates (IPs). Due to their reusability, they are subjected to normal wear and tear from scratches, scuffs, cracks, and contamination with dust and dirt, which may interfere with the production of an appropriate diagnostic image. Some manufacturers discard the IPs only based on the number of exposures. However, this parameter is insufficient to evaluate their quality and lifetime indications. The aim of this study is to investigate quantitative and qualitative quality control (QC) procedures which can assure the IPs quality in CR systems, providing evidences of the lost of diagnostic quality. Two groups of Fujifilm HR-BD IPs were investigated: four plates were in use and four plates had been discarded. The IPs were stimulated using phantoms (PMMA, aluminium sheets and a mammographic phantom) in Mammomat 3000 Siemens mammography equipment, and scanned by Fuji FCR system, model Profect CS Plus. The QC procedures evaluated were: signal-to-noise ratio (SNR); contrast noise ratio (CNR); contrast; ghost effect; uniformity; visual analysis of the image; and integrity. The results indicated that the ghost effect, integrity and uniformity QC tests give evidences to evaluate CR imaging plates’ degradation.
there was not a significant difference between RA vs. SA-VMAT (p=.393).

Conclusion: RA&SA-VMAT outperformed HT in all parameters measures and statistical difference was observed in ten parameters, none of which showed VMAT to be inferior. Despite an increase in dose to the heart and bronchus, this study shows that VMAT is dosimetrically advantageous in treating early-stage NSCLC with SBRT compared to fixed-beam IMRT, while providing significantly shorter treatment times than any other modality studied.

SP130.2 - Development and Validation of an Open Source Tool for Determining Planning Target Volume Margins in Intracranial Stereotactic Radiotherapy

Author(s): Winnie Li, Tim Craig, An Wang, Young-Bin Cho, Tara Rosewall, Kristy Brock, David Jaffray
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Purpose/Objective(s): Awareness of inter- and intra-fraction uncertainties is increasingly important in the era of stereotactic radiotherapy (SRT); their incorporation into the planning target volume (PTV) margin (MPTV) is essential to ensure prescribed dose to the target. The purpose of this work is to develop a method to formulate MPTV for Gamma Knife (GK) intracranial SRT to manage geometric uncertainties.

Materials/Methods: The Margin Calculator was developed in open-source software to determine patient-specific MPTV. The tool was initially validated against van Herk’s (MvH) formula using a synthetic sphere and stochastic simulations for a range of systematic and random uncertainties over several fractionation schedules. Under ethics approval, 10 GK intracranial stereotactic radiosurgery targets and dose distributions underwent stochastic simulations for systematic and random uncertainties ranging from 0 – 1.5 mm and 4 fractionation schedules (1, 3, 5, 10). Simulation of MPTV expansion in the calculator was performed through dose distribution image scaling. Incremental MPTV expansions were performed until cumulative dose population histograms reached a goal of 90% population receiving a near-minimum dose of 95%. The performance of image scaling as a method of MPTV expansion was validated through comparison of the automatic scaled plans on the required MPTV versus manually generated replans for 22 cases in the treatment planning system. The new dose distribution was imported back into the Margin Calculator, and simulations repeated using the original target volume (i.e. no MPTV added), the new dose distribution (i.e. including the MPTV), specified fractionation schedule, and original set of systematic and random uncertainties. If the MPTV-Initial satisfies the coverage criteria with the prescribed dose, additional MPTV (MPTV-Additional) required should be minimal.

Results: Phantom sphere validation results showed strong agreement between the MvH-predicted and calculator-generated MPTV (R2=0.965). 640 MPTV were generated for 10 intracranial targets over 4 fractionation schedules. A 73% agreement within ±1 mm between calculated to MvH-predicted MPTV was observed, showing larger (80%) margins were required with the MvH approach. Lower fractionation and irregularly shaped targets required larger MPTV. Compared to manual replans, the automatically scaled plans required an additional 0.2 mm MPTV-Additional in 81% (18/22) of the cases; all targets required <1 mm additional MPTV-Additional to ensure dosimetric coverage.

Conclusion: A process for a Margin Calculator has been developed and validated. This open-source tool accounts for patient-specific target size, target contour, dose specifications, geometric uncertainties, fractionation schedules and treatment goals, and is useful for deriving evidence-based MPTV for intracranial GK-SRT.

SP130.3 - Dosimetric impact of accurately delineating of the left anterior descending artery in photon and proton radiotherapy

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Purpose: The purpose of this study was to quantify the dosimetric impact of motion on the dose delivered to the left anterior descending artery (LAD) in deep inspiration breath hold (DIBH) CT using proton uniform scattering (US), pencil beam scanning (PBS) and 3D conformal photon radiotherapy (3DCRT). Because dose volume histogram (DVH) indicators based on whole heart dose do not consistently predict radiation-induced risk for myocardial infarction, dose to the LAD itself has been suggested as a better indicator of radiation-induced cardiac toxicity. Routine radiotherapy treatment planning clinical imaging protocols do not compensate for heart motion, introducing a source of uncertainty in contouring and in reported dose to the LAD. Ultimately, a method that quantifies the dosimetric impact of motion could improve the LAD’s dose estimate.

Materials and Methods: Ten consecutive patients with left breast cancer received a routine clinical DIBH CT where cardiac motion was not accounted for during patient simulation. An expert radiologist contoured the LAD in the routine DIBH CT. Using an unsharp filter, the LAD’s uncompensated motion blurring in the DIBH CT images was extracted from the contoured LAD to create a corrected LAD volume. Treatment plans were created using proton (US and PBS) and photon (3DCRT) planning techniques. In order to be consistent with literature, the maximum and mean dose to the LAD were used as DVH endpoints. The relative dosimetric impact of using a corrected LAD volume on the LAD DVH indicators was determined by quantifying the relationship between the DVH indicators, which were calculated from the corrected versus the uncorrected LAD volume.

Results: Using a corrected LAD volume for calculation of the maximum dose LAD DVH indicator reduced its reported value by 2% (3DCRT), 4% (US), and 25% (PBS). The maximum absolute dose reduction was greatest for the 3DCRT plans, where the corrected LAD volume reduced the maximum dose by 87.5±117.4cGy. Proton plans had a smaller difference: US and PBS plans had a LAD maximum dose reduction of 35.8±55.4cGy and 16.3±17.0cGy respectively. The corrected LAD volume had the dosimetric impact of increasing the mean LAD dose for each treatment modality by 25% (3DCRT), 61% (US), and 35% (PBS). The greatest overall mean dose increase was found in the 3DCRT plans, where the average mean LAD dose increase was 167.9±163.9cGy. Both the US and PBS plans had less average mean dose difference (1.9±3.8cGy and 0.4±1.3cGy, respectively).

Conclusion: Uncompensated coronary motion in DIBH CT might reduce the accuracy of the LAD DVH indicators for all photon and proton modalities. Therefore, overestimating LAD volume could potentially be the source of inconsistencies within dose and radiation-induced cardiac toxicity correlations reported in the literature. These findings may be more clinically relevant for photon therapy, since proton therapy tends to deliver higher LAD doses relative to proton modalities (proton modalities are already associated with low LAD doses with or without motion correction).
ABSTRACTS | IUPESM 2015 WORLD CONGRESS ON MEDICAL PHYSICS & BIOMEDICAL ENGINEERING

SP130.4 - Objective function surrogates for iterative beam angle selection
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1Division Of Medical Physics In Radiation Oncology, German Cancer Research Center DKFZ, Heidelberg/GERMANY, 2Radiation Oncology, Massachusetts General Hospital, Boston/UNITED STATES OF AMERICA

Optimized non-coplanar beam ensembles may yield substantial improvements of radiation therapy treatment plan quality. However, beam angle selection (BAS) is a non-trivial process and automated beam ensemble optimization is not supported by most commercial treatment planning systems, in part due to the lack of efficient algorithms.

We focus on iterative BAS, where a beam ensemble is sequentially constructed: the basis for BAS during iteration \( n \) is a treatment plan containing \( n-1 \) fixed beams. To select the \( n \)th beam, each remaining beam from a discrete set of candidate beams is added one-by-one to the current beam ensemble and the fluence map optimization (FMO) problem is solved. The beam that yields the lowest objective function value is selected.

In this work we investigate two alternative methods relying on objective function surrogates to score candidate beams in order to make iterative BAS computationally more efficient: Conventional iterative BAS is compared to (1) an approach where the FMO problem is not solved to optimality but stopped after five iterations of a gradient based algorithm and (2) an approach where candidate beams are scored based on a projected gradient of the FMO problem in the first iteration.

In a treatment planning study including one pancreas, one prostate, and one intracranial case, it is observed that both iterative BAS methods using objective function surrogates yield similar plan quality compared to naive iterative BAS with regard to the resulting objective function values (see figure 1) and DVHs (see paper). At the same time, the surrogates enable reductions in computation time by a factor of 50-100 making them highly attractive for clinical application.

![Figure 1: Normalized objective function value vs. number of beams for the three investigated cases for iterative BAS using the objective function value after a full FMO (plus signs), the objective function value after five FMO iterations (circles), and the initial projected gradient (crosses). 1 corresponds to the objective function value of a coplanar equi-spaced beam ensemble with the same number of beams; 0 corresponds to the objective function value of an unattainable benchmark IMRT plan that uses all candidate beams.](image)

**Figure 1.** Dose-volume histogram for XMRT (solid) and IMRT (dashed) solutions for a prostate patient.

SP130.5 - A preliminary study on the effect of modulated photon radiotherapy (XMRT) optimization for prostate cancer treatment planning
Author(s): Philip Mcgeachy1, Jose E. Villarreal-Barajas1, Yuriy Zinchenko2, Pooyan Shirvani2, Rao Khan1
1Medical Physics, Tom Baker Cancer Centre, Calgary/CANADA, 2Mathematics And Statistics, University of Calgary, Calgary/CANADA

This preliminary work compared a new optimization technique, modulated photon radiotherapy (XMRT), with intensity modulated radiotherapy (IMRT) in a treatment planning study on a cohort of eight prostate cancer patients. XMRT differs from IMRT in that it allows the typically fixed beam energy to act as a variable such that the optimizer finds a dose distribution by simultaneously optimizing photon beamlet fluence and energy. Plans were comprised of a seven-coplanar beam arrangement, with IMRT restricted to 6 MV while XMRT used 6 and 18 MV beams. Both IMRT and XMRT optimization was based on a linear programming model with partial-volume constraints implemented through the conditional variable at risk (cVaR) approach. A dose-volume histogram for one of the patients is given in figure 1. XMRT and IMRT provided similar coverage to 95% of the target (PTV) with the prescribed dose (78 Gy), however XMRT improved the homogeneity index (HI) (Table 1). XMRT was able to reduce the dose to a greater extent (\( p < 0.05 \)) for the rectum, bladder, and femoral heads, particularly in the low-dose region (\( \leq 40 \) Gy). Further, XMRT provided an improvement in the high dose-region of the bladder with a lower near maximum dose, \( D_{2\%} \), Bladder, and reduced volume receiving at least 80 Gy, \( V_{80} \), Bladder (\( p < 0.05 \)).

Although there was a statistically significant decrease in certain dosimetric parameters for healthy organs using XMRT, whether or not this has a clinical impact has yet to be determined and is a point of interest for future investigations. Further, neutron dose needs to be considered for XMRT and the possible ramifications on the risk of secondary cancers.
The preliminary, unoptimized implementation finds the most similar plan in less than 7 minutes when choosing from 5 plans, and it is anticipated that increasing the number of plans will result in only a small relative increase in computation time. The estimated computation time for 10 comparison studies is less than 10 minutes, which is acceptable for this use case. This system, while currently set up for five studies, can easily be extended to hundreds or thousands of studies with little effort if other patients’ plans are also included. The decrease in time required to perform this computation when using the cloud decreases the time to the point where it would be reasonable to perform this computation clinically. This will lead to a reduction in the time required to create a new optimized radiation plan for the same patient.

Table 1. XMRT and IMRT results for cohort of eight patients, presented as the mean ± standard deviation.

<table>
<thead>
<tr>
<th></th>
<th>XMRT</th>
<th>IMRT</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>V95,PTV</td>
<td>95.6 ± 3.2</td>
<td>95.8 ± 2.5</td>
<td>0.4</td>
</tr>
<tr>
<td>D2,PTV</td>
<td>83.6 ± 0.3</td>
<td>85.7 ± 2.0</td>
<td>0.003</td>
</tr>
<tr>
<td>HI</td>
<td>0.108 ± 0.05</td>
<td>0.136 ± 0.06</td>
<td>&lt;&lt; 0.05</td>
</tr>
<tr>
<td>V20,Rectum</td>
<td>69.7 ± 13.9</td>
<td>82.6 ± 7.0</td>
<td>0.007</td>
</tr>
<tr>
<td>D2,Bladder</td>
<td>81.9 ± 0.4</td>
<td>83.0 ± 0.8</td>
<td>0.001</td>
</tr>
<tr>
<td>V80,Bladder</td>
<td>8.7 ± 3.1</td>
<td>10.3 ± 3.5</td>
<td>&lt;&lt;0.05</td>
</tr>
<tr>
<td>V40,Bladder</td>
<td>34.0 ± 11.0</td>
<td>38.7 ± 9.6</td>
<td>0.03</td>
</tr>
<tr>
<td>V20,Bladder</td>
<td>46.1 ± 13.0</td>
<td>51.3 ± 10.2</td>
<td>0.07</td>
</tr>
<tr>
<td>V20,FemHeadLT</td>
<td>33.7 ± 18.0</td>
<td>48.8 ± 12.0</td>
<td>0.1</td>
</tr>
<tr>
<td>V20,FemHeadRT</td>
<td>31.0 ± 18.3</td>
<td>50.5 ± 9.0</td>
<td>0.05</td>
</tr>
</tbody>
</table>

SP130.6 - Measuring radiation treatment plan similarity in the cloud
Author(s): Jennifer Andrea, Csaba Pinter, Gabor Fichtinger
School Of Computing, Queen’s University, Kingston/ON/CANADA

Radiation therapy is a form of cancer treatment in which carefully designed plans are used to direct treatment over multiple occasions (fractions). Creating radiation plans is quite laborious, so it is not feasible to manually create a plan for each fraction to maintain treatment quality. We propose to use a database of plans to find the most similar anatomy, based on which a suitable daily plan might be automatically created, thus reducing staff time. However, the computation for finding the most similar plan is long and computationally intensive, which presents an obstacle to performing the procedure clinically. We present a method for finding the most similar plan using cloud resources to reduce computation time. Using the cloud to perform the comparison computation enables each comparison between the daily study and an assigned study from the database to be computed in parallel.

The similarity analysis computation was performed on Amazon Web Services (AWS) Elastic Cloud Compute instances, using 3D Slicer and SlicerRT. 3D Slicer (www.slicer.org) is an open source platform for medical image analysis and visualization and SlicerRT (www.SlicerRT.org) is a radiation therapy research extension for 3D Slicer. The AWS Simple Storage Service and Simple Queue Service were also used, for storage of the studies and messaging between the local computer and the instances, respectively. The similarity of the studies were evaluated by computing the Dice coefficient for pairs of matching contoured structures from each study. As contouring is a time-consuming process, contour comparison was used as a proof-of-concept for using the cloud and SlicerRT together to find the most similar plan. In the future, the similarity measure of raw anatomical data will be used for comparison instead.

The system was tested on simulation data created by applying random deformation fields to an existing phantom radiation plan. The system was evaluated both in terms of accuracy and in terms of time. Five different studies were presented to the system as the daily study, and the system returned the correct result in each case.
SP131 - Quality Assurance: Part 3

SP131.1 - Sensitivity of Helical Tomotherapy and Elekta Agility VMAT dose distributions to multileaf collimator motion uncertainties for breast radiation treatment with extensive nodal irradiation

Author(s): Jason Belec, Eric Vandervoort
Medical Physics, Ottawa Hospital Cancer Center, Ottawa/Canada

Purpose: Breast radiation therapy treatments including extensive nodal irradiation require additional photon intensity modulation to properly spare normal tissues such as the heart and the lungs. In this work, we use Monte Carlo dose calculation methods to quantify the sensitivity of those treatments to uncertainties in the motion of multileaf collimator (MLC) for treatment delivered using Helical Tomotherapy (HT) and Elekta Agility VMAT (EA-VMAT).

Materials and Methods: Treatment plans for 10 patients were generated using Tomotherapy Planning 5.0 and Elekta Monaco 3.1 treatment planning systems. Monte Carlo simulations were performed with a modified version of the BEAMnrc/DOSXYZnrc codes. Errors in the MLC motion were introduced in the treatment plans and the impact on the dose distribution was assessed by comparing the dose with and without the errors.

Results: Figure 1 shows an example of dose volume histograms for HT and EA-VMAT. The EA-VMAT plans were optimized using a 5 mm minimum leaf gap soft constraint to achieve similar treatment plan quality as with HT. The sensitivity of the EA-VMAT mean target dose to MLC position uncertainties is 0.5% per ms of error in the opening time of each leaf. The sensitivity of the HT mean target dose to MLC position uncertainties is 0.5% per ms of error in the opening time of each leaf.

Conclusion: Breast radiation therapy treatments including extensive nodal irradiation require additional photon intensity modulation to properly spare normal tissues such as the heart and the lungs. Results show that it is possible to achieve similar treatment plan quality with EA-VMAT as with HT. The sensitivity of the EA-VMAT mean target dose to MLC position uncertainties is 3.0% per mm of error in the leaf gap size (0.5 mm error in the position of each leaf). The sensitivity of the HT mean target dose to MLC position uncertainties is 0.5% per ms of error in the opening time of each leaf.

SP131.2 - Use of Varian Trajectory Log Files for Patient Specific Quality Control of TrueBeam VMAT FFF Treatment Deliveries with Portal Dosimetry and Eclipse

Author(s): Michael Fan, Francois Deblois, Jonathan Thebault
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Purpose:
Varian Portal Dosimetry System (PDS) (Varian Medical System) is an integrated tool for dosimetric quality control (QC) of flattened beams. However, flattening filter free (FFF) beams are not yet supported in PDS. In this work, we propose a workaround to (1) analyze FFF beam deliveries in PDS and (2) visualize treatment delivery discrepancies within Varian Eclipse treatment planning system (ETPS) by using the Varian TrueBeam trajectory log files.

Method and Material:
Five brain stereotactic radiosurgery plans were optimized with ETPS using a volumetric modulated arc delivery (VMAT) technique for 6 MV FFF beam on TrueBeam. Treatment verification plans were validated in a phantom by taking a point dose measurement with a Farmer-type ionization chamber (IC) and with a Gafchromic EBT3 film (Ashland Inc.). The trajectory log-files (version 1.5) were generated for every treatment and QC plan delivered. The log-files contain cumulative monitor units (MU) delivered, leaf positions, gantry positions, and other machine parameters sampled every 20 ms. We developed a user-friendly web application to parse log-files and automatically generate corresponding DICOM-RT reconstructed CTs using the delivered MUs. The planned mean dose to the IC was compared to the measured dose and the DRP dose. Gamma map analysis was performed between (1) the planned photon fluence (FFF) and the film measurement and (2) the FFF and DRP dose. The latter was analyzed in PDS by converting the DICOM dose files (PFF and DRP) to a format readable by PDS. Treatment delivery discrepancies on planning objectives were analyzed by comparing dose-volume histogram metrics between the original plan and the DRP.

Results:
The point dose differences between ETPS and IC and between ETPS and DRP were 1.6 ± 1.5% and 0.17 ± 0.08% respectively. The percentage of pixels passing fluence map gamma analysis between ETPS and film was 99.0 ± 0.7% (3%/3 mm) and between ETPS and DRP (Fig1) was 99.8 ± 0.2% (0.5%/0.5 mm). Across all analyzed plans, ETPS and DRP showed an average difference of 0.56 ± 0.33% for V[10 Gy] to brain excluding PTV and an average difference of 0.22 ± 0.15% for V[100% of prescription] to PTV.

Conclusion:
This work demonstrates the successful use of TrueBeam trajectory log-files with a user-friendly web application to reconstruct the delivered dose in ETPS for patient specific QC.
SP131.3 - Machine Learning Facilitates Failure Mode Analysis and Virtual QA for IMRT

**Author(s):** Gilmer Valdes, Ryan Scheurmann, Chun-Yu Hung, Marc Bellerive, Arthur Olszanski, Timothy D. Solberg
Radiation Oncology, University of Pennsylvania, Philadelphia/UNITED STATES OF AMERICA

**Purpose:** To develop metrics that describe the deliverability of IMRT plans and use them for a priori prediction of IMRT QA results.

**Methods:** 498 IMRT plans from multiple treatment sites were planned in Eclipse version XI and delivered using a dynamic sliding window technique on two linac platforms (Clinac iX and TrueBeam, Varian Medical Systems, Palo Alto, CA). Using 2% dose / 2 mm distance tolerances with local normalization, 38 plans failed the 90% gamma criterion. Four failure modes were identified: MLC leaves’ transmission, leaf end leakage, jaws’ transmission and the tongue and groove effect. 23 different metrics were defined to characterize these failure modes. Geometrical features as well as those features weighted by the monitor units were included. Machine Learning Algorithms (MLA) were developed to analyze the data. A two-leaf decision tree with information gain maximization was used for each feature to determine thresholds that result in maximizing the probability of identifying failing plans. Features were ranked according to T-test, Kolmogorov-Smirnov Test and the information gain in 2 leaf decision trees. Additionally, a RUSBoost algorithm with oversampling was developed to predict the virtual passing results of each plan. All the statistical analysis was performed using Matlab R 2014a.

**Results:** All features analyzed were significantly different in the plans that failed compared to the plans that passed QA at a 5% confident interval for all the tests performed, and the weighted geometrical features were determined to be highly significant. Thresholds resulting in a substantial increase of the probability of plans failing QA were determined. The most important feature for each failure mode, and accompanying threshold, are shown in Table 1. The weighted average ratio of MLC to jaw aperture (WAVERatio) was the most important feature overall. Plans with a WAVERatio smaller than 0.1090 were approximately 37 times more likely to fail. The modulation factor, which relates to different failure modes, was also an important feature in that plans exceeding a value of 6.86 were approximately 19 times more likely to fail. Finally, a cross-validated decision tree ensemble resulted in correctly classifying 87% percent of failing plans and 88% of passing plans.

**Conclusion:** Passing rates of IMRT plans can be described by weighted geometrical features. Different thresholds for these features can be used to improve the plan deliverability. MLA can play a key role in planning and QA, particularly for adaptive strategies, which may require QA to follow clinical delivery.

**Table 1. Failure Modes, features and their respective thresholds.**

<table>
<thead>
<tr>
<th>Failure Mode:</th>
<th>Features:</th>
<th>Threshold:</th>
<th>Increased probability of plans failing:</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLC leaves’ transmission</td>
<td>Weighted average ratio of MLC to jaw aperture</td>
<td>&lt;0.11</td>
<td>37.02</td>
</tr>
<tr>
<td>Leaf end leakage</td>
<td>Fraction of Monitor Units delivered through leaf gaps smaller than 2mm</td>
<td>&gt;0.21</td>
<td>9.13</td>
</tr>
<tr>
<td>Jaws’ transmission</td>
<td>Weighted fraction of area receiving out-of-field radiation</td>
<td>&gt; 0.01</td>
<td>5.86</td>
</tr>
<tr>
<td>Tongue and Groove effect</td>
<td>Weighted average perimeter</td>
<td>&gt; 45.05 mm</td>
<td>5.29</td>
</tr>
</tbody>
</table>

SP131.4 - Dosimetric analysis of respiratory-gated RapidArc with varying gating window times

**Author(s):** Ju Young Song
Radiation Oncology, Chonnam National University Hwasun Hospital, Hwasun-Eup/KOREA

The volumetric modulated arc therapy(VMAT) which modulates beam intensity with the variation of a dose rate, a gantry speed and a multi-leaf collimator(MLC) positioning in each rotation angle can also use the respiratory gated method for the treatment of moving lesions. The gated VMAT method is inherently can make a dosimetric inaccuracy due to the uncertainty of gantry position during the stop and go motion of the heavy gantry. In this study, the dosimetric inaccuracy in a gated VMAT was reviewed with the analysis of measured dose distribution according to the variation of beam-on time period. The linear accelerator used in this study was Novalis Tx (Varian, USA) and total 10 VMAT plans for the treatment liver cancer were prepared. The used gate system was RPM-gating system (Varian, USA) and the Dynamic Platform Model 008PL (CIRS Inc., USA), which can simulate respiratory motion, was used to set up the beam-on time. Two different delivery quality assurance(DQA) plans for VMAT plans were created. One is the portal dosimetry method which use EPID(electronic portal imaging device) measurements and the other is the measurement of dose distribution using 2-dimensional diode detector array, MapCHECK2(Sun nuclear, USA). The respiratory period was set to 4 sec and the DQA for gated VMAT was performed with the two different beam-on time sets, 1 sec and 2 sec. The matching rate in absolute dose mode was calculated by the gamma evaluation method for the gamma index, a 3% dose difference, 3 mm distance to agreement with 10% dose threshold. The calculated matching rates in each DQA measurement are shown in Table1. The average matching rates of portal dosimetry analysis were 98.72% in the no gating treatment, 94.91% in the gating with 1 sec beam-on time and 98.23% in the gating with 2 sec beam-on time. The average matching rates of MapCHECK2 analysis were 97.80% in the no gating treatment, 95.38% in the gating with 1 sec beam-on time and 97.50% in the gating with 2 sec beam-on time. The dosimetric error was increased as beam-on time became shorter, which made more stop and go motion during a gated VMAT process. The results showed that a gated VMAT is proper to the patients who can sustain longer exhalation phase time, which enables longer beam-on time and less stop and go motion.
For 6% of the fractions, the DIR algorithm did not succeed in creating an invertible deformation vector field using the default settings. In those cases, a volume of interest (VOI) excluding the shoulder region was defined and used as input to the DIR algorithm. For DIR, the ANACONDA algorithm was used. It has shown to perform well in comparison with state-of-the-art methods for thoracic 4DCT data as well as being an improvement with respect to rigid registration for CT / CBCT DIR (Weistrand, Svensson, Med Phys, 2015). ANACONDA was run without using contour guidance as no contours were initially defined on the CBCTs. All DIRs, together with propagated contours, were qualitatively validated by visual comparison to rigid registration in a side-by-side view. Contours on pCT and CBCT were shown overlaid. In all cases, the DIR and propagated contours were satisfactory.

Average processing time for one fraction using scripting was 53 seconds on a machine running Windows 8.1 (64-bit) operating system with 32GB RAM, one Intel Xeon E5-2697 (12 cores) CPU and two AMD FirePro D700 GPUs. Both DIR and dose computation use GPU acceleration. Estimated time spent on visual inspection of external contour, propagated contours and DIR was around one minute. VOI creation and DIR recomputation took around two minutes for the fractions mentioned above.

To summarize, we have shown that retrospective dose-tracking can be done in an integrated commercial system. The process can be efficiently implemented using scripting. Some manual interaction is still required (6-10%) for initialization and occasional adjustment in segmentation and DIR.

**References**


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**Table 1. The calculated matching rates in each DQA process for a gated VMAT**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Portal Dosimetry</th>
<th>MapCHECK2 with MapPHAN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Gating</td>
<td>Gating(1sec)</td>
</tr>
<tr>
<td>A</td>
<td>96.5%</td>
<td>95.2%</td>
</tr>
<tr>
<td>B</td>
<td>98.8%</td>
<td>95.4%</td>
</tr>
<tr>
<td>C</td>
<td>98.5%</td>
<td>94.6%</td>
</tr>
<tr>
<td>D</td>
<td>99.0%</td>
<td>91.7%</td>
</tr>
<tr>
<td>E</td>
<td>99.1%</td>
<td>93.0%</td>
</tr>
<tr>
<td>F</td>
<td>98.8%</td>
<td>95.3%</td>
</tr>
<tr>
<td>G</td>
<td>99.2%</td>
<td>95.5%</td>
</tr>
<tr>
<td>H</td>
<td>99.4%</td>
<td>96.6%</td>
</tr>
<tr>
<td>I</td>
<td>99.1%</td>
<td>94.4%</td>
</tr>
<tr>
<td>J</td>
<td>98.8%</td>
<td>97.4%</td>
</tr>
</tbody>
</table>
Abstracts

SP131.6 - Enabling Continuous Quality Improvement in a Rapidly Changing Clinical Environment through a Multi-Year Multi-Centre IMRT QC Program: 3 Year Experience

Introduction: Several different audit or credentialing programs have been created in multiple jurisdictions to assess radiotherapy planning and/or delivery performance using a variety of methodologies. The Collaborative Quality Assurance (CQA) Program is unique in that it was created as a multi-year program to assess site-specific planning and delivery quality through on-site visits that also incorporate diagnostic tests. Quantitative results for phantom positioning accuracy and MLC calibration from Year 3 is reported as well as the cumulative experience.

Methods and Materials: Fourteen independent radiotherapy centres have participated in the CQA Program. The yearly test includes a clinically realistic site-specific planning exercise (Year 1: head and neck, Year 2: prostate, Year 3: spine SBRT), and an on-site visit. The site visits include phantom imaging (diode array), dose calculation and dose delivery. The measurement portion of the visit includes delivery of the centre's own plans (IMRT or VMAT), re-delivery of plans from previous visits and diagnostic tests. Diagnostic components include a vendor/MLC-specific IMRT plan created by the CQA program and quantitative analysis of phantom positioning accuracy and MLC calibration (introduced year 2 and 3 respectively). Measured to planned dose agreement is analyzed using both 3%/3mm criteria with gamma analysis and 3%/2mm criteria with composite analysis.

Results: 41 site visits completed to date, 14 in Year 3, including measurement of 17 spine SBRT plans (15 VMAT and 2 IMRT), re-delivery of 11 H&N and 6 prostate plans, and 3 new H&N plans and 6 new prostate plans. There has been a rapid adoption of VMAT delivery during the 3-year course of the program as only 3 of the 15 H&N plans in Year 1 were VMAT. Year 3 visits included 9 difference combinations of treatment planning system (4) and linac/MLC (5), and over 3 years the site visits have included 14 difference combinations. For the Year 3 spine SBRT plans, the percentage pass rate ranged from 97.3 – 100% for 3%/3mm gamma analysis and 89.4-100% for 3%/2mm composite analysis. Phantom positioning was good (all translational errors <2 mm) and was found to have no correlation with dosimetric results. Tighter tolerances are being investigated for correlation with MLC calibration. MLC calibration was quantified on 15 different linacs using portal imaging with all leaves (assessed at 5 different positions) within 2 mm of nominal position, and average impact on field size was < 1mm for 14/15 linacs. Overall, no significant change in performance was observed over three years for a single treatment site, however, on a single-centre basis, improvements up to 10% (3%/2mm criteria) were observed and can be linked to changes in planning technique and infrastructure.

Conclusion: The CQA Program has been established as a unique multi-year IMRT QA program incorporating diagnostic tools that can enable continuous quality improvement through feedback to the participants. Achievable performance levels have been identified as targets and the repeat visit model can highlight changes in IMRT planning and delivery performance and assess the impact of clinical practice changes, technology implementation or infrastructure change.

SP131.7 - A new approach to spatial gradient signal encoding for external beam radiotherapy delivery verification

Introduction: A spatially encoding dose-area product transmission chamber provides an effective method to monitor the delivery of external beam radiotherapy. Previous designs achieved spatial signal encoding by introducing a sloped separation between electrodes. The wedge shaped collection volume generates a linearly varying signal which depends on the position of the field on the chamber. In this study, we report on a chamber design to achieve a spatial gradient from a uniform electrode separation while providing measurements from complementary spatial gradients.

Methods: A spatial gradient is achieved by replacing the uniform area collecting electrode with an interleaved conducting comb pattern etched into an insulating substrate. The gradient is achieved by changing the width of the tines in the comb linearly with position, while the complementary interleaved pattern varies in the reversed pattern. In this configuration, a constant electrode plate spacing of 0.5 cm was used between polarizing and collection electrodes, with each measurement comprised of signals from each of the two combs.

Results: Investigations of this chamber configuration used collection patterns etched into a PCB circuit board and a fluorine doped TiO2 coating on a glass substrate, with a pair of complimentary tines occupying a width spanning 0.5 cm with a maximum widths varying from 0.05 to 0.45 cm over a length of 23 cm and 26 cm on PCB and glass, respectively. Field sizes on the order of 1 to 6 cm were investigated, with the chamber moved through the beam to sample chamber positional response.

Conclusions: This study demonstrates the feasibility of using an interleaved comb collection electrode in a parallel plate chamber geometry to achieve spatial encoding for radiotherapy treatment monitoring. Comparable signal behavior was achieved for both the PCB and glass based substrates. Future work will focus on optimizing the design of chamber for clinical use.

Conclusion: The CQA Program has been established as a unique multi-year IMRT QA program incorporating diagnostic tools that can enable continuous quality improvement through feedback to the participants. Achievable performance levels have been identified as targets and the repeat visit model can highlight changes in IMRT planning and delivery performance and assess the impact of clinical practice changes, technology implementation or infrastructure change.

Figure 1: Detector signal as a function of position along the gradient direction. Note that the negative gradient has been reflected in position for ease of comparison.
SP132 - Guidelines and Radiation Protection Reference Levels for Patients and Personnel

SP132.1 - Implementation of the new BSS including radiation safety culture in medicine

Author(s): M.M. Rehani1, O. Holmberg2, P. Jimenez3

1Radiology, Harvard Medical School, Massachusetts General Hospital, Boston/MA/UNITED STATES OF AMERICA; 2Radiation Protection of Patients Unit, IAEA, VIENNA/AUSTRIA; 3World Health Organization/Pan American Health Organization (PAHO), WASHINGTON/DC/UNITED STATES OF AMERICA

The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, commonly known as BSS, provide a robust framework of safety requirements for medical exposures that can serve as a powerful tool for countries to strengthen radiation safety regulations and for medical physicists to strengthen their position and professional involvement. The new BSS have been jointly sponsored by 8 intergovernmental organizations, including the WHO, and published by the IAEA in 2014. The medical physicist (MP) as defined in the BSS is: “A health professional with specialist education and training in the concepts and techniques of applying physics in medicine and competent to practice independently in one or more of the subfields (specialties) of medical physics”. This definition is very important as it categorizes the MP as a health professional. Previously the requirements for MPs were stringent primarily for radiotherapy; now, they have expanded as well for other areas like high dose procedures in radiology, image guided interventional radiology and nuclear medicine. The words medical physics/physicist occur more than 20 times in new BSS as many requirements and responsibilities have been assigned to the MP. Further there is clear assignment of responsibility to the Radiation Protection Officer (RPO) as pertains to oversight of the application of regulatory requirements, particularly insofar as radiation protection of workers and members of the public rather than patient protection. In some facilities, the MP can have additional responsibility as RPO whereas the inverse is not applicable. Promotion and maintenance of safety culture are requirements in the new BSS and MPs have an inherent role in its implementation, in fostering commitment and creating a common understanding, in providing means for implementation at the level of individuals and teams, and in practicing and encouraging dually inquisitive and learning attitudes. The presentation, while reviewing actions on implementation taken by IOMP, IAEA and WHO, will invite feedback and suggestions on implementation in different countries.

SP133 - Validation and Verification of Therapy Dose Delivery: Part 2

SP133.1 - Dosimetric Comparison of 3DCRT, IMRT and VMAT for Spine Radiotherapy based on Secondary Cancer Risk

Author(s): J Rehman1, J Ashraf1, M Isa1, M Afzal1, G Ibbott2, James Chow3

1Islamia University of Bahawalpur, Bahawalpur/Pakistan, 2UT MD Anderson Cancer Center, Houston/UNITED STATES OF AMERICA, 3Princess Margaret Cancer Center, Toronto/CANADA

This study evaluated the secondary cancer risk after 3D-conformal radiotherapy (3DCRT), intensity modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT) for spine. Computed tomography image set of a RPC spine anthropomorphic phantom was exported to the Pinnacle3 treatment planning system. Radiation treatment plans for spine were created using the four-field 3DCRT, seven-field IMRT and dual-arc VMAT techniques. The mean and maximum doses (Table 1), dose-volume histograms and volumes receiving more than 2 Gy and 4 Gy of organs-at-risk (OARs) (Table 2) were calculated and compared. The lifetime risk for secondary cancers was estimated according to NCRP Report 116. Quality Assurance of IMRT and VMAT were performed using the ArcCHECK method with gamma index criteria set to 3%/3mm. For our dosimetric comparisons, planning target volume coverages were found to be 90.5%, 91.4% and 95.9%, for 3DCRT, IMRT and VMAT, respectively. VMAT was found to deliver the lowest maximum dose to esophagus (3.22 Gy), bone (6.48 Gy), heart (1.69 Gy), spinal cord (5.15 Gy) and the whole lung (4.52 Gy). Volumes of esophagus receiving more than 4 Gy were 0% for VMAT, 37.56% for IMRT and up to 43.76% for 3DCRT. The estimated risk for secondary cancer in the respective OAR is considerably lower in VMAT compared to other techniques. Results of maximum doses and volumes of OARs suggest that the risk of secondary cancer induction for spine in VMAT is lower than in IMRT and 3DCRT, whereas VMAT has the best target coverage.

Table 1: Maximum and mean doses of OARs.
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SP133.3 - Dosimetric verification for tangential breast irradiation in commercial treatment planning system using indigenous female wax torso.

**Author(s):** Kamlesh R. Passi, V.Saran Raj, Konthoujam Manimala Devi, Ishu Sharma, Naveen Kanda, Sandhya Sood

*Mohan Dai Oswal Hospital Department of Radiation Oncology, Ludhiana/INDIA*

**Introduction:**

Volumetric modulated arc therapy (VMAT) allows for a simultaneous integrated boost (SIB) technique to be employed for the delivery of brain fractionated stereotactic radiation therapy (FSRT). The goal of this study is to validate VMAT FSRT plans by comparing calculated doses against measured doses using a variety of dosimeters in a multi-configurational phantom.

**Methods**

VMAT FSRT plans were prepared using Eclipse treatment planning (Varian) and delivered with a Truebeam linac (Varian) onto an acrylic multi-configurational phantom (Fig. 1) that allows gel (Fricke-xylene orange), film (EBT3 Gafchromic), or ion chamber (Capintec PR-05P 0.07 cm³) dose measurements. In each plan, an 18 cm diameter spherical structure was contoured to mimic the whole brain within the phantom. Additionally, four spherical boost PTV structures ranging in diameter from 3-20 mm were contoured and positioned in a diamond pattern in the coronal mid-plane of the phantom (100 cm SAD). An SIB VMAT plan comprising two 6 MV coplanar full arcs was then optimized (AAA v10.0.25) to deliver 200 cGy/fraction to the whole brain structure and 400 cGy/fraction to each boost PTV. The plan was normalized to ensure that 95% of each boost PTV volume was covered by 400 cGy. Dose profiles were generated to compare calculated and measured dose. Gamma analysis was also performed for both film (2D) and gel (3D) dosimeters.

**Results/Conclusion**

Dose profile comparisons for certain boost PTV sizes are shown in Fig. 2. Ion chamber point dose measurement (at isocentre) agreed within 1% of the calculated dose. Measured peak boost PTV doses agreed with calculated doses to within 3.1% and 4.9% for gel and film respectively. Both 2D and 3D gamma analyses (3%/3 mm) showed greater than 95% agreement with calculated dose distributions. Film and gel dose profiles successfully characterized the full shape and gradients of the calculated profiles.

Table 2: OARs receiving doses greater than 2 and 4 Gy.

<table>
<thead>
<tr>
<th>Organ-at-Risk</th>
<th>3DCRT</th>
<th>IMRT</th>
<th>VMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>% Val &gt; 2 Gy</td>
<td>% Val &gt; 1 Gy</td>
<td>% Val &gt; 2 Gy</td>
</tr>
<tr>
<td>Bone</td>
<td>13.24</td>
<td>18.24</td>
<td>12.79</td>
</tr>
<tr>
<td>Heart</td>
<td>32.13</td>
<td>47.39</td>
<td>31.12</td>
</tr>
<tr>
<td>Spinal Cord</td>
<td>60.56</td>
<td>80.56</td>
<td>59.56</td>
</tr>
<tr>
<td>Lung</td>
<td>12.57</td>
<td>17.57</td>
<td>12.12</td>
</tr>
</tbody>
</table>

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**SP133.2 - Validation of VMAT FSRT calculated doses using a multi-configurational phantom**

**Author(s):** Michel Lalonde¹, Kevin M. Alexander², Tim Olding², Tim Owen³, Andrew Kerr³

¹Cancer Centre Of Southeastern Ontario (ccseo), Kingston General Hospital, Kingston/ON/CANADA, ²Department Of Physics, Engineering Physics And Astronomy, Queen’s University, Kingston/ON/CANADA, ³Department Of Oncology, Queen’s University, Kingston/ON/CANADA

**Introduction**

Volumetric modulated arc therapy (VMAT) allows for a simultaneous integrated boost (SIB) technique to be employed for the delivery of brain fractionated stereotactic radiation therapy (FSRT). The goal of this study is to validate VMAT FSRT plans by comparing calculated doses against measured doses using a variety of dosimeters in a multi-configurational phantom.

**Methods**

VMAT FSRT plans were prepared using Eclipse treatment planning (Varian) and delivered with a Truebeam linac (Varian) onto an acrylic multi-configurational phantom (Fig. 1) that allows gel (Fricke-xylene orange), film (EBT3 Gafchromic), or ion chamber (Capintec PR-05P 0.07 cm³) dose measurements. In each plan, an 18 cm diameter spherical structure was contoured to mimic the whole brain within the phantom. Additionally, four spherical boost PTV structures ranging in diameter from 3-20 mm were contoured and positioned in a diamond pattern in the coronal mid-plane of the phantom (100 cm SAD). An SIB VMAT plan comprising two 6 MV coplanar full arcs was then optimized (AAA v10.0.25) to deliver 200 cGy/fraction to the whole brain structure and 400 cGy/fraction to each boost PTV. The plan was normalized to ensure that 95% of each boost PTV volume was covered by 400 cGy. Dose profiles were generated to compare calculated and measured dose. Gamma analysis was also performed for both film (2D) and gel (3D) dosimeters.

**Results/Conclusion**

Dose profile comparisons for certain boost PTV sizes are shown in Fig. 2. Ion chamber point dose measurement (at isocentre) agreed within 1% of the calculated dose. Measured peak boost PTV doses agreed with calculated doses to within 3.1% and 4.9% for gel and film respectively. Both 2D and 3D gamma analyses (3%/3 mm) showed greater than 95% agreement with calculated dose distributions. Film and gel dose profiles successfully characterized the full shape and gradients of the calculated profiles.

**SP133.3 - Dosimetric verification for tangential breast irradiation in commercial treatment planning system using indigenous female wax torso.**

**Author(s):** Kamlesh R. Passi, V.Saran Raj, Konthoujam Manimala Devi, Ishu Sharma, Naveen Kanda, Sandhya Sood

*Department Of Radiation Oncology, Mohan dai oswal hospital, Ludhiana/INDIA*

Dosimetric verification for tangential breast irradiation in commercial treatment planning system using indigenous female wax torso.

Kamlesh Rani Passi, Saran raj, Konthoujam Manimala, Ishu Sharma, Naveen Kanda, Sandhya sood.

*Mohan Dai Oswal Hospital Department of radiation Oncology, Ludhiana (Punjab), INDIA*

**Introduction:**

Accuracy of Clarkson algorithm employed in a commercial 3D TPS was evaluated for conditions simulating tangential breast treatment. A breast phantom was fabricated from machineable wax to examine the accuracy of tangential breast irradiation. The phantom was made of acrylic, measures 20.4 cm diameter by 30 cm length and is supported over the end of the linac couch. The third configuration for a point ion chamber is not shown.
Material and Method:

A Wax phantom of size $\{33(l)^{*}34(w)^{*}29(h)\} \text{cm}^3$ was fabricated in the departmental mould room. An important consideration in the design of the phantom was the reproduction of a geometry that could realistically duplicate the female torso in treatment position was taken care. The ion chamber was positioned 4.5 cm below from the surface of the breast phantom. The medial, lateral, superior, and inferior field borders previously marked on the phantom, were delineated with fiducial marker. CT images of the phantom with 0.6cc chamber were taken with 3-mm slice thickness. The images were imported to Cms Xio TPS for planning via Focal system after contouring. A phantom plan was created taking the calculation point at centre of chamber cavity volume by superimposing each patient plan in the indigenous breast phantom. 20 patients were taken for this study & Measurements were performed using a 0.6cc ionization chamber.

Result and Discussion:

Comparison was made between measured and calculated dose. We got good results for maximum number of patients within 1.5% and few patients above 3%. The dose-calculation verification measurements performed in this study utilizing a indigenous phantom clearly demonstrate absolute homogenous dose calculation accuracy even in case of tangential irradiation of the breast.

Conclusion:

A measurement of dose in the phantom shows good agreement in variety of treatment field configurations. This confirmed the utility of an indigenous breast phantom as a tool to assess accuracy of 3D tangential breast dose measurements for photon dose calculation.

References:


SP133.4 - Dosimetric comparison of IMRT versus RapidArc (VMAT) optimization in whole breast irradiation of early stage breast cancer

Author(s): Nader Moshiri Sedeh

Physics, Florida Atlantic University, BOCA RATON/UNITED STATES OF AMERICA

Dosimetric comparison of IMRT versus RapidArc (VMAT) optimization in whole breast irradiation of early stage breast cancer

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2. South Florida Radiation Oncology, Boca Raton, FL, 33431
3. South Florida Radiation Oncology, Jupiter, FL, 33458

Purpose: The purpose of this study is to compare the dose-volumetric results of intensity modulated radiation therapy (IMRT) with RapidArc (VARian Medical Systems, Palo Alto, CA) for whole breast irradiation.

Methods: 25 patients previously treated for whole left breast (either RapidArc plan or IMRT) were the subjects of this planning study. Eclipse v 11.0.47 was used to make all retrospective plans using the same contours, energy, machine and normalization. Prescription dose to the planning target volume was 5000 Gy in 25 fractions. All plans were normalized such that 100% covered 95% of planning target volume (PTV).

Results: V10, V20 and Dmean Gy of left lung significantly differed between the two plans (p-value <0.0001, =0.0473 and <0.0001 respectively), but V30 Gy did not (p-value 0.463). V25, D33 and Dmean Gy of heart significantly differed between the two plans (p-value =0.034, <0.0001 and 0.01 respectively), but V10 Gy did not (p-value 0.058). V5 of both right breast and right lung significantly differed between the two plans (p-value <0.0007 and =0.0112, respectively). Also Dmean of both right breast and right lung significantly differed between the two plans (p-value <0.0001 for both). The mean conformity index did not significantly differ, p-value 0.142. There was a significant difference between the mean MUs of the two plans as well, p-value <0.0001.

Conclusion: The dose-volumetric results of IMRT vs RA were different for most of the constraints although all plans were made within the threshold values recommended by RTOGs. Mean doses to left lung, heart, right lung and right breast were significantly different in RA than IMRT plans. It’s been said that RA is more efficient/faster in the treatment delivery than IMRT in terms of total monitor units used, but in this study the results did not prove that. In fact, since both plans have the same mean of conformity index, based on what was observed in this study IMRT is not only faster but also safer regarding not irradiating the organs at risk.

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Cell: +1 561 318 1659
Dry-contact electrodes allow for rapid, preparation-free EEG acquisition and new applications of brain signal analysis. However, dry electrodes require reproducible and stable electrode-skin contact to provide signal qualities comparable to conventional wet electrodes. Our recently introduced dry multipin electrodes comprise 30 pins on a flat baseplate. A non-conductive Polyurethane substrate is subsequently coated with a conductive Ag/AgCl film. Our earlier studies proved this design to enable hair layer penetration and a stable contact as long as sufficient contact force is applied.

In this study we focused on the influence of contact force and substrate flexibility (shore hardness) on the electrode-skin impedance on a hairless frontal position (Fpz) and a hairy temporal position (T4). The study was performed with 10 volunteers of similar age and different gender and hair length. An analogue force sensor and a custom-made electrode adduction and fixation mechanism allowed reproducible variation of the adduction force between approx. 0.25 to 4 N. Furthermore, we tested shore A98, 90, 80, and 70 substrates. Positioning of the electrodes was performed manually. The evaluation of wearing comfort was performed using a scale 1-10 where 1 is absolute comfort while 10 is maximum pain. Impedance and force were recorded simultaneously. Comfort evaluation was performed prior and after each measurement.

The mean interfacial impedance for shore A98 electrodes decreased on average from 67 kOhm at 1 N to 36 kOhm at 2N, 30 kOhm at 3N, and 26 kOhm at 4 N at the frontal position. Furthermore, the standard deviation decreased from 34 kOhm to 20 kOhm, 16 kOhm, and 14 kOhm, respectively. Mean impedances on the hairy temporal positions decreased similar from 79 kOhm at 1N down to 21 kOhm at 4 N with standard deviations of 200 kOhm and 11 kOhm, respectively. A similar trend was visible for the other shore values. However, Shore A80 and A70 electrodes showed increased standard deviation and required higher contact pressure. The wearing comfort was best up to 1 N while it in started to decrease to 1.2, 1.7 and 2.1 at 2, 3 and 4 N, respectively.

In summary, a shore hardness of A98 or 90 in combination with contact forces between approx. 2 and 3 N reliably provide sufficiently low and reproducible impedances while avoiding excessive pressure and thus maintaining wearing comfort. This information provides the base for designing future cap or helmet systems enabling comfortable, reliable rapid dry EEG acquisition.

SP134.2 - Wearable Gait Analysis using Vision-aided Inertial Sensor Fusion

Author(s): Eric Ma, Milos Popovic, Kei Masani
Toronto Rehabilitation Institute, University Health Network, Toronto/CANADA

Gait analysis is useful in characterizing impaired gait in patients with various neuromusculoskeletal disorders. Contemporary gait analysis is conducted in a laboratory setting, typically consisting of numerous optical cameras and force plates. However, this setup is restricted to a constrained and artificial testing environment, which may lead to unnatural movements that poorly represent real-world human gait. In recent years, it has been demonstrated that the wearable inertial measurement units (IMU)—composed of accelerometers, gyroscopes, and magnetometers—can be an alternative for gait analysis in natural and ambulatory environments. IMU is capable of estimating the position and orientation of the human body during walking by integrating from acceleration and angular velocity. However, they are prone to unbounded drift due to the integration operation. Additionally, the relative positions of multiple IMUs cannot be accurately estimated using IMUs alone. These limitations prohibit the estimation of the global COP, which is an important gait parameter for the evaluation of postural stability and requires the knowledge of the relative positions of the feet. In this study, we introduced a solution to constrain the integration drift and to obtain the relative position of IMUs using vision-aided inertial sensor fusion.

We proposed a shoe-mounted system composed of two 9-axis IMUs, an IR camera, and a pair of instrumented shoes. Foot orientations and 3D foot travel trajectories were estimated using the IMUs, enhanced using zero-velocity updates and maximum spatial separation constraints. Using the camera on one foot and a four-point LED frame on the other foot, the relative position between the two feet was obtained using a pose estimation algorithm from computer vision. The inertial and vision measurements were sensor fused using an Extended Kalman Filter to minimize the errors in the 3D foot position outputs. The in-shoe COP of each foot was estimated using the instrumented shoes. Knowledge of the 3D foot positions was fused with the in-shoe COP to calculate the global COP. The proposed system estimated the 3D foot trajectories and the global COP. Based on these, the system was capable of estimating for key gait parameters such as step length, stride length, gait phases, and COP excursion. The validation of this system was performed against gait laboratory results for standing and walking tasks.

The proposed system is the first wearable system that provides...
the estimation of global COP during gait. It provides a portable and unobtrusive method of performing lower-limb gait analysis in unconstrained and ambulatory environments, and it may enable new and practical applications in areas of clinical gait evaluation, long-term monitoring, rehabilitation, and sports performance.

**SP134.3 - Two-Vector Capacitive Electrocardiogram Measurement Using Three Fabric Electrodes for Automobile Application**

Author(s): Shunsuke Takayama, Akinori Ueno

Electrical And Electric Engineering, Tokyo Denki University, Tokyo/JAPAN

With a view to applying to driver’s sensing, we propose a method for measuring two-vector capacitive electrocardiogram (cECG) from three electrodes placed on a driver’s seat. The proposed method consists of three techniques of electrode arrangement, circuit grounding and an electrode configuration. The proposed electrode arrangement (see Fig.1) enables detection of biopotentials corresponding to limb lead I, II and III. Also, it has a feature that can keep steady electrode coupling. As shown in Fig.1, two of electrodes were horizontally placed on the right and left side of backrest, and another is placed beneath driver’s left breech. Consequently, three electrodes form a triangle similar to Einthoven’s triangle. The introduced circuit grounding technique is so called virtual middle point. All of three electrodes were used as exploring electrode and connected indirectly to the middle point. Two-vector cECG corresponding to lead I and II can be measured without any ground electrode. This technique has a tolerance to individual vectorcardiographic difference. Fig.2 shows measured two-vector cECG while subject is sitting on the driver’s seat. The employed electrode configuration is composed of fivefold layers of sensing layer, shielding layer, ground layer and insulating layers (see Fig.1). It is reported to have a tolerant with movement artifact. [1]


**SP134.5 - Detection of REM Behaviour Disorder Based on Low-Power Compressive Sensing of EMG**

Author(s): Jeevan K. Pant¹, Mehrnaz Shokrollahi², Sridhar Krishnan¹

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**Background:**

Rapid eye movement (REM)-behaviour disorder (RBD) can be detected by using electromyogram (EMG) signals measured from the chin of the subject. Portable sensors attached to the chin and equipped with wireless transmission capability can be effective for the acquisition of such EMG signals. For durable operation, such sensors are desired to be power efficient. We study a low-power sensing framework based on compressive sensing (CS) for detection of RBD. This framework involves application of the CS technique based on sparse random projection matrix, and application of the CS reconstruction algorithms based on promoting temporal correlation. Classification algorithm used is based on nonnegative matrix factorization followed by kernel-based sparse representation.

**Method:**

The database contained several EMG signals recorded during the period of REM from the persons suffering from the RBD disorder and from those not suffering from it. Each record contained two signals obtained using two sensors placed on the left and right sides of the chin. CS was applied on the difference of the left-chin and right-chin signals with four values of the compression ratio (CR), namely, . Reconstruction of the difference signal was carried out by using the -RLS, -RLS, and BSBL-BO algorithms. The classification algorithm was used to classify whether the reconstructed difference signal corresponded to the RBD disorder or not.

**Results & Conclusion:**

Fig.1(a) shows classification accuracy (CA) averaged over total 10 realizations of the CS measurement matrix, and Fig.1(b) shows variance of CA over the same 10 realizations. As can be seen, approximately 72% average CA of RBD can be attained by applying CS with a compression ratio of 90%. By realizing a CS-based wireless sensor with a CR of 90%, its power consumption can be significantly reduced. Yet, 72% classification performance can be acceptable in various applications, including the one requiring rough estimation of the risk of happening RBD.

Variance of CA for -RLS algorithm is the smallest relative to that for the other algorithms. Thus, the -RLS algorithm offers the most stable classification performance.

Hence, the CS-based RBD classification system can be useful for the development of low-power CS-based sensor for a stable detection of RBD.

![Fig. 1: (a) Average classification accuracy, (b) Variance of classification accuracy.](image-url)
The objective of this abstract is to introduce the effects of externally applied pressure on the skin-electrode impedance for electrodes such as standard Ag/AgCl and orbit electrodes. This issue is of interest because it is one of the factors that affect the quality of signal collected from that electrode. Skin-electrode impedance is modeled as an electrical circuit including a resistor ($R_s$) in series with a parallelled resistor ($R_d$) and capacitor ($C_d$). Skin-electrode impedance is measured by an impedance interface device and a frequency response analyzer.

Pressure is applied with a regular Omron blood pressure cuff. Experiments are done in several trials to verify electrodes behaviour under pressure and their tendency to keep the changes due to applied pressure. Measurement procedure steps are as follows:

a. Two electrodes were placed on the subject’s right bicep at a 7 cm distance from each other and connected to the measurement devices.

b. The Omron cuff was wrapped around subject’s bicep on top of the electrodes.

c. The pressure was set to 0 mmHg or 30 mmHg appropriate for the trial (Table 1).

d. Wait for 1 minute.

e. The impedance was measured.

f. Repeat, starting from step c, until all trials are completed.

Table 1 Cuff pressure per trials

<table>
<thead>
<tr>
<th>Trial</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
<th>T7</th>
<th>T8</th>
<th>T9</th>
<th>T10</th>
<th>T11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cuff pressure (mmHg)</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Results show that skin-electrode impedance of orbital electrodes decreases as pressure increases and after some trials they tend to keep the changes and vary less and less when pressure is applied and removed, whereas Ag/AgCl electrodes variation due to pressure are small and negligible.

Figure 1 Skin-electrode impedance of Orbital electrodes
The world elderly population is growing at its fastest rate ever; by 2050, 2 billion people will be aged over 60. For many individuals, age-related diseases cause cognitive decline and eventually limited functional capacity. Across North America, Alzheimer’s disease (AD) has become the fifth leading cause of death in persons aged over 65 years. In order to tackle these problems, the WHO, together with Alzheimer’s Disease International, have called on governments to implement national dementia plans to improve early diagnosis. In response to this call, several new biomarkers have been found based on expensive equipment, such as SPECT and fMRI. Such equipment, however, is scarce in low- and middle-income countries, as is the availability of trained medical personnel to operate them. Recent projections, on the other hand, suggest that by 2050, 71% of all people with dementia will live in low- or middle-income countries, thus it is crucial that lower-cost solutions be found.

Recently, the authors have proposed a new feature extracted from electroencephalography (EEG) that showed to discriminate healthy elderly patients from patients with AD with over 90% accuracy [1-3]. The proposed features characterize the cross-frequency coupling of EEG amplitude modulations, as detailed in [3]. These previously obtained results, however, relied on 20+ channel EEG systems, which can cost in the order of several tens of thousands of dollars. In this paper, we explore the use of a lower-cost solution, namely the use of the 7-channel portable COGNITION™ system (Neuronetrix, USA). Data was collected across seven centers in the USA during a clinical trial led by Neuronetrix [4]. Eighty-three healthy participants (age: 73 ± 7 years; education: 15 ± 3 years; 49 female) and 93 patients with mild-AD (age: 76 ± 7 years; education: 14 ± 3 years; 49 female) were recruited and performed a 30-minute ERP test followed by a 3-minute resting (eyes-open) period.

Here, fourteen cross-frequency amplitude modulation features were extracted, for each of the seven electrodes, from the 3-minute resting period. Features were extracted after automated EEG artifact removal [1]. A Kruskal-Wallis test with Dunn-Sidak posthoc correction was performed to test the discriminative power of the features. Of the 14 extracted features, six were found to provide significant difference between the two groups across the seven tested electrode sites. Features that resulted in superior separation between the two classes related to beta-theta, alpha-delta, and alpha-theta amplitude modulation couplings. These features coincide with those found with higher-density EEG systems, thus show their importance for AD diagnosis. Such findings suggest that AD risk assessment may be done in-situ not only in some of the poorest countries in the world, but also in remote or rural regions of developed countries that have with limited access to qualified medical personnel. In such cases, remote patient monitoring could play a key role.

References

The Bereitschaftspotential (BP), a negative-slope electroencephalog-raphic (EEG) activity that precedes voluntary movement, is related to the neuronal motor planning and postural control strategies. Generally, this pre-motor potential is generated 2s prior to onset-movement, with predominance over the contralateral motor cortex area. In this study, the influence of cortical dominance was investigated using the BP from 26 healthy subjects (17 right-handed). Mo-tor task consisted of self-paced unilateral shoulder flexion carried out in orthostatic posture with eyes open (in order to minimize alpha activity). During this task, EEG (C3: right shoulder cortical response; C4: the left one), EMG of the anterior deltoid muscle and acceler-activity). During this task, EEG (C3: right shoulder cortical response; C4: the left one), EMG of the anterior deltoid muscle and acceler-meter signal (positioned on the styloid process of the radius) were acquired simultaneously. A set of 100 unilateral movements (50 for each shoulder) and 50 bilateral movements (used as distracter stim-ul) were carried out in random order and distributed into five blocks. An inter-block interval of 3min (subjects resting seated) was used to avoid EEG habituation and muscle fatigue. The BP was estimated by coherent averaging artifact-free EEG epochs, synchronized by the onset-movement detected by the accelerometer. Figure 1a depicts, for a right-handed volunteer, the BP and its PMM (movement-monitoring potential), in which it is noticeable higher slopes and PMM amplitude in the dominant cortex (C3: right shoulder) compared to those of the non-dominant (C4: left shoulder). Besides, the PMM oc-curred previously for dominant cortex. Similar results was observed for left-handed volunteer (Figure 1b). These findings could suggest that the motor planning is related to cortical dominance and there-fore the ability to perform the task with the dominant limb. Neverthe-less, for all subjects, independently on the laterality, the Wilcoxon sign-rank test suggested no difference (p=0.38) between the slopes (and also the PMM amplitudes) for dominant and non-dominant cortices. Moreover, no difference was observed (Wilcoxon p=0.58) in the PMM time occurrences. Besides, regardless the dominant cortex, no difference was observed between right and left-handed volunteers (Wilcoxon-Mann-Whitney, p=0.16). These findings are maybe explained by the inter-subjects variability to plan and perform the motor task. Alternatively, independent on the laterality of the subjects, they indicate no influence of the dominant cortex in the pre-motor potential during unilateral self-paced shoulder tasks.

Cortical processing of visual motion and self-motion sensation has been related to the perception-action cycle during postural control protocol. The dynamic virtual reality stimulation (DS) was employed to investigate postural control response using the motion-related visual evoked potential (M-VEP) and linear vection. The multi-channel electroencephalogram (EEG) and the center-of-pressure (COP) displacement signals were acquired simultaneously during stabili-metric test with DS scenes interspersed by 10s of static scene (SS). The trials from 29 healthy volunteers were performed in orthostatic position on a force platform observing a virtual scene (1.72 × 1.16m) projected 1m ahead and centered at the vision line (visual angle: 0°, 81.4° and 8° = 60.2°). The scenario was moved randomly in forward (DSF) or backward direction (DSB), during 250 ms (velocity: 2m/s), so that the furniture was expanded or reduced, while the chess-board floor, walls and ceiling were moved in parallel direction. For each DS, the luminance varied 2 cd/m². Such dynamic effect was employed to generate an optical flow as a tunnel pattern. Thus, DSF increases optical flow up to the periphery of the visual field. Otherwise, DSB, optical flow decreases. For each subject, the M-VEP was estimated by coherent averaging up to 50 artifact-free EEG epochs, synchronized by the onset of DS. Similar procedure was applied for the COP signal. Figure 1 depicts the grand-averaged M-VEPs (N2 peak dominance) and the COP displacement response due to vection. The running t-test (alpha = 0.05) suggested that there is difference between DSF and DSB M-VEPs 600 ms after DS onset, with an increasing time delay from occipital to central derivations (gray area, Figure 1a). Moreover, considering no significant change in COP displacement just preceding DS (ANOVA, p > 0.8), the DS induced COP displacements in the same direction of the exhibiting scene (Figure 1b, p < 0.001). Therefore, vection is dependent on the DS direction, mainly during DSF, for which the linear vection varies from 72% to 90% (Figure 1c). These findings suggest that the cognitive, planning and motor processing to control balance depends on the DS direction and hence indicate the potential applications of this dynamic virtual protocol in postural control studies.

Figure 1. Coherent average of the spontaneous EEG and task (C3: right shoulder; C4: left shoulder): a) right-handed volunteer (#14); b) left-handed volunteer (#3). The regression line (red) estimated from the minimum of BP (between -2500 and -700ms) and PMM.
SP135.6 - Assessment of Bilateral SSEP Signals Enhancement following Transectional Spinal Cord Injury Using Linear Modeling

Author(s): Hasan Mir1, Hasan Al-Nashashy1, Thow Thow Xin Yuan2, Jukka Kortelainen2, Soo Min Chua2, Janani Manivannan2, Astrid Astrid2, Angelo H. All3

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Introduction: Partial or complete loss of sensory and motor function between the brain and peripheral nerves is a likely consequence of spinal cord injury. However, it has been reported that a certain degree of plasticity in the central nervous system may result in functional recovery. Somatosensory evoked potentials (SSEP) have been used extensively in assessing the functional integrity of spinal cord pathways by examining the reduction or increase in signal amplitude and time latency. In this study, we use linear modeling coefficients values to quantify the degree of relationship between contralateral forelimb SSEP recordings. Preliminary results demonstrate the effectiveness of this method in quantifying the level of similarity between SSEP signals obtained from different limbs.

Protocol: The SSEPs were recorded from 4 epidural screw electrodes implanted to the cranium of 22 rats. The electrodes were located at the specific somatosensory cortex areas of hindlimbs and forelimbs. Dental cement was applied to fix the electrodes to the cranium. Four different types of spinal cord transection injuries were produced, located at either the T8 or T10 of the rat spinal cord: (i) left-hemisection at T8, (ii) right-hemisection at T10 (iii) left T8 and right T10 hemisection and (iv) full transection at T8. SSEPs were recorded from a cohort of 20 animals with 5 animals in each injury type. The SSEP recordings were recorded day 4, 7, 14, and 21 post-injury. The evoked potentials were generated by stimulating the left and right Tibial nerves of the hindlimbs and Median nerves of the forelimbs, one limb at a time, with a pair of stainless steel sub-dermal needle electrodes. The stimulation of each limb was carried out using 150 consecutive current pulses with amplitude of 3.5 mA and a duration of 200 µsec delivered at a frequency of 0.5 Hz. During the stimulation, the SSEPs were recorded with a sampling frequency of 4882 Hz.

Method: The post-injury SSEP signals were modeled as a transformation of the baseline signal. The transformation was assumed to generate from a finite-impulse response (FIR) filter with a sparse set of delays. The solution of the filter coefficients were combined into a single metric, termed the H-index, in order to reflect the level of injury.

Results: Figure shows the H-Index obtained after modeling the SSEP signals recorded from the left cortex (corresponding to LF) after stimulating the RF. The SSEP signals recorded on Days 4 and 7 from the right cortex (corresponding to LF). The x-axis shows the rat number increasing with the level of injury. It is observed that the H index increases with injury level depicting an increased degree of correspondence between signals recorded from left and right sides of the cortex.

SP136 - Brain, Head/Neck, Spine: Part 1

SP136.1 - Photopolymerization device for minimally invasive implants: application to nucleus pulposus replacement

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Photopolymerization is a common tool to harden materials initially in a liquid state. A surgeon can directly trigger the solidification of a dental implant or a bone or tissue filler. Traditionally, photopolymerization has been used mainly in dentistry. Over the last decade advances in material development including a wide range of biocompatible gel- and cement-systems open up a new avenue for in-situ photopolymerization for musculoskeletal, cardiovascular or neurosurgical applications.

However, at the device level, surgical and endoscopic probes need to be developed to deliver the liquid polymer, harden it by light and to monitor that the hardened material has the appropriate property. Here we present a miniaturized light probe where a photocurable material can be 1) mixed, pressurized and injected 2) photopolymerized or photoactivated and 3) monitored during the chemical reaction. The device enables surgeries to be conducted through a hole smaller than 1 mm in diameter. Beside basic injection mechanics, the tool consists of an optical fiber guiding the light required for photopolymerization and also for chemical analysis. Using fluorescence spectroscopy, the current state of the photopolymerization is inferred and monitored in real time.

Biocompatible and highly tunable Poly-Ethylene-Glycol (PEG) based hydrogels were used as injected material. The device was tested on a model for intervertebral disc replacement and hydrogels were successfully implanted into a bovine caudal model. These in-situ photopolymerized implants were evaluated at the tissue level (tissue integration and mechanical properties), at the cellular level (biocompatibility and cytotoxicity) and ergonomic level (sterilization procedure and feasibility study) and thus seem to be a promising alternative to traditionally used tissue and bone fillers.

Currently further promising applications are under investigation. The results will be presented at WC2015.

SP136.2 - Design and Technical Evaluation of an Implantable Passive Sensor for Minimally Invasive Wireless Intracranial Pressure Monitoring

Author(s): Mohammadhossein Behfar, Elham Moradi, Lauri Sydänheimo, Toni Björninen, Leena Ukkonen

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Elevated Intracranial pressure (ICP) is characterized as neurological problem mainly caused as a consequence of traumatic brain injuries (TBI) and cerebrospinal fluid (CSF) circulation disorders. Early detection of increasing ICP is of great importance in management of TBI. The main complications with the existing methods are the risk of infection and hemorrhage due to catheter insertion into the intracranial cavity. To address this issue, battery powered implant-
able wireless ICP measurement devices were proposed. The main drawback of this kind of devices is the increased size of the implants and limited lifetime. Therefore, passive (battery less) implantable sensors are attractive for minimally invasive ICP monitoring.

In this research, we designed and evaluated an implantable passive sensor for continuous wireless subdural ICP monitoring. The sensor consists of a 30-turn spiral loop in parallel with a mm-size (1.4×1.4×0.8 mm³) microelectromechanical systems (MEMS) capacitive pressure sensor forming an LC tank (Fig. 1b). The sensor is made on an ultra-thin (50 µm) flexible polyimide substrate making it minimally invasive for implantation. The pressure sensor is wirelessly interrogated through the near field inductive link between the implantable sensor and an on-body reader coil. The on-body reader coil is connected to a capacitor to form an LC circuit. The two LC tanks form a simple and efficient telemetric system communicating through strong magnetic coupling. Consequently, ICP variation can be detected through: 1) change in the resonance frequency of the implantable sensor, 2) variations of the magnitude and phase angle of the reader coil’s input impedance.

The effect of human skin on the wireless operation was simulated by placing a 5-mm thick pig skin between the sensor and the reader coil (Fig. 1e). The sensor was designed so that the spiral loop is implanted under the skin and the pressure sensor is placed into the subdural space (Fig. 1a). The spiral loop and the pressure sensor are connected through a coaxial cable with the length of 1 cm (Fig. 1c). In order to evaluate effects of the cable on the sensitivity of the pressure readout, we conducted two sets of experiment with and without the cable. The results show that the cable only reduces the pressure readout, we conducted two sets of experiment with and without the cable. The results show that the cable only reduces the sensitivity toward the magnitude and phase angle variation without the cable. The results show that the cable only reduces the sensitivity toward the magnitude and phase angle variation without the cable.

The sensor proved the capability of highly linear pressure measurement ranging from 0 to 70 mmHg at 5-mmHg intervals.

In this study, we investigated the relationship between characteristic features of the extracted field potentials (FPs) of EVestG signal in people with side-impact concussion in comparison to those of control subjects. Our study included 10 side-impact concussed individuals (4 Right side-impact and 6 left side-impact) and 10 age and gender matched healthy individuals as control subjects. We analyzed the EVestG signals recorded during side tilt motion. The results show that the difference between the left and right FP width, is significantly (P<0.05) different between two groups. Figure 1 shows the left-right difference in the area (bounded by the baseline and the action potential (AP) point) of the normalized FPs extracted from acceleration and deceleration phases of the EVestG signals during the side tilt. The features show a clear asymmetry between the left and right side vestibular responses for the concussed but not control group. In 3 out of the 4 right side-impact patients, the FP in the right side was narrower than the left side. In 5 out of the 6 left side impact patients, the FP in the left side was narrower than the right side.

The results of this study is encouraging on the use of EVestG analysis for monitoring the effects of concussion.

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**SP136.3 - Investigating the Feasibility of EVestG Assessment for Screening Concussion**

**Author(s):** Abdelbaset Suleiman¹, Brian Lithgow², Behzad Mansouri³, Zahra Moussavi³

¹Biomedical Engineering, University Of Manitoba, Winnipeg/CANADA, ²Electrical And Computer Engineering, University Of Manitoba, Winnipeg/MB/CANADA, ³Internal Medicine (neurology), University Of Manitoba, Winnipeg/MB/CANADA

In this project we evaluated a new technology, Electrovestibulography (EVestG™) that holds the potential to objectively, quickly and cost-effectively measure both the severity of concussion and quantitatively measure recovery from concussion. EVestG signals are recorded painlessly and non-invasively from the external ear in response to a vestibular stimulus; they are the brainstem sensory oto-acoustic signals modulated by the vestibular response. When concussed, people commonly experience balance (vestibular) problems, dizziness, confusion and memory loss. Considering the well-known bidirectional anatomical links of the vestibular system, it is expected that the EVestG signals will change after a concussion.

In this study, we investigated the relationship between characteristic features of the extracted field potentials (FPs) of EVestG signal in people with side-impact concussion in comparison to those of control subjects. Our study included 10 side-impact concussed individuals (4 Right side-impact and 6 left side-impact) and 10 age and gender matched healthy individuals as control subjects. We analyzed the EVestG signals recorded during side tilt motion. The results show that the difference between the left and right FP width, is significantly (P<0.05) different between two groups. Figure 1 shows the left-right difference in the area (bounded by the baseline and the AP point) of the normalized FPs extracted from acceleration and deceleration phases of the EVestG signals during the side tilt. The features show a clear asymmetry between the left and right side vestibular responses for the concussed but not control group. In 3 out of the 4 right side-impact patients, the FP in the right side was narrower than the left side. In 5 out of the 6 left side impact patients, the FP in the left side was narrower than the right side.

The results of this study is encouraging on the use of EVestG analysis for monitoring the effects of concussion.

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**SP136.4 - Transcranial Direct Current Stimulation of the Rat Medial Prefrontal Cortex: Antidepressant Effects and Regional Brain Changes**

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Transcranial direct current stimulation (tDCS) is a neuromodulation procedure that employs weak DC to stimulate brain regions non-invasively. Its basic design has been investigated for psychiatric disorders, such as melancholic depression, as far back as the early 19th century (Parent, *Can J Neuro Sci* 2004). It has recently regained attention and has been demonstrated to produce some benefits in cognitive performance and psychiatric symptoms (Mondino et al., *Biol Psychiatry* 2014). However its precise therapeutic mechanisms remain unknown. We therefore developed a rat model of tDCS and tested effects in the forced swim test (FST), novelty-suppressed feeding test (NSFT) and elevated plus maze test (EPMT), all of which
predict antidepressant/anxiolytic activity. We targeted the medial prefrontal cortex (mPFC) because clinical and animal studies have shown antidepressant effects of mPFC deep brain stimulation (DBS) (Hamani and Nobrega, *Eur J Neurosci* 2010). We devised a current generator that delivered low power current (0.1 mA) onto a conductive cathodal metal plate (1.5±0.25 x 2.5±0.25mm) fixed on the skull surface over the mPFC (AP+4.7 to +2.2mm; Paxinos and Watson, *The Rat Brain in Stereotaxic Coordinates* 2005). The anodic end was connected to a stainless steel screw lodged behind the cerebellum (AP+18). Animals received sham (n=6) or tDCS (n=6) twice on day 1 and once on day 2 (30 min before behavioural testing). In the FST, stimulated animals exhibited significantly lower (56.16%) immobility episodes (p<0.05), which was not a result of non-specific motor activation, and therefore suggests an antidepressant-like activity. Indeed, motor activity was increased only during stimulation, and not immediately after cessation of stimulation or 5-6 hours after the last stimulation. A non-significant increase in anxiety-like behaviour was observed in tDCS animals in the NSFT and EPMT. Post-mortem brain analyses using in situ hybridization imaging of the immediate early gene zif268, a marker of cell activation, revealed lasting significant increases in neural activity almost exclusively within the target regions. In particular, there was an increase (p<0.01) in the cingulate (Cg), prelimbic (PrL) and orbital (Or), as well as in the insular cortex (Ins) and claustrum (Cl), as indicated in the figure. Together, these data suggest that tDCS can be effectively modeled in the rat, yielding highly selective patterns of brain activation. Furthermore, mPFC tDCS shows antidepressant-like properties, which can further be investigated as a potential non-invasive alternative for mPFC DBS.

**SP137 - SPECIAL SESSION: Building Medical Physics Capacity in Developing Countries**

**SP137.2 - Implementing Training Modules of the Emerald Program in Brazil**

**Author(s):** Ricardo A. Terini1, Paulo R. Costa2, Slavik Tabakov3, Elisabeth M. Yoshimura4, Denise Y. Nersissian5

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**Introduction:** The Leonardo EU project for European Medical Radiation Learning Development (EMERALD) (www.emerald2.eu/cd/EMERALD2/), a Consortium of Universities and Hospitals from many countries, developed three training modules in medical radiation physics: X-ray Diagnostic Radiology, Nuclear Medicine and Radiotherapy. The modules are for the training of graduated university students in Medical Physics (MP) or related disciplines, their tutors, as well as other Hospital employees. The Institute of Physics of the University of São Paulo, Brazil, and the King’s College of London established a research cooperation program to conduct the translation to Portuguese language, adaptation and update of the X-Ray Diagnostic Radiology training module of the Emerald Program. The Emerald teaching material in X-Ray Diagnostic Radiology is divided in ten topics covering the basics of Diagnostic Radiology, Quality Control and Radiation Protection.

**Methodology:** The referred work, besides the translation of the texts into Portuguese, comprised the review of the previously produced material. During the review process, it was decided to update some of the training tasks and add more information related to current topics, such as digital X-ray imaging modalities, multi-slice computed tomography and tomosynthesis. These new additions will also be available in English. The translated or composed texts have been submitted to a cross-reviewing process by the co-authors in order to standardize the language. Moreover, national radiological protection recommendations were included to assist the users of the teaching material with the Brazilian rules of radiation safety and quality control in X-ray medical applications. A Workshop was held in São Paulo in March 2014, to diffuse and discuss a preliminary version of the Brazilian modules, named Emerald-BR. During this meeting, part of the material was submitted to a validation and also to a practical assessment process by means of a critical analysis by experts in Medical Physics education (Fig. 1).

**Results and Discussion:** Finally, a pilot implementation has been organized and scheduled in order to do the last adjustments before making the material available to other users in Portuguese language. Further assessment and feedback procedures were planned in both London and São Paulo, aiming to evaluate and disseminate the final product (*Med. Phys. Int. J.*, v. 2(1), p. 18-21, 2014). Emerald-BR will certainly contribute to the offer of organized training programs in the country (and in Latin America) to the growing number of young physicists starting in Medical Physics area each year in the region.
the residents was employed by the hospitals where they did their residency. Two residents worked for a company providing radiology equipment testing services, three worked for the national regulatory agency for radiation facilities, one worked for another hospital, one taught undergraduate physics, and one was supported by her parents.

Assistance from the IAEA in the form of experts sent to give lectures and to undertake assessment of the residents during and at the end of the residency training were invaluable, especially because none of the supervisors had had previous experience in a structured on-the-job training program.

Three ROMP residents successfully completed the program. Seven out of eight DRMP residents successfully completed the program.

Important lessons have been learned from the pilot. Solutions for the problems encountered have been proposed.
SP138 - Biosensor, Nanotechnology, Biomems And Biophotonics / New Technologies In Cancer Research And Treatment

SP138.1 - Measurement of the Received Power in a Realistic Intrabody Communication Scenario

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In intrabody communication (IBC) the human body is an integral part of the signal transmission channel. Previously, we have measured transmission characteristics of the IBC channel in the frequency range from 100 kHz to 100 MHz using the same network analyzer as the transmitter and the receiver, galvanically decoupled from the IBC channel by two balun transformers. In this paper, a proprietary battery-powered transmitter and battery-powered spectrum analyzer mimicking the receiver are connected directly to the test subject. The received signal power is measured for four electrode configurations (transmitter A - receiver A (AA), transmitter A - receiver B (AB), transmitter B - receiver A (BA), and transmitter B - receiver B (BB)) and eight transmitter-receiver distances along both arms. The results agree qualitatively with the transmission characteristics of the IBC channel. It was also noticed that, especially for some electrode configurations, a standing wave occurs between a transmitter and a receiver along the human body.

SP138.2 - Focused ultrasound-triggered release of Sorafenib from temperature sensitive liposomes for treating renal cell carcinoma

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Specific Aims: High-intensity focused ultrasound (HIFU) emerges as a powerful technology for noninvasive or minimally invasive non-ionizing treatment of cancer. HIFU deposits a large amount of acoustic energy at the focal region within the target tissue (i.e., tumor), causing tissue heating and necrosis. Limited research has been performed applying focused ultrasound, alone or in combination with other therapeutic modalities, to renal cell carcinoma. The aim of this study was to explore focused ultrasound as an adjuvant to chemotherapy; particularly as a method to thermally trigger the release of drug from temperature sensitive liposomes for treating renal cell carcinoma.

Research Methodology: Liposomes were fabricated using Dipalmitoylphosphatidylcholine, L-a-Phosphatidylcholinehydrogenated Soy and Cholesterol at a molar ratio of 70:20:10 using the thin film preparation method. Sorafenib was encapsulated liposomes with HIFU 72hr post-treatment. Thus, focused ultrasound triggered liposomes show significant promise as a feasible strategy for chemotherapy.


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Abstract- In this study, 9 nm superparamagnetic iron oxide nanoparticles (SPION) were functionalized by polyamidoamine (PAMAM) dendrimer. Magnetodendrimer samples were conjugated by gold nanoparticles (Au-NPs) using two reducing agents of sodium borohydride and hydrazine sulfate. Presynthesized 10-nm Au-NP were used to evaluate the efficiency of conjugation method. Laser Induced Fluorescence Spectroscopy (LIF) of these materials showed that the nanocomposite and magnetodendrimer have the fluorescence properties covering the whole range of visible spectrum. For targeting and the biocompatibility, the synthesized materials were conjugated by folic acid molecules. Laser-induced hyperthermia using Au-NPs was performed. The samples were characterized using X-ray diffractometry (XRD), transmission electron microscopy (TEM), Fourier transform infrared (FTIR) spectroscopy, UV-Visible spectroscopy, and fluorescent spectroscopy. Two cell lines of breast cancer, i.e. MCF 7 and MDA MB 231, were chosen for cytotoxicity evaluation of the synthesized nanostructures. The Results indicated a high biocompatibility of nanoparticles (up to 50 µg/mL).
A miniature, integrable surface plasmon biosensor using a dielectric sub-micron diameter core utilizes a noble metal spherical shell structured with a subwavelength nanoaperture believed to excite stationary surface-plasmon-resonances at the biosensor’s surface. The sub-micron cavity enhances the measurement sensitivity of bonding molecules to the sensor surface. Visible range spectroscopy is used to study the wavelength shift as bio-molecules absorb/desorb at its surface. The microcavity surface plasmon resonance sensors (MSPRS) were used to analyse conformational changes of bound biomolecules as the oxidation state changes. Present work uses Scanning Electron Microscopy (SEM) and Focused Ion Beam (FIB) to study the characteristics of MSPRS using a novel fabrication technique.

The MRT trials for animal pets as tumor patients required substantial work for developing, upgrading and progressively implementing instrumentation, dosimetry protocol, as well as the crucial patient safety systems. Progress on the homogenous dose measurements using ionisation chambers and Alane dosimetry as well as the comparison of high resolution dosimeters with the dose calculations based on a novel tumor planning system will be summarised. A general overview on the different achievements will be presented as well as a vision for possible human trials.

SP139.1 - Toward super-resolution imaging of proton radiation-induced DNA double-strand breaks for characterization of γ-H2AX foci clusters

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Repair kinetics assays can be used to characterize the sensitivity to radiation for patients that require radiotherapy as a treatment option. γ-H2AX foci assays have been recognized as one of the most powerful techniques to characterize the repair kinetics properties of radiation induced damage to DNA. The interests in these assays are the rate at which radiation-induced foci disappear, which is presumably related to the rate of DNA damage repair, and the foci size, which is related to the clustering complexity of the DNA damage. Both aspects are interconnected by the fact that larger foci take longer time to disappear, meaning that the larger the clustering the slower the repair rate. Therefore, it is important to understand both aspects in order to understand repair kinetics effects, especially after radiotherapy with particles high linear energy transfer (LET), such as protons. Due to much higher damage density in the DNA in the case of irradiation by protons compared with the case of irradiation by particles with low LET, using high-resolution microscopy to enhance the imaging resolution for γ-H2AX foci characterization is desirable.

Foci counting and size measurement is usually performed by optical microscopy, however, the far-field spatial resolution of any standard lens-based optical microscope is limited by the wavelength of imaging light (λ) and by the numerical aperture (NA) of the lens system due to diffraction of light waves. A variety of imaging techniques have been developed in the past to overcome the diffraction-limit in optical microscopy; most of these techniques, however, have complex design and high economic cost, and require scanning across the specimen that increases the acquisition time.

In this work, we investigated a novel simple super-resolution imaging technique for application in γ-H2AX foci characterization. We fabricated super-resolution microscope coverslips composed of barium titanate glass microspheres (Diameters ~30-150 µm and refractive index ~1.9-2.1), fixed in a polydimethylsiloxane (PDMS) elastomer layer, to collect high spatial frequency harmonics present in the optical near-field of the object and transmit them to the far-field with magnification providing high imaging resolution. When the super-resolution coverslip is placed over the specimen, each microsphere forms a magnified virtual image underneath the specimen’s surface that is simply captured by the objective lens.

We used microsphere-assisted imaging technique for the observation of double-strand DNA breaks, manifested as foci using an immunofluorescence treatment, in U87 glioblastoma cells irradiated by proton beams. Our results indicate magnification and resolution advantages of microsphere-assisted super-resolution imaging over conventional fluorescent microscopy. Our imaging method is a promising candidate in developing various applications in biomedical imaging and nanophotonics.
SP139.2 - Solution of radiative transport equation in turbid layered media in spatial and frequency domains  
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Study of light transport in turbid media has many applications in biomedical imaging and therapeutic research. Although approximate diffusion solution is widely used to circumvent difficulties in exactly solving for the radiative transfer equation, seeking exact solution is still interesting biomedical optics community as it not only serves as a benchmark for Monte Carlo (MC) simulation, but also well describes light transport in the region where diffusion theory falls (in high absorption region). This abstract obtains exact solutions for two layered media in spatial and frequency domains. Monte Carlo method has been employed to verify the obtained solution. The turbid medium consists of a top layer with the absorption and scattering coefficients 0.02/mm and 1.3/mm, and a bottom layer with the absorption and scattering coefficients 0.01/mm and 1.2/mm. The thickness of the first layer was 2.0 mm. The second layer is much thicker than that of the first one and can be considered as semi-infinite. The refractive index of the medium was 1.4. Anisotropic factor in Heneyy-Greenstein phase function is 0.9. The source beam was incident perpendicularly on the top layer with no lateral dimension. Exact solution of RTE was obtained through the method of rotated reference frame (MRRF) as demonstrated in previous literatures. In this method, all quantities were expanded in terms of the spherical harmonics which was defined in a coordinate system, whose z axis coincided with the direction of the wave vector k. The solutions can be expressed with eigenvalues and eigenvectors of a series of infinitely-dimensional matrices in an analytical form. In practice, sufficiently accurate solutions were obtained through truncating those matrices to finite dimensions. Spatially-resolved reflectance, photon density waves at 100MHz modulating frequency (amplitude and phase shift) were calculated using the exact solution and were successfully verified by Monte Carlo methods.

SP139.3 - Development of a hybrid optical-gamma camera: A new innovation in bedside molecular imaging  
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**Introduction:**

A novel prototype compact hybrid optical-gamma camera has been developed through collaboration between the Space Research Centre at the University of Leicester and Medical Physics at the University of Nottingham. This system offers high resolution gamma imaging together with real-time optical imaging for use at the patient bedside or in the operating theatre. This presentation describes the innovative design characteristics and the first results of use in the clinical setting.

**Material and Methods:**

The camera comprises of a CsI(Tl) columnar scintillator coupled to a charge-coupled device (CCD), a tungsten pinhole collimator and an optical camera. Both optical and gamma cameras are co-aligned to allow accurate fusion of images. The camera can be mounted on a trolley with flexible articulated arm for hand free use. A qualitative user survey was carried out to obtain feedback for optimising ergonomic factors for use of the camera and trolley system in the clinical environment. A sentinel node phantom was fabricated using polymethyl methacrylate (PMMA) to validate the performance of the camera for sentinel node localisation in the presence of high activity at the injection site.

12-20 MBq sources of Tc-99m were used to simulate radioactivity at the injection site and lymph nodes with the node-to-injection site activity ratios of between 1:100 and 10:100. These were placed at different separations and depths to simulate the uptake at different anatomical sites in the body.

The first patient studies using the hybrid camera were carried out in the Nuclear Medicine Clinic at Queen’s Medical Centre, Nottingham.

**Results:**

The system spatial resolution, system sensitivity and energy resolu-
tion of the camera system with 0.5 mm diameter pinhole collimator was 1.28 mm (@ 13 mm), 214 cps/MBq (@ 3 mm) and 58 % (full width half maximum at 141 keV) respectively. Phantom simulations revealed that the camera system could detect low-activity in nodes up to the depth of 45 mm from the phantom surface by visual examination of images. Overall the user feedback indicated satisfactory design of the bedside trolley system and influenced the final design of the camera head casing, mounting and arm assembly. The initial patient studies included bone, lymphatic, and lacrimal drainage investigations. These showed that the hybrid images provided good evidence of localisation of radiotracer distribution with reference to the visible anatomical features, thus aiding the diagnostic utility.

**Conclusion:**

A novel hybrid optical-gamma camera system has been developed, characterised and the first studies performed in the clinical environment. This system would be ideally suited to use in operating theatre for procedures such as sentinel node detection and tumour localisation. This system offers potential for use with the new generation of hybrid fluorescent-radionuclide tracers currently under development.

**SP139.4 - Sidestream Dark-Field Oximetry with Multicolor LEDs**  
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We investigate the possibility of oxygen saturation (SO2) estimation from images obtained by the sidestream dark-field (SDF) technique. The SDF technique is a noninvasive optical technique allowing direct visualization of microvessels near tissue surfaces.

To advance the capability of the SDF technique, we develop an image-based oximetry method with the SDF technique (SDF oximetry) with LED illumination sources. This method is based on the Lambert-Beer’s law with dual-wavelength illumination. For establishing the method, we developed a trial SDF device used multicolor light-emitting diodes (LEDs) (peak wavelengths: 470 and 527 nm) to obtain two-band images. Figure 1 shows the configuration of our trial device and microvessel images.

![SDF Device Configuration and Microvessel Images](image1)

In this study, we propose a SDF oximetry method with the trial device and report evaluation results of the validity of the method. As an approach to verify the method, we performed both a Monte Carlo photon propagation simulation and experiments with a phantom and in vivo small intestine of a pig. In the phantom experiment, we tested the proposed method with a phantom made of agar and 10% Intralipid. In order to simulate vessels, glass tubes filled with bovine blood were embedded just below the surface of the phantom. Figure 2 shows the phantom, the SDF images, and SO2 estimation results with different internal-diameter tubes. From the results, we found that there was strong correspondence between estimated SO2 values and measured values by a blood gas analyzer. This result suggested the validity of the proposed SDF oximetry method. Moreover, we estimated SO2 of microvessels near the surface of the small intestine of a pig. Although the validation of the experiment is still under study, the results of the validation and computer simulation will be presented at the conference.

**Conclusion:**

A novel hybrid optical-gamma camera system has been developed, characterised and the first studies performed in the clinical environment. This system would be ideally suited to use in operating theatre for procedures such as sentinel node detection and tumour localisation. This system offers potential for use with the new generation of hybrid fluorescent-radionuclide tracers currently under development.

**SP139.5 - Development of Polymer Substrates for Waveguide Evanescent Field Fluorescence Microscopy**  
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False color representation of a dye distance map with four osteoblasts. The inset represents an overexposed Waveguide Evanescent Field Fluorescent (WEFF) Microscopy image of the same field of view. Osteoblasts appear at dye/plasma membrane distances between ~ 75 to 110 nm. Dye locations very close to the surface, adhesion areas, are labeled blue. Both scale bars represent 50 μm. The color bar shows a range from - 50 nm to 200 nm. One pixel is equal to $(0.266 \ \mu m)^2$.

WEFF Microscopy was developed recently to image ultra thin films (quality control) and to investigate adhesions of cells to substrates and to produce quantitative distance maps of the plasma membrane to the substrate.

A key component in WEFF microscopy is the glass substrate optical
Previous work has shown a better growth of cells on polymer substrates. Therefore, the objective of this study is the development and fabrication of polymer based substrates with similar characteristics to existing glass substrates.

Polymethymethacrylate (PMMA) substrates were fabricated by hot embossing a coupling grating from a master silicon mold, and subsequent spin coating of OrmoCore, a photoresist, or alternatively polystyrene serving as waveguides. The master mold was fabricated by spin coating Shipley 1805 photoresist on a silicon wafer followed by laser interference lithography implementing the grating pattern. Photoresist gratings were developed and oxygen plasma cleaned before preforming reactive ion etching to embed the structure within the silicon.

The correlation between the embossed substrate and the silicon mold grating constant was examined with scanning electron microscopy: taking the variations of temperature, the time and process pressure into consideration. The results determined a set of parameters for PMMA substrate fabrication, and demonstrated that the same quality of coupling gratings can be achieved as seen in existing glass substrates. The next step is the fabrication of optical quality polymer waveguides on top of the PMMA substrate to start imaging fixed and living cells.

WEFF microscopy could have many applications, especially in the field of tissue engineering, cellular biology and implant development. Paving the rode for mass production of WEFF substrates and to foster WEFF microscopy, spreading it among optical microscopy users which will be able to upgrade their existing microscopes to a surface sensitive tool and extend research capabilities without major modifications, is the driving force and importance of this work.

Septins belong to a family of GTP-binding structural proteins that are thought to have various functions in mammalian cells including acting as scaffolds for protein recruitment, forming diffusion barriers, and participating in cytokinesis. Defects in Septin organization have been linked to hereditary neuralgic amyotrophy and several types of cancers. During interphase, these heterooligomeric complexes colocalize with F-actin stress fibers and have been shown to stabilize their formation through direct interaction with non-muscle myosin II. However during cytokinesis septin complexes maintain NM II association and form characteristic higher order ring structures at the midbody scaffold to facilitate cell division. The structural versatility of septins is likely directly related to their many roles yet the organizational motifs by which oligomeric building blocks form filaments and higher order structures has not been elucidated in mammalian cells. In addition, their intricate spatial relationship with F-actin and myosin is of great interest in understanding the formation of stable cytoskeletal stress fibers. To address these questions, we used the sub-diffraction imaging technique dSTORM (Direct Stochastic Optical Reconstruction Microscopy), one of several recently developed methods of super-resolution microscopy. Also known as nanoscopy, it has revolutionized the optical study of proteins and cellular processes by achieving resolution below 20 nm, and its implementation is at the crossroads of cell biology, biomedical engineering and computer science. We report two-colour dSTORM imaging of Septin2/Septin9 in filament and ring structures and characterization of their periodic structural contribution in human fibroblast cells using AlexaFluor 647 and ATTO 532 on a custom-built combinatorial microscopy platform. To gain insight into septins’ role in nanoscale cytoskeletal protein organization, an array of two colour superresolution imaging was carried out on combinations of septin proteins, F-actin and non-muscle myosin II isoforms A and B and discrete nanoscale spatial arrangements were characterized.
SP140.1 - Credentialing of radiotherapy centres in Australasia for a phase III clinical trial on SABR
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Aim
Stereotactic Ablative Body Radiotherapy (SABR) is a relatively new treatment modality that utilises image guidance, motion management and many small often non-coplanar radiation beams to deliver high biological doses of ionising radiation in very few fractions. A randomised phase III clinical trial comparing SABR with conventional radiotherapy for early stage lung cancer in peripheral location is running in Australia and New Zealand under the auspices of the Trans Tasman Radiation Oncology Group (TROG). As SABR technology at the commencement of the trial was new to most participating centres a credentialing program was developed for centres wishing to join the trial.

Methods
The credentialing program was developed using a prospective risk management approach. Key elements include the ability to create a plan that meets all dosimetric constraints, the dose calculation in the presence of inhomogeneities and the management of motion. Participating centres were asked to develop treatment plans for two test cases made available in DICOM format, and inhomogeneity corrections and dose delivery was assessed during a site visit using a phantom with moving inserts as shown in figure 1.

Results
Site visits were conducted in 20 radiotherapy facilities. All centres were able to produce acceptable plans for both test cases using 54Gy in 3 fractions, or for lesions close to the chest wall, 48Gy in 4 fractions. The tests with lung and air inhomogeneities confirmed known shortcomings of the AAA algorithm for dose calculation behind the inhomogeneity. The dose was assessed in the phantom using an ionisation chamber and radiochromic film both in a stationary and moving cylinder as shown in figure 1 (sinusoidal motion, 1cm amplitude, 4s period). These measurements including at least one non-coplanar beam, confirmed in an end-to-end test that all participating centres were able to treat a lesion with the required accuracy. The site visit took 3 hours of linac time and was well received by participating staff proving to be a useful step in the process of developing a SABR program.

Conclusion
The credentialing process based around a site visit documented that participating centres were able to deliver dose to a phantom as required in the trial protocol. It also gave an opportunity to provide education about the trial and discuss technical issues such as 4D CT, small field dosimetry and patient immobilisation with staff in participating centres.

Acknowledgement: We would like to acknowledge the financial support of the study through Cancer Australia

SP140.2 - LED-optimized SBRT for Peripheral Early Stage Lung Cancer: A technique to reduce lung dose and potentially allow for re-irradiation
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Introduction
Stereotactic Body Radiation Therapy (SBRT) is a treatment option for early stage lung cancer. Initial reports suggest local control rates comparable to surgery (87.2%, 3 years). Survivors are at risk of developing a second primary lung cancer (SPLC) at a rate of approximately 3% per year. Patients with recurrent disease or SPLC may benefit from a second course of SBRT, but normal lung dose may limit retreatment. Recently, we developed LED-optimized SBRT (LED-SBRT), which exploits lateral electron disequilibrium (LED) to produce steep dose gradients at the tumor/lung interface. Here, we demonstrate that LED-SBRT can potentially reduce normal lung dose to avoid possible toxicity from re-irradiation.

Methods
Ten early stage lung cancer patients, with peripherally located disease, were retrospectively selected at random. Time-averaged 4-Dimensional CT image sets were acquired with a Philips 16-slice helical CT scanner. For each patient, two treatment plans (Pinac® TPS) were created for comparison: 1) a 6MV 225° VMAT plan (control), and 2) a 6MV 180° arc LED-SBRT plan (field size = 2x2 cm²). An internal target volume (ITV) was created to account for tumor motion due to breathing. Two planning target volumes (PTV) were created: PTVVMAT = ITV + 5mm, and PTVLED = ITV + 2mm. A reduced margin was used for PTVLED to accommodate a smaller field size. Plans were generated using the collapsed-cone convolution algorithm, and dose was normalized such that 95% of the PTV received at least the prescription dose (i.e. 54Gy/3fractions or 60Gy/8fractions).

Results
The LED-SBRT plan created a steeper dose gradient at the tumor/lung interface (see Figure 1), which reduced normal lung dose. For example, the average percent reduction [(LEDSBRT – VMAT)/VMAT x 100%] in the mean lung dose, V5, and V20 were 27.4+/-11.9%, 25.0+/-8.5%, and 35.1+/-11.9%, respectively, averaged over all pa-
tients. On the contrary, the PTV hot spot and mean dose increased on average by 86.4 +/- 32.5% and 45.1 +/- 11.9%, respectively.

Conclusions

LED-SBRT can be used to reduce normal lung dose, and may allow for retreatment of small peripheral early stage lung lesions. As this technique relies on small field sizes (< 3x3 cm<sup>2</sup>) and reduced target margins, advanced forms of image-guidance, gating, and/or tracking must be implemented for tumor targeting. Furthermore, only those algorithms that model electron transport must be used to ensure dose accuracy in regions of severe LED. With these precautions, LED-optimized lung re-irradiation could prove to be clinically viable for re-treatment situations.

SP140.3 - Delivery of VMAT treatments with nonstandard SAD using dynamic trajectories

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Introduction: The Varian TrueBeam<sup>TM</sup> offers an optional research mode that permits dynamic control over many of its radiation and mechanical systems. Translational couch motion can be programmed in synchrony with gantry rotation to emulate treatment at either shortened or extended SADs. Shortened SADs offer the benefit of an increased dose rate and better dose conformity to the target volume due to the decreased leaf projection size, while extended SADs allow for increased field sizes and can obviate the need for field junctions (for example in cranio-spinal irradiation).

Materials and Methods: Water tank measurements were used to commission an 85 cm SAD and a 120 cm SAD beam model in the Varian Eclipse<sup>™</sup> treatment planning system. For each beam model, reference dosimetry (AAPM TG-51) and beam validation tests (IAEA TRS 430) were performed. A total of 9 VMAT treatment plans were generated (four at 85 cm SAD, five at 120 cm SAD) and exported from Eclipse<sup>™</sup> to DICOM-RT plan files. A software routine was developed in Python using the pydicom library (v0.9.8) to convert the plans into an .xml-formatted file for delivery with the TrueBeam<sup>™</sup> research mode. To emulate nonstandard SAD delivery on a conventional SAD linear accelerator, translational couch motion was added to move the treatment couch in a circular trajectory as a function of the gantry and couch rotation angles, and the MLC leaf and jaw positions were scaled by the ratio of conventional to nonstandard SAD. Ionization chamber and Gafchomnic EBT3 film measurements were used to record point dose and planar dose distributions for comparison with corresponding dose calculations in Eclipse<sup>™</sup>. MATLAB software was written to generate gamma index comparisons with the Eclipse-exported dose planes.

Results: The beam models for both 85 cm SAD and 120 cm SAD agreed with measurement to within 1% for in-field profiles and PDDs beyond dmax for all field sizes. For profiles in penumbra and out-of-field regions, agreement was mostly within 5%, with some exceptions reaching up to 10%. Validation measurements indicated good agreement between measurement and Eclipse<sup>™</sup> calculation. Ionization chamber measurements for the treatment plans at 85 cm SAD yielded an average agreement of -3.9±2.0%; Eclipse<sup>™</sup> underestimated the measured dose in all cases. With 120 cm SAD, the average agreement for four of the five plans was -0.33±0.55%, with an outlier measurement of -7.4% for ionization chamber positioned in a steep dose gradient area. Ignoring out-of-field regions, the film gamma index pass rates for all treatment plans at both SADs were above 90%.

Conclusion: Dynamic couch trajectories were used to emulate nonstandard SAD delivery on the Varian TrueBeam<sup>™</sup> STx with VMAT treatment plans, yielding good agreement between Eclipse<sup>™</sup> treatment planning system dose calculations and both ionization chamber and film measurements. Discrepancies included a systematic underestimation of the delivered dose compared to measurement at 85 cm SAD, and poor agreement for one measurement located in a high dose gradient region at 120 cm SAD, but relative dose distributions showed good agreement as evidenced by the gamma index analysis of film measurements.

SP140.4 - Cone-Beam CT assessment of inter-fraction and intra-fraction motions during lung stereotactic body radiotherapy with and without abdominal compression

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Purpose/Objective(s): The purpose of this study is to assess the effect of abdominal compression on the inter-fraction and intra-fraction variations for lung stereotactic body radiotherapy (SBRT) using cone-beam computed tomography (CBCT).

Materials/Methods: Sixty-nine lung stereotactic body radiotherapy patients were investigated in this study. The patients were separated into two groups, one with abdominal compression, and the other without abdominal compression. Seven to nine conformal beams were used for SBRT treatment plans. The prescriptions doses were 50 Gy in 5 fractions or 48 Gy in 4 fractions. At each treatment, two CBCTs were performed before and during the treatment. Set-up errors were measured on the first CBCT, which were recorded as inter-fraction variation. Tumor movements during treatment were measured by the second CBCT during treatment, which were recorded as intra-fraction variation.

Results: For intra-fraction variation, the shifts ≥ 3 mm for “abdominal compression” group were 12.0% in AP direction, 4.6% in SI direction, 5.0% in LR direction, corresponding to 17.3% in AP direction, 21.2% in SI direction and 11.5% in LR direction respectively, for the group “without abdominal compression” For inter-fraction variation, The shifts ≥ 5 mm for “abdominal compression” group were 22.8% in AP direction, 22.8% in SI direction, 24.9% in LR direction, corresponding to 15.4% in AP direction, 48.1% in SI direction and 15.4% in LR direction, respectively for the group “without abdominal compression”. Abdominal compression reduced breathing organ motion during SBRT lung treatment in all three directions. However, setup error was just reduced significantly in SI direction for abdominal compression group. There is a slightly increase for setup error in AP and LR direction for abdominal group. Both inter-fraction and intra-fraction variations had been greatly reduced in SI direction after abdominal compression was applied.
Conclusion: Abdominal compression reduced the amplitude of intra-fraction lung breathing motion in all directions during lung SBRT treatment. However, the use of abdominal compression seemed to increase the inter-fraction variation in AP and LR directions although the inter-fraction variation in SI direction was reduced significantly. Therefore, target matching is required to localize the inter-fraction variation.

SP140.5 - Initial experience in establishing frameless intra-cranial stereotactic radiosurgery program with Varian TrueBeam STx, 6DoF couch and VisionRT motion control system

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Implementation of a stereotactic radiosurgery (SRS) program requires linac and TPS commissioning, selecting planning and delivery techniques, "end-to-end" treatment delivery verifications for clinically appropriate treatment scenarios, establishing planning and imaging protocols (including planning CT and MRI, pre-treatment position verification and image-based intra-fraction monitoring). The program must also include SRS-specific daily and monthly QA procedures (on top of regular machine QA) as well as pre-treatment patient dose verification.

Commissioning of the TrueBeam STx linac and Eclipse TPS was performed keeping in mind its intended use for both intra- and extra-cranial treatments; therefore the beam model was tuned to cover small as well as medium VMAT/IMRT fields. Micro-diamond detector was used in beam data collection in the range of field sizes from 1x1cm² to 22x40 cm².

Conformal, conformal arc, IMRT and VMAT techniques were evaluated, and VMAT was the method of choice for the majority of cases due to its versatility and capability of combining steep dose fall-off with fast delivery. We anticipate mostly using co-planar treatments with 6MV and 10MV-FFF beams and simultaneous dose delivery to multiple targets.

End-to-end target localization and dosimetry tests were performed using a customized anthropomorphic head phantom with imbedded tungsten bead and an insert for the detector. Treatment plans for localization tests were created with the isocentre of circular conformal fields positioned on the bead. CBCT imaging was used for moving the phantom to treatment position. Portal images were then taken for each field, and offset of the beam axis from the bead was measured. For dose verification the center of calculated dose distributions was positioned at the measurement point of micro-diamond detector, and measured dose was compared to TPS calculation. QFix S-Frame Aqualast (3.2mm thick) head immobilization mask is also being evaluated for intra-fraction motion control by acquiring CBCT images pre and post treatment from CNS patients enrolled in this study.

For patient-specific dosimetry QA we intend to use in-house EPID-based 3D dose calculations as well as Monte Carlo calculated dose, reconstructed from trajectory files. Isocal calibration that confirms the congruence of imaging and treatment isocentres will be performed pre-treatment.

Anticipated work-flow of the SRS treatments involves patient CT and MR imaging, treatment planning, patient-specific QA, pre-treatment daily SRS-specific machine QA. During treatment CBCT images will be used to move the patient to the treatment position and to verify the move. Optical image will be captured by VisionRT system (not installed yet) immediately after verification CBCT and will be used to insure no motion during treatment. Once the treatment completed, trajectory log files will be saved for dose reconstruction.

So far results for the mask immobilization intra-fraction were acquired for 3 patients and showed a mean intra-fraction motion of 0.7mm and a maximum of 1.1mm. Localization tests confirmed the beam axis to be within 0.5 mm from the bead target. Dosimetry verification tests showed good agreement (within 2%) of planned and measured dose for targets of 10 mm diameter and larger. For smaller targets the measured dose exceeded the plan by as much as 11%.
The work is supported by the German government BMBF (no. 03Z1N511).

Purpose: Even if the calculation is done for plane-parallel chambers, the result is valid if the repetition rate is less than 1.2 times the inverse collection time. This new formula contains the two existing descriptions for exposure by single pulses and continuous irradiation as limiting cases.

Method: The process of charge collection and recombination between two pulses was described for a plane-parallel ionization chamber with a differential equation system. This differential equation system was solved by assuming simplified charge distributions and calculating the first terms of series expansion at recombination. The resulting complex formula for the correction term was simplified for easier handling and discussion.

Result: A formula describing the collection efficiency of plane-parallel ionization chambers in pulsed fields with arbitrary repetition rate was developed which allows calculating the exact amount of recombination. This new formula contains the two existing descriptions for exposure by single pulses and continuous irradiation as limiting cases. By comparing the dependency of the new formula with the different dependencies on chamber voltage for the two existing cases, it was possible to determine the pulse rate range for which each of the three descriptions is applicable.

Discussion: As long as the time between two pulses is lower than one third of the collection time of the chamber, the collection efficiency can be very well described by the description for a continuous exposure. The description for single pulse irradiation is only possible to determine the pulse rate range for which each of the three descriptions is applicable.

Result: A formula describing the collection efficiency of plane-parallel ionization chambers in pulsed fields with arbitrary repetition rate was developed which allows calculating the exact amount of recombination.

Discussion: As long as the time between two pulses is lower than one third of the collection time of the chamber, the collection efficiency can be very well described by the description for a continuous exposure. The description for single pulse irradiation is only possible to determine the pulse rate range for which each of the three descriptions is applicable.

Conclusion: The new method is suitable for in-vivo dosimetry in therapeutic electron beams with arbitrary pulse rate, for which the prerequisites of the two existing descriptions are not fulfilled. Furthermore, an extension of the validity of the two existing cases is investigated.

REFERENCES:


SP141.3 - Photon and electron spectra inside small field detectors for narrow and broad 6 MV photon beams

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To investigate differences in detector response with respect to field size and detector type, photon and electron fluence spectra were calculated inside eleven small field detectors and in a small volume of water in narrow (0.5cm x 0.5cm) and broad (10cm x 10cm) Varian Clinac 6 MV photon beams. The usercode PenEasy, based on the PENELOPE MC system, was used to simulate three ionization chambers (IBA-CC01, PTW-T31016, PTW-T31018), two diamond detectors (PTW-T60003 and PTW-T60019), and six silicon diodes (IBA-EFD, IBA-PFD, IBA-SFD, PTW-T60016, PTW-T60017, PTW-T60018). This work follow the calculations in Benmakhlouf et al. 2014 Med Phys. This compilation of detectors include air and liquid ion chambers, natural and synthetic diamond detectors, shielded and unshielded silicon diodes of different sizes, all of interest for small field dosimetry.

Peaks in the photon spectra were found in all silicon diodes at energies between 22 keV and 26 keV due to characteristic x-rays emitted from some detector components surrounding the active detector volume. An additional very large peak was found (for both fields) in the shielded IBA PFD diode due to the emission of characteristic x-rays from the dense shielding material surrounding the diode. The photon fluence spectra inside the detectors for both field sizes were in general similar to the photon fluence spectra in water except for the shielded silicon diodes (in the case of the broad beam as expected) where the shielding causes a significant reduction of the fluence at low energies. The electron fluence spectra inside the ion chambers and diamond detectors were close to that in water whereas large differences between the detector spectra and water spectra (up to 50% difference) were found; the difference increased with decreasing field size due to lack of charged particle equilibrium.

The MC-calculated doses for both field sizes were compared to analytically determined collision kerma and restricted cema using the scored fluence spectra. The collision kerma was always larger than the MC-dose for the narrow beam due to lack of lateral charged particle equilibrium whereas the restricted cema (based on a common cutoff value of 15 keV for all detectors) was smaller and larger than the MC-dose (within ±2%) depending on the detector type and field size. The differences increased with decreasing field size.

SP141.4 - Real Time Dose Reconstruction in MV Photon Therapy using a 2D solid state detector array.

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Introduction: Real time verification of the dose delivered during the patient treatment is important step for quality assurance in IMRT and VMAT. We have developed such a system based on a solid state transmission 2D detector array called “Magic Plate”.

Purpose: We study the performance characteristics of the MP system operated in Transmission Mode(MPTM). Of particular interest is to quantitatively demonstrate direct dose reconstruction for different field sizes in a phantom based on the response of the MPTM.

Methods and Materials: The MPTM was positioned in the block tray of a linac so that the central detector of the array lies on the central axis of the radiation beam. The response of the central MPTM diode was compared with depth dose distribution along the central beam axis in a phantom for field sizes ranging from 5x5 cm² to 40x40 cm² to determine a conversion factor from measured diode response to dose in the phantom, which is independent of the field size. The same conversion factor is used for all diodes in the 2D array to reconstruct the dose along rays projected from the source through each detector and into the phantom, at any depth of interest.

Results: The optimum(i.e. independent of field size) response-to-dose conversion factor for the central diode of MPTM was found at a depth of 1mm in the phantom. Figure 1(a) shows a comparison of the measured and reconstructed dose profiles in the phantom for several field sizes. Figure 1(b) demonstrates that for all detector in-field elements in the 2D array and all field sizes that the 2D reconstructed and measured doses in a phantom at depth of Dmax agree to within ± 2.48%(2 SD). Both in and out of field PDD change is less than 1% with the MP in place.
SP141.5 - Energy Correction factor for Plane Parallel ion-chamber and its Use in Clinical photon Beam Dosimetry

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Purpose:

Plane Parallel ion-chambers are recommended as reference dosimetry for photon beam measurements. In dosimetry protocols, experimental values of energy correction factor available for a particular chamber can compare with theoretical calculation considering perturbation factors. However, for Plane parallel chamber, energy correction factor are not available as they are not recommended for photon beam due to the relatively large uncertainty in the wall perturbation factor. Brag-gray theory and Spencer–Attix water/air stopping-power ratios, $s_{\text{w,air}}$, of beam qualities $Q_a$ and $Q_o$, are employed in this study to investigate the energy correction factors for plane parallel chambers considering the perturbation factor of the specific chamber in high energy photon beams.

Material and Method:

Water phantom RFA-300, Exradin A19 farmer chamber, PPC-40 Roos, and Standard imaging Max 4000 electrometer were used. Using TRS-398 and Spencer Attix data available in TRS-277 protocol, values of perturbation factor are calculated with high statistical precision for Plane parallel chamber for both 6 and 15 MV photon beams. The dependence of perturbation factor on the beam quality are also studied.

Result and Discussion:

The variations of beam quality index for “PPC-40Roos” from “Exradin A19” were very much lesser as 0.0026 (or 0.39%) and 0.0022 (or 0.29%) for 6 and 15 MV respectively. This result indicates that the responses of both the chambers are within acceptable limit of 1%. Energy correction factors $K_{QQo}$ for PPC-40Roos which was determined theoretically and experimentally shows that the variation between theoretical and experimental for PPC-40 Roos was very much less as 0.5% and 0.08% for 6 and 15 MV respectively. Variation of 0.5% and 0.09% of absorbed dose was observed for 6 &15 MV respectively between theoretical and experiment values of
Conclusion:

The appropriate selection of the reference point of plane parallel chamber is an important issue. If it is accounted correctly then $P_{dis}$ would be almost independent of depth. With precise calculation of perturbation factor, energy correction factors of PPC-40 for higher beam energy can be determined theoretically and compared with experimental value, obtained a good result which is within 0.5%. So, PPC-40 Roos can be recommended for dosimetry of high energy photon beams after considering specific chamber perturbation factor.

SP142 - Light Ion Radiotherapy

SP142.1 - Proton Minibeam Radiation Therapy (pMBRT): implementation at a clinical center

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Purpose

The more selective energy deposition of protons in depth is advantageous compared to photons to preserve normal tissues. Nevertheless, an even better tissue sparing might be possible in proton therapy if combined with the well-established tissue preservation of spatially fractionated submillimetric beams. This sparing effect has been observed in studies performed with synchrotron minibeam radiotherapy (MBRT) [1,2].

The innovative approach proposed here, called pMBRT, was shown to provide favourable dose distributions in Monte Carlo studies [3]. The dose profiles in normal tissue consist in peaks and valleys, while the tumour receives a (quasi)-homogenous dose distribution [3]. The goal of this study was to verify the technological feasibility of creating minibeam in a clinical environment and to evaluate their dosimetric aspects.

Material and methods

The implementation of pMBRT was carried out at the ICPO. To generate minibeam patterns, collimators with micromillimetric line apertures were manufactured. Gafchromic EBT3 films were irradiated in water phantoms by an array of 100 MeV protons (700 μm-wide) minibeam. Depth dose distributions and lateral dose profiles were studied. Relevant dosimetric parameters in spatially fractionated techniques, namely peak and valley doses and their ratio (PVDR) [4], were assessed. Beam penumbras and output factors were also evaluated.

Results

The technical implementation met pMBRT dosimetric specifications. A spatial fractionation of the dose was obtained in normal tissues (PVDR up to 7) while a quasi-homogeneous dose distribution was reached at the Bragg peak location (see figure 1), in agreement with theoretical predictions [3]. The reduced penumbra (600-1100 μm) in healthy tissue make pMBRT a good candidate for radiosurgery applications.
Hadron MBRT combines the advantages of MBRT with the high dose conformability and the remarkable biological effectiveness of hadrontherapy. This novel strategy might guarantee tissue recovery and reduce the side effects of radiation in healthy tissues. The main goal of this study was to explore this new approach from dosimetric point of view and to verify its technical feasibility at a clinical center (Heidelberg Ion Therapy Center, Germany). In particular, carbon and oxygen minibeams were studied.

Materials and Methods
Carbon and oxygen minibeams were generated through a tungsten multislit collimator with line apertures of 700 µm-wide separated by 3600 µm. Several beam spots were used to cover a given irradiation field size (1x1 cm²) and a spread out Bragg peak (SOBP) region of 5 cm at 8 cm-depth in water. Radiochromic films (EBT3) were placed at several depths in a solid-water slab phantom to evaluate dose distributions. Quenching effects of these films were also assessed and results were accordingly corrected. Metal Microstrip and Micropixel (TimePix) detectors were explored for beam distribution measurements [4].

As a figure of merit, the ratio between the central dose of one minibeam (peak dose) and the dose in the middle of two consecutive beams (valley dose) was evaluated. This magnitude, named peak-to-valley dose ratio (PVDR), is a very relevant magnitude in such spatially fractionated techniques [5].

Results
The measured lateral dose profiles in carbon and oxygen MBRT consisted in a pattern of peaks and valleys, which prove the technical feasibility of this approach. This first dosimetric study showed PVDR values around 10-20 in the first centimeters of the phantom. PVDR values progressively decrease up to around 5 at 8-cm-depth. These PVDR values are in the order of the ones obtained in x-rays MBRT, for which biological effectiveness has already been proven. Finally, Metal Microstrip and Micropixel (TimePix) detectors have demonstrated excellent performance measuring PVDR values, in agreement with radiochromic films.

Conclusions
This is the first exploratory study that experimentally proves the technical feasibility of hadron MBRT at a clinical center. The PVDR values obtained showed the potential of this radiotherapy approach, which might allow to reduce side effects in the healthy tissues. Animal experiments are warranted.

References
For radiation treatment of cancer, proton therapy efficacy is limited by range uncertainty. The ability of protons to deliver substantial dose at the Bragg peak is a benefit that improves localization, but it also magnifies the risk of range uncertainty; over- or undershooting the target drastically changes the delivered dose. In-vivo proton range monitoring has the potential to eliminate range uncertainty and the associated risks. The measurement of sound waves generated by proton beams (protoacoustics), is an undeveloped technique with potential for in-vivo range verification. Similar to thermoacoustics, protoacoustic emissions are generated because the energy deposited by pulsed proton beams is converted into heat, which causes expansion and emission of pressure waves.

Previous work has established the viability of protoacoustic range verification under ideal conditions. Simulations with 5 mm diameter, 1 µs proton beams have shown that protoacoustic measurements can determine the Bragg peak position to 1 mm accuracy. Previous experiments with fast, <1 µs rise-time proton pulses have measured the acoustic signals. Simulations and experiments under non-ideal, common clinical conditions are still lacking. Here, through Green’s function based numerical simulations of 5 mm diameter pencil beams, we assess the challenges to translating protoacoustics into the clinic, where proton currents are often limited to nanoamperes and proton pulse rise-times are in the 10’s of microseconds.

Based on the simulation results, the protoacoustic signal amplitude is linearly proportional to the current and weakly dependent on the rise-time. A current of 300 nA is expected to generate ~0.1 Pa, which is at a level that is measurable with commercially available detectors. As the rise-time increases from 1 to 40 µs, the pressure amplitude drops by 20%. The most significant observed effect of increasing rise-time is a broadening of the protoacoustic signal, which decreases the time-of-flight range-verification accuracy from 1 mm (1 µs rise-time) to greater than 1 cm (40 µs rise-time). For a homogeneous medium irradiated with 5 mm diameter beams, the simulated signals have frequency spectra centered at 80 kHz (1 µs rise-time) and 5 kHz (40 µs rise-time). Although clinical proton beam characteristics limit the protoacoustic amplitude, simulations predict that protoacoustic signals are detectable under clinical conditions. Long proton pulse rise-times degrade the accuracy of range calculations based on simple time-of-flight calculations, suggesting that multiple measurements or comparisons to modeling are necessary to improve accuracy.
Methods

The 3DMD has a XY-stage with high precision and a range-compensator is attached to the XY-stage. Two CCD laser displacement sensors were employed to measure the height of each point of the range-compensator by detecting reflected laser. We verified some range-compensators.

Results

Due to the shape there were some points which cannot be measured, but the ratio of the number of the unmeasured points to that of all points was less than 1%. The precision of the measurements by the 3DMD was within less than 0.1 mm, and the concave positions were verified as acceptable. It took less than 20 minutes to measure and verify all points of the large patient compensator such as 20 cm x 20 cm x 15 cm.

Conclusion

After further commissioning of the 3DMD, we plan to use this device to check the range-compensators routinely.

References

SP143 - Radiotherapy and Guidance

SP143.1 - Sliced Mary: a deformable phantom for the validation of set-up based on surface imaging in radiotherapy treatments

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Ionizing radiation is generally used to check patient setup in radiotherapy treatments but data concerning patient position can also be derived using surface imaging (SI) systems. The absence of additional radiation exposure and the execution rapidity make this approach particularly interesting. The main drawback of these techniques consists in the worse accuracy caused by the deformation of external body surfaces. As deformable image registration algorithms could potentially solve this problem, some SI developers have included elastic deformation tools in their software. In this work a deformable phantom, suitable for SI acquisition, and with internal tissue contrast for both kilovoltage (kV) and megavoltage (MV) imaging modalities has been developed to evaluate deformable image registration algorithms. The phantom consists in 33 slices of expanded polystyrene slabs shaped thus to simulate part of a female body. Anatomical details, simulating ribs and spinal cord, together with internal targets are included in thorax and abdominal parts. Two mammalian prosthesis and two objects, simulating arms, were fixed to the phantom which was finally covered with a white Ly-cra tissue. Independent and realistic head rotation, arms flexion as well as body torsion around a longitudinal axis and bending around lateral and vertical axes can be achieved. A preliminary test to assess the deformable phantom usability was performed. The elastic registration algorithm implemented in C-RAD Catalyst software was tested by applying to the phantom different head and arm rotations and comparing SI and portal imaging (PI) registration results.

SP143.2 - Evaluation of ion chamber response in high dose per pulse electron beams of IORT accelerator using EGSnrc Monte Carlo code

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Introduction: The use of high dose per pulse electron beams produced by mobile dedicated linacs for intraoperative radiotherapy (IORT) has been increasing in recent years. The dosimetry of such beams requires particular care when performed by ionization chambers. A delicate aspect in this respect is the determination of the factor, ks , that corrects for ion recombination in the irradiated chamber. There are some methods and studies in evaluation of Ks for the purpose of application in IORT fields. One of the standard methods in dosimetry is the Monte Carlo (MC) simulation. In this study, we evaluated the response of parallel plate chamber response in high dose per pulse electron beams of dedicated IORT linac using MC simulation.

Material and Methods: The following MC calculations are performed with the EGSnrc user codes. The BEAMnrc code was used for linac head modeling and DOSRZnrc was used for tuning of the relative and absolute dosimetry. In evaluation of relative dosimetry gamma-index was used. The criteria for this purpose was selected 2% (Dose Difference) and 2mm (Distance To Agreement). In the tuning of the virtual linac for absolute dosimetry, we used the fact that linac was tuned to deliver the 1 cGy/MU in the depth of maximum dose (Dmax). The dose of the monitor chamber of the linac was used as a normalization point and application of MU in dose calculations. The geometry of ion chamber in water phantom and dose in sensitive volume of the chamber was simulated using CAVITY. CPP code. The correction factors of chamber such as Pcav , Pwall , and absolute dose in Dmax was calculated in this code. Finally, the absolute dose value using this code was compared by experimental data.

Results: There was good agreement between experimental and simulated relative dosimetry. More than of 95% of gamma values were passed in evaluation of relative dose comparisons. The experimental measurements using ion chamber were performed in Dmax. The correction factors of chambers (Kq, Kp) was done using IAEA-TRS398. The Ksat in experimental measurements were performed by Laitano method. The chamber response in experimental measurements was 0.994 cGy/MU whereas the simulated value for chamber without and with applying the Kwall and Kcav was 0.9374297±0.21% and 0.993072951±0.3% cGy/MU, respectively. The discrepancy between the measured and experimental response of chamber was about 0.09%.

Conclusion: One of the uncertainty sources in high dose per pulse electron beams in dedicated IORT linac is determination of Ksat. In this study, we showed that the response of parallel plate chamber using mentioned correction factors has a good response in high dose per pulse electron beams of dedicated IORT linacs.

SP143.3 - Compared QA of APEX Radiosurgery System using ARCHECK Phantom in Dynamic Conformal Arc System and VMAT System

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Purpose

In this study, we estimated the accuracy and usefulness of APEX system for the radiosurgery with the use of the ArcCHECK phantom in dynamic conformal arc therapy (DCAT) and volumetric modulated arc therapy (VMAT) system.

Material and Method

We used the ArcCHECK phantom and APEX system. When APEX system which is mounted to the gantry is rotating, we compared DCAT and VMAT System. MONACO (ver. 3.3) was utilized as a radiation treatment planning system (RTPs). APEX system has the micro multi leaf collimator (mMLC) with leaf thickness of 2.5 mm. INFINITY Tx Machine was used. We performed two different techniques for the comparison. One is DCAT plan and the other is VMAT plan. In order to evaluate the APEX system, 3D gamma analyses were conducted using 3% / 3 mm and 2% / 2 mm criteria.
RESULTS
The difference between the DCAT and VMAT plans was found to be less than 3%. Also, the 3D assessment showed a significant difference between the DCAT and VMAT (both gamma pass rate of above 98% with 3% / 3 mm criteria, both gamma pass rate of above 95% with 2% / 2 mm criteria).

CONCLUSIONS
DCAT plan can not modulate the intensity of radiation while the gantry is rotating. And mMLC shape and gantry rotating speed is fixed at the each control point. However, VMAT plan can modulate the intensity of radiation through the optimized mMLC shape and gantry rotating speed. Therefore, our results show that the VMAT plan is superior to the DCAT plan. We conclude that APEX system should adapt the VMAT system for the accurate radiosurgery.

SP143.4 - Head and Neck CT/CBCT Deformable Registration for Image-guided Accurate Radiotherapy System ARTS-IGRT
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Objective: Deformable image registration (DIR) between the planning CT and the daily cone-beam CT (CBCT) played a key component in image-guided radiation therapy (IGRT). The traditional DIR algorithms, such as Demons, failed in CT/CBCT image registration due to CBCT worse image quality and intensity inaccuracy. The purpose of this work was to develop a CT/CBCT DIR method for ARTS-IGRT prototype system and implementation GPU in CUDA programming environment.

Methods: Our algorithm tried to correct CBCT intensity value in the processing of symmetric Demons registration. CBCT intensity value was corrected based on that of the corresponding CT, because of the relative better image quality and more accurate intensity value of CT. The algorithm was carried on as follows: (1) CT and CBCT images were split into several disjoint tissues by intensity histogram matching, image label was assigned to voxel according to the intensity value and spatial neighboring voxels. (2) The deformation field was calculated by the displacement field formula of symmetric force Demons. (3) CBCT intensity value was corrected voxel by voxel. There didn’t exist a global intensity correspondence in light of all voxels of CT and CBCT. We firstly modeled the intensity correspondence by linear polynomial model; and further interpolated the intensity values where the voxel pairs were at the same tissue to estimate those of voxel pairs consisting of different tissue type, because over-correction will appear for different tissue type voxel pairs. (4) CBCT was rescaled and a new deformation field was calculated with the corrected CBCT and the deformed CT, then returned to (3) for the next iteration.

Results: Registration tools were tested for head-neck images. From the result of symmetric Demons algorithm, we can found that anatomical structures in the deformed CT were significantly distorted due to CBCT intensity inconsistency, especially in those regions with severe scatter artifacts. Our algorithm yielded undistorted deformed CT that matched well with corrected CBCT. The performance was also quantitatively evaluated by normalized mutual information (NMI), the average NMI increased to 0.68±0.02 and the computational time decreased to 50 seconds for the image size of 256x256x49.

Conclusions: We implemented an effective intensity correction based CT/CBCT DIR method. CT/CBCT was considered as monomodality image after CBCT intensity correcting and the corrected CBCT with better image quality could be used for radiotherapy such as inter-fractional setup error correction and replanning.

Keywords: Image registration; Demons algorithm; Cone-beam CT; Intensity Correction; Image guided radiotherapy
SP144.1 - Estimation of dorsiflexion torque from a mechanomyogram using a Kalman filter
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A mechanomyogram (MMG) is a vibration detected on a skin surface with a displacement sensor or an acceleration sensor. Measuring an MMG is easier than measuring dorsiflexion torque because sensors are simply fixed on the skin's surface. The measurement technique does not require the restriction of human motion. An MMG is a signal that reflects mechanical properties of muscle and subcutaneous tissue. We assume that an MMG contains a signal from muscle contraction as a low-frequency component and noise from subcutaneous tissue as a high frequency component. We propose a method for estimating dorsiflexion torque from the mechanomyogram smoothed by using a Kalman filter. Six healthy male subjects participated in the experiments. A subject sat on a chair, and his thigh and leg were immobilized with nylon belts. His foot was fixed on the equipment to measure the dorsiflexion torque during isometric contraction. First, the dorsiflexion torque was measured by applying a transcutaneous electrical stimulation to the common peroneal nerve with Ag-AgCl surface electrodes. The system from the electrical stimulation to the dorsiflexion torque was identified by the singular value decomposition method, and the system, control, output, and feed-forward matrices of the state-space equations were calculated. Then, a Kalman filter was constructed using the matrices. Second, the subject was instructed to perform a task while tracking a target dorsiflexion torque displayed on a screen in front of the subject. The torque was approximately 50% of the maximum voluntary contraction. The onset and duration of the contraction were random. The MMG of the tibialis anterior muscle was measured with a laser displacement meter. The neural action potential was measured for 60 s with the Ag-AgCl electrodes, which were used as stimulation electrodes in the first experiment. The EMG of the tibialis anterior muscle was also measured to compare the proposed method to the conventional method of using the root mean square of the full-wave rectified EMG (EMGrms). The signals were sampled at 2,000 Hz and stored on a PC. The MMG was smoothed with a Kalman filter constructed by the matrices of the state-space equations of the dorsiflexion torque. Here, the neural action potential was used as an input signal to the system. We regarded the smoothed MMG as the extracted dorsiflexion torque from the MMG. The time course and frequency response of the extracted torque and the EMGrms were compared to those of the observed dorsiflexion torque. The observed torque was approximated well by the extracted torque as compared to the EMGrms in both the time and frequency domains for all six subjects. In conclusion, a noble method of extracting the dorsiflexion torque from the MMGs was proposed in this study. The method provided a better approximation of the dorsiflexion torque as compared to the conventional method that uses EMGrms.

SP144.2 - Upper-Limb Force Modeling using Rotated Ensembles with Fast Orthogonal Search on High-Density Electromyography
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Robust estimation of net limb forces has a plethora of important applications. However, the most reliable methods are invasive and not feasible in most cases. The use of surface electromyography (EMG) for estimating muscle forces is non-invasive, and generally unobtrusive. However, many physiological and non-physiological factors limit the precision of these methods. The rich spatiotemporal information collected from high-density surface EMG (HD-EMG) grids has been used to mitigate the problem; however, the instability of electrode-skin contact for these systems creates outlying channels, which may lead to substantial error. We build non-linear predictors on rotated ensembles, which when aggregated provide robust and highly accurate (RMSE < 2.6%) estimation of the force induced at the wrist under isometric contractions.

SP144.3 - MMG detection of intentional movement in the presence of dyskinetic movements
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Cerebral palsy (CP) is a permanent disorder that affects an individual's development of movement and posture and is characterized by the presence of variable involuntary movement that may affect the individual’s desire to communicate and interact with their surroundings. Assistive technologies may enable individuals to perform functional activities such as communication (Tai, Blain, and Chau 2008, 204-219).

One of the access pathways commonly used for assistive technologies is muscle activity. Muscle activity can reflect the condition of muscles as well as reveal the underlying user intention. While EMG is widely used in many fields for the study of muscle activity, the mechanomyogram (MMG) is gaining popularity in biomedical engineering applications. MMG is a technique used to study the mechanical activity of muscles which arises from the lateral oscillation of muscle fibers during active voluntary contraction (Posatskiy and Chau 2012, 320-324; Uchiyama and Miyazaki 2013, 461-464; Islam et al. 2013; Kim et al. 2008, 33-42; Orizio 1993, 201-243; Jaskólska et al. 2007, 336-347).

This research intends to answer the following question:

In what ways can information about muscle contractions be combined to enhance the detection of intention amid dyskinetic movements beyond that achievable by conventional agonist-based detection?

This study has two main objectives: first, to detect the contribution of task muscles in a reaching movement in children with DCP, and second, to combine information from a group of task muscles to enhance the detection of movement intention.

We are recruiting a control group of typically developing children and a group of children and youth with dyskinetic cerebral palsy between the ages of 8 and 18. MMG signals are simultaneously recorded using a tri-axial accelerometer placed on the surface of the skin of 6 muscles (flexor, extensor, biceps, triceps, anterior deltoid and pectoralis major) involved in the reaching and drawing task. Participants are asked to perform horizontal and vertical lines on a tablet for a period of 25 minutes. The signal has been processed by wavelet analysis decomposition and denoising in order to filter out gross motor movement. The mother wavelet used for this analysis is Daubechies 10. Preliminary data collected from participants has shown that Singular spectrum analysis (SSA) is a promising noise reduction technique to determine muscle contraction, onset time of contraction, and offset time of contraction.

In order to achieve objective 2, we will develop a model to predict movements with varying number of MMG inputs. Possible mod-
els will include an artificial neural network with time series inputs (Specht 1990, 344-353). We will compare the predictability of a movement while changing the number of MMG signals used for input data.

Children and youth with physical disabilities could benefit from the use of MMG as an access technology system. However, there is not enough research on the adequate use of MMG on children with dystkinetic movements. This project aims to evaluate the information from task muscle contractions during a reaching task in order to enhance the detection of intentional muscle activity in the presence of dystkinetic movements.

**SP144.4 - Dynamic Noise Reduction in Accelerometer-based Mechanomyography during Pediatric Gait**

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Neurological lesions result in a loss of motor and sensory function needed to effectively produce complex movements. The patient’s adaptability to these dysfunctions depends on their substitution for missing afferent information; therefore, measuring impaired muscles during gait may provide a pathway for redefining that functional movement. Mechanomyography (MMG) is a method for measuring muscle activity, contraction timing, and providing biofeedback [1]. However, research in MMG has been limited to simple contractions because the muscle signal is lost within motion artifacts from gross limb movements during dynamic activities [1].

Improving the signal-to-noise ratio of MMG is important because of the overlapping frequency content of both motion artifact and useful muscle information [1]. Although microphone and coupled transducers have been suggested for measuring MMG in dynamic environments [2, 3], this study will focus on improving accelerometer-based MMG by developing noise reduction and feature extraction techniques that have been previously utilized [4, 5]. Wavelet-based methods have been successful in de-noising and detecting muscle contractions; however, they have not been implemented in dynamic environments. Therefore, the main objective of this study is to optimize accelerometer-based MMG during gait.

MMG data will be collected from 100 healthy pediatric participants (ages 8-18) during self-paced gait using tri-axial accelerometers. MMG will be measured at four muscle locations (i.e., tibialis anterior, medial gastrocnemius, vastus lateralis, and biceps femoris). Electromyography (EMG) data will be simultaneously collected from the same muscles and used to validate MMG muscle activity. Once the sensors have been attached, participants will be asked to walk at their typical pace around a track for 15-minutes. MMG and EMG data will be bandpass filtered, then wavelet-based denoising will be applied to the MMG signals to isolate muscle activity. Feature extraction algorithms will then be applied to identify muscle contractions. We will further use this MMG data to characterize the sequence of coordinated muscle activations and derive stride intervals for fractal analysis. Initial results indicate that wavelet-based denoising is a promising method for isolating muscle signals from noise and singularity analysis has been successful at identifying bursts of muscle activity. We hope that by improving MMG noise reduction methods in dynamic activities, we can utilize MMG for fractal analysis of gait and as a biofeedback tool in gait rehabilitation settings.

**References:**


SP145 - Developing Tools for Successful Aging: Independent Mobility & Visual Impairment

SP145.1 - Aging Successfully at Home: Research and Development to Address the Biggest Challenges Older Adults Face

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Idapt, Toronto Rehab Institute, Toronto/ON/CANADA

Learning Objectives:

1. To support older adults living in their homes we need to find better ways to prevent falls while encouraging safe mobility and preventing injury in caregivers. We can do this through the development of new products and policy changes.

2. Researchers need to stay involved with the product ideas they develop to ensure they get on the market. The passion and vision behind a disruptive product can be lost if intellectual property is transferred to a centralized technology transfer office.

3. The use of simulators allows for efficient and safe iterative testing of new products/policy changes.

Abstract:

Older adults often do not have the tools they need to age successfully in their own homes. Our team develops products and policies to overcome the biggest barriers to growing older in place.

Our team includes clinicians (OTs, PTs, nurses), technical experts (industrial designers, machinists, engineers) as well as trainees. We work closely with commercial partners and policy makers throughout the development process to ensure products/policies get taken up quickly.

We use a series of simulators to safely evaluate products with target users in challenging conditions ranging from a cold, snowy winter day to cramped home to a patient’s room in a hospital. Three projects will be described that demonstrate our development process:

1. It is difficult for consumers to assess the performance of footwear - most marketing information available to consumers is misleading. We have developed a method for accurately measuring footwear slip resistance by having participants walk on ice and snow covered surfaces to determine the maximum angle that each type of footwear can achieve (Figure 1).

2. Development of the MoveEasy Pole System (Figure 2): An affordable, modular system of pressure-fit vertical grab poles and clip-on horizontal rails. The MoveEasy system can be easily installed using pressure-fit poles in areas where the user needs support without permanently modifying the home (no screws or nails are needed).

3. Caregiver back injury prevention with a novel patient lifting tool called SlingSerter (Figure 3) that removes the need to turn/log-roll patients when inserting a sling under them. This device makes using a patient lift effortless even with very large bariatric patients.
SP145.2 - The effect of age and previous exposure to slippery surface on gait adaptation

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1Engineering Science, University of Toronto, Toronto/CANADA, 2Technology Lab, Toronto Rehab, Toronto/ON/CANADA, 3Surgery, University of Toronto, Toronto/CANADA

Introduction

Falls are a leading cause of injury in Canada [1]. Many falls result from slipping on ice [2]. Humans adapt their gait when exposed repeatedly to a postural challenge or in anticipation of a slippery surface to prevent injury [3]. It is unclear whether individuals will continue to employ gait adaptations when moving from a slippery to a non-slippery surface. This study examines the gait adaptations of both young and older adults after walking on ice to understand the preventative strategies adopted.

Methods

Twelve younger adults (7 females-5 males; 19-34 years) and twelve older adults (8 females-4 males; 65-78 years) participated in this experiment. Harnessed participants walked along surfaces made of concrete (baseline surface) and wet ice, both 4m by 0.5m. Reflective markers on the footwear and pelvis were used to quantify kinematics using motion capture system before and after walking on a wet-icy surface. All participants wore the same winter boots and walked at a preferred self-selected pace. All variables were analyzed with a mixed model repeated measures ANOVA, with significance defined as p<0.05.

Results

Younger participants demonstrated significant decrease in adaptive gait changes in floor foot angle (FFA) and anterior-posterior distance from the pelvis to the heel (PHAP) at heel contact, and step time between both baseline surfaces (Table 1). Age was not found to have a significant effect on the change of any of the gait parameters. A decreased FFA is often associated with hazardous slips, indicating a more conservative gait strategy [5] and possibly a mechanism to prevent backward falls.

Discussion & Conclusion

Younger participants showed adapted gait strategies after walking on a slippery surface, demonstrating the preservation of adaptations when walking on a non-slippery surface. Age was not found to be a significant factor; only young adults altered their gait to prepare for future surfaces. The alteration was small but statistically significant. Further research is required to investigate whether this conserved gait strategy represents a large enough modification to be beneficial in preventing future falls and moreover, understanding the implica-

References


SP145.3 - An intelligent rollator for people with mobility impairment

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Assistive technology for the mobility impaired includes canes, wheelchairs and walkers. The walker is a very common mobility device and is used by approximately 0.7 percent of the population according to statistics for US in the mid 1990’s. Corresponding statistics for Sweden show almost 4 percent in 2003. More than 47,000 accidents related to falls associated with walkers and canes occurred in the US 2009. Apart from direct costs related to the accidents, increased and safer usage of walkers will delay transition of the elderly people to nursing homes considerably. Hence, technical improvements of walkers can lead to large cost savings for society, in addition to greater convenience and safety for the users. Possible improvements include support for collision avoidance, automatic braking, navigational support, and additional functionality like automatic parking. Navigating walkers in small passages and doorways are regarded as particularly problematic.

We describe the development of an automated walking aid, an intelligent rollator (IRO). While walkers strictly do not have wheels, and rollators do, the two words are often used interchangeably. We refer to IRO as a rollator, while other walking aids most often are referred to as walkers. IRO functionality for indoor and outdoor use includes detection and avoidance of corners, doorposts, furniture and other obstacles. The IRO rollator is a retrofit on a commercial four-wheeled rollator. The added equipment comprises rollators (Rebel and Carl-Oscar, Human Care), an embedded computer (Arduino Mega 2560), two electrically controlled solenoid brakes (Multicom MCSMT-3257L 12STD), rotation hall sensors on the wheels (Allegro Microsystems A3423) and a series of IR-distance sensors (Sharp GP2Y0A02). The sensors are used to detect obstacles and direction of motion, and brakes are used to influence the direction of motion. The distance reported by each distance sensor is compared to the nominal distance determined from reflection against a surface (wall or floor). A shorter distance indicates presence of an obstacle such as a wall or piece of furniture. Negative obstacles such as curbs and holes in the ground cause the distance to be longer than normal and can be detected in a similar fashion. The information from the sensors is used to control the brakes and thereby affect the direction of motion. A detected obstacle to the left causes activation of the right brake, causing the rollator to turn away from the obstacle if and when the user continues to push the rollator forward. This passive control mechanism leads to safer usage. Detection of an obstacle straight in front of the rollator will activate both brakes such that the rollator rather stops than turns. The design also includes a novel approach to detect and prevent sideways drift that may occur both indoors and outdoors. Our approach to use a
commercially available rollator as base, and low cost components with low power consumption is believed to enable an affordable and useful product for the health care market. Preliminary testing on healthy subjects and patients with stroke in a controlled indoor and outdoor environment shows promising results.

**SP145.4 - Rehabilitation Engineering: A review of current teaching tools ad project based learning**

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Many of Ontario colleges are developing an applied research capacity to participate in industrially relevant R&D activities. The key drivers for Canadian biomedical industry are the aging population, managed care/cost containment, and miniaturization of devices and equipment. Taking into account that only a few formal academic rehabilitation training programs exist in Ontario, rehabilitation engineering was identified as a key area for potential expansion. While “learning by doing” is a popular mantra at many engineering schools, many experts agree that it needs to be formally reinforced through project based learning (PBL). Tools exist for teaching biomechanics and robotics and these have resulted in “Lego Mindstorms” and means for teaching hepatics. A project based educational paradigm is currently being used to design assistive rehabilitation devices (Roach et al., IEEE Pulse 51). A review of currently available teaching tools, and our experience with the project based education in rehabilitation engineering, will be presented.

**SP145.5 - Effects of sloped icy surface on older adults’ gait in a simulated winter environment**

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Introduction

Falls and fall-related injuries among older adults are a significant and growing public health concern. Fall-related injuries among older adults are associated with adverse weather events[1]. Slips and falls occur more frequently while walking up and down slopes[2]. However, older adults’ balance and gait on icy slopes have not been examined. This study investigates how older adults alter their gait on icy slopes.

Methods

This study was conducted in WinterLab (Challenging Environment Assessment Laboratories). The ice walkway was 4m long by 0.5m wide and 7 incline angles were tested (-7.1°, -4.8°, -2.9°, 0°, +2.9°, +4.8°, and +7.1°). A positive angle denotes walking uphill, negative angle denotes walking downhill. All 12 able-bodied older adult participants (65-78 years; 4 male, 8 female) wore the same type of winter boots and walked at their preferred self-selected pace. Step length, step width, step speed and cadence were calculated using an operation method that improves the accuracy of a white cane target recognition. The primary purpose of using a white cane is to be able to detect street conditions and obstacles based on the reverberations and tactile information that is gathered from the tip. But some users reported being able to differentiate between specific kinds of materials and objects. All data were analyzed across 7 slope angles with a mixed model repeated measures ANOVA (p < 0.05).

Results & Discussion

During uphill walking on the icy surface, as the angle of incline was increased, older participants increased their step width and decreased their cadence, step length and walking speed (Figure 1) to avoid a slip[3]. However, during downhill walking, when the incline angle increased to 7.1°, older adults increased their cadence significantly but did not change their walking speed. Moyer et al.[4] showed that hazardous slips were associated with greater step lengths and decreased cadence, and that walking with increased cadence was beneficial when anticipating a slippery floor [5]. Older participants appeared to intuitively increase their cadence and step width while decreasing step length, in order to negotiate the most slippery condition (downhill at 7.1°).

**Conclusion**

Spatiotemporal kinematic data were measured and analyzed for 12 able-bodied older adults walking on level, up and downhill slopes. A similar data set has not been previously reported for a cohort on this range of inclines on an icy surface. When walking on the sloped icy surface, older adults adopted different strategies for uphill and downhill walking. Additional research is needed to determine if this gait speed control strategy is effective for reducing slip events.


**SP145.6 - Judging Weight of an Object by a White Cane**

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The purpose of this study is to collect basic knowledge to develop an operation method that improves the accuracy of a white cane target recognition. The primary purpose of using a white cane is to be able to detect street conditions and obstacles based on the reverberations and tactile information that is gathered from the tip. But some users reported being able to differentiate between specific kinds of materials and objects. Allowing the recognition of target attributes through the contact of a white cane is an important function. In training courses for the visually impaired, three methods...
are taught for holding a white cane: 1) stretch the index finger across the flat face of the grip and lightly hold the grip with the thumb and other three fingers, 2) hold the grip like a pen or pencil, and 3) press the thumb on the flat face of the grip and hold the grip with the four fingers. Different methods can be selected based on the circumstances. In this study, to understand a weight perception using white canes, we compared using a hand pushing and using a white cane without accompanying auditory information. And to examine the influence of a manner to grasp a white cane on object’s weight perception, we compared the three methods for holding a white cane. Participants were sighted university students. They gave magnitude estimates for six weights that changed by 100g from 500g to 1,000g. Results indicated that using a white cane produced higher sensitivity level than using a hand. Therefore, using a white cane enhances the information of object’s weight. And the difference of sensitivity for weight perception was caused by manner to grasp the white cane.

In the third world and sodium azide (a herbicide) extensive use in the farms have necessitated this study. **Purpose:** This research is designed to investigate the effect of low dose DDVP (dichlorvos) and sodium azide co-administration on some bone biochemical parameters (calcium and phosphate) of Albino rats bearing in mind the rising cases of chronic arthritis and deformities. **Method:** Seven groups of five rats each were used for the study. Group A was used as control and received no chemical treatment, groups B and C were injected with 1% and 3% LD50 of sodium azide respectively, while groups D and E received 1% and 3% LD50 of DDVP respectively. Equally, group F received combined doses of 1% LD50 of DDVP and 1% LD50 of Sodium azide while group G received 3% LD50 of DDVP and 3% of LD50 Sodium azide. The chemicals were administered at alternate days for twenty one days. At the end of twenty one days study period, the animals were anesthetized with chloroform and blood were aspirated through cardiac puncture into empty clean 5ml containers and then allowed to clot. The serum were then separated and frozen before calcium and phosphate estimations were carried out. **Results:** The two dose levels of sodium azide did not produce any statisticant significant effect on calcium and phosphate levels where as 3% DDVP did. The calcium and phosphate values of group G (3% LD50 of DDVP and 3% LD50 of Sodium azide) produced significant increase when compared to control and also dose dependently increased compared to group F. **Conclusion:** Co- administration of DDVP and sodium azide produced significant increase in calcium and phosphate values in rats in sub chronic administration.

### The effect low dose DDVP and Sodium azide on the calcium and phosphate values Albino rats

<table>
<thead>
<tr>
<th>Group</th>
<th>Calcium</th>
<th>Phosphate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A Control</td>
<td>2.08±0.08</td>
<td>3.58±0.09</td>
</tr>
<tr>
<td>Group B (1% sodium azide)</td>
<td>2.08±0.16</td>
<td>3.54±0.06</td>
</tr>
<tr>
<td>Group C (3% sodium azide)</td>
<td>2.2±0.15</td>
<td>3.6±0.12</td>
</tr>
<tr>
<td>Group D (1% DDVP)</td>
<td>2.24±0.11*</td>
<td>3.58±0.083</td>
</tr>
<tr>
<td>Group E (3% DDVP)</td>
<td>2.8±0.02*</td>
<td>3.64±0.11*</td>
</tr>
<tr>
<td>Group F (1% DDVP &amp;1% sodium azide)</td>
<td>2.22±0.15*</td>
<td>3.6±0.07</td>
</tr>
<tr>
<td>Group G (3% DDVP &amp;3% sodium azide)</td>
<td>2.44±0.11*#</td>
<td>3.64±0.11*</td>
</tr>
</tbody>
</table>

Results expressed as mean ± SEM

*= Statistically significant compared to control

#= Statistically significant compared to group E

P ≤ 0.05
SP146 - MSK

TRACK 12: MEDICAL DEVICES

SP146.1 - Development of Personalized Tourniquet Systems Using a New Technique for Measuring Limb Occlusion Pressure

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A new technique has been developed to facilitate safer personalized tourniquet systems for surgery, using a unique dual-purpose tourniquet cuff that enables automatic measurement of tourniquet Limb Occlusion Pressure (LOP), while overcoming limitations inherent in manual and automatic techniques of LOP measurement. A study was performed to determine the accuracy of this new technique compared to LOP measured using a gold standard Doppler ultrasound technique. 252 pairs of LOP measurements were taken from upper and lower limbs of 143 surgical patients, enrolled from three different surgical clinics, using the new technique and the Doppler technique. LOP difference was defined as new technique reading minus Doppler technique reading. The mean LOP difference (new-Doppler) ± SD mmHg was +0.56 ± 11.73 for all limbs (252 limbs), +0.99 ± 7.79 for upper limbs (134 upper), and +0.08 ± 15.03 for lower limbs (118 lower). Additional analysis was performed to further improve the performance of the new technique by noise detection and by development of rules allowing identification and removal of outlier data prior to completion of each LOP measurement. In this study, the additional analysis removed 3/252 pairs of LOP measurements and reduced the SD: mean LOP difference (new-Doppler) ± SD mmHg was improved to +0.30 ± 10.31 for all limbs (249 limbs), +0.99 ± 7.79 for upper limbs (134 upper), and -0.50 ± 12.62 for lower limbs (115 lower). We conclude that the new technique of LOP measurement has surgically acceptable accuracy comparable to LOP measurement by Doppler ultrasound. Additionally, the new technique may facilitate adoption of safer personalized tourniquet systems by incorporating inherent advancements over manual and automatic techniques of LOP measurement, including: elimination of a distal LOP sensor; reduced procedural complexity and surgical time; related improvements in the rate of success of LOP determination; and reduced direct and indirect costs.

SP146.2 - Vertebral Metrics – development of a third and improved prototype

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Back pain is among the most common health problems worldwide and is the leading cause of activity limitations. A forehand identification of people affected by spinal disorders is extremely important because early and specific interventions may be applied. Methods currently available to assess spinal curvatures include several types of diagnostic imaging, however, the most frequently used techniques are not radiation free and, for that reason, its application should be avoided. Vertebral Metrics is a non-invasive system that was designed to study the biomechanical changes of the spine. Through the identification of the tridimensional position of the vertex of the spinal processes it is able to provide a 3D reconstruction of the spinal column, in the standing position. Studies with the two previous prototypes indicated that the equipment is reliable and has sufficient accuracy for the global evaluation of the spinal column, however, the required time for data collection is too long. Because of that the further development of the system has become necessary. The required steps to develop a new prototype are presented in this work. Before each scan a fluorescent dye will be used to identify the spinal processes above the skin. During a complete scan, the improved device will move upwards while is recording a video of the back. Once finished the video recording, image processing algorithms will be applied to recognize the fluorescent marks in the skin. The stereo vision method will be used to determine the spatial position of each mark. Preliminary tests were performed using a skin phantom. Fluorescent points became clearly visible in the binarized images. The determined position of each point is very close to reality. In addition, pictures of the skin were collected and binarized. The perfectly identification of the fluorescent marker in the images is a huge success for the development of equipment.
**SP146.3 - Does low-intensity pulsed ultrasound stimulation effectively promote bone fracture repair? An overview**

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This work is an overview of evidences to evaluate the effectiveness of low-intensity pulsed ultrasound (LIPUS) stimulation to promote bone fracture repair. A search of MEDLIN, LILACS and Google Scholar was performed using the keywords ‘low-intensity ultrasound’ and ‘bone fracture’, limited to English and Spanish languages up to December 2014. Clinical eligible studies were randomised and quasi-randomised trials (RCTs) that considered skeletal maturity patients with any kind of fractures. Also, special attention was dedicated to the results reported in previous reviews and meta-analyses conducted in the issue, resulting finally 19 trials for our analyses. Furthermore, LIPUS physical mechanisms of action that can be paralleled to an improvement of bone healing and the associated biological responses were reviewed. It was found that the efficacy of LIPUS to enhance fracture healing is reported controversially in several RCTs, showing substantial heterogeneity in the related outcomes. In addition, there was not appreciated a consensus concerning how to evaluate the efficacy of LIPUS therapy regarding important outcomes for the patient. Therefore, the impact of this physical intervention in the medical management of bone fracture is relatively limited nowadays. But, frequently insufficient attention has been devoted to the ultrasound beam profile and its characteristic parameters that finally determine the local ultrasonic cellular or tissue stimulation, in a context that besides consider the biomechanical model utilized to validate the therapy, even for a process of fracture healing consistent for all fractured bones. Despite, when the healing criterion was a radiological and/or a clinical healing of the fracture, LIPUS significantly shorten the time to the radiological healing of non-operative treated distal radius fractures and the treatment time in tibial distraction osteogenesis. On the other hand, physical mechanism of action of LIPUS and its mechanotransduction pathways are not well understood, basically by the intrinsic complexity of the biological tissue and the number of cells that respond to the mechanical stimulus in a complex cellular-molecular network of signal pathways. Yet, some of the reported LIPUS induced effects are a higher cellular membrane permeability; in vitro increase of collagen synthesis in human fibroblast; augmentation of intracellular concentration of calcium; stimulation to IGF, TGF-β, VEGF and PDGF-AB growth factors; elevation of levels of PGE2; increment of the vascularity at the fracture site; enhancement to osteogenic activity in human periosteal cells; promotion to osteogenic differentiation of human bone marrow stromal cells. **Conclusion:** further randomized controlled trials of high methodological quality are needed to investigate LIPUS effectiveness to improve bone fracture repair using a multidisciplinary approach, considering important healing outcomes for the patient.

**SP146.4 - Electrical Stimulation of the Calf Muscle to Reduce Seated Leg Fluid Accumulation and Subsequent Rostral Fluid Shift While Supine**

**Author(s):** Daniel Vega, Milos Popovic, Azadeh Yadollahi
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**Introduction:** A sedentary lifestyle or prolonged sitting could enhance the effects of gravity to increase fluid accumulation in the legs during the day. Upon lying supine, fluid shifts rostrally from the legs and accumulates in the neck. Fluid accumulation in the neck is a risk factor for increases in the upper airway narrowing and resistance during sleep. Therefore, reducing leg fluid accumulation during the day could be an effective method for reducing neck edema when lying supine and protecting against the partial or complete collapse of the upper airway. The objective of this study is to test the efficacy of electrical stimulation (ES) of the calf muscle pump on reducing daytime leg fluid accumulation and the subsequent rostral fluid shift upon lying supine.

**Method:** The study is a randomized, single-blind double cross-over protocol in which participants sit for two and a half hours and receive either active ES or sham ES (control). Following the seated period, participants lie supine for one hour. After one week, participants crossed-over to the other study arm. Fluid is estimated by measuring bioelectrical impedance in the dominant leg and neck simultaneously and continuously throughout the seated and supine periods.

**Results:** Two men (age 49 and 63) have completed the protocol to date. Results demonstrate that ES substantially reduces fluid accumulation in the legs, where mean increases in leg fluid were 8.4% (75 ml) with sham ES and only 1.6% (13 ml) with active ES (Figure 1a). Upon lying supine, the amount of fluid leaving the legs was similar, however less fluid shifted into the neck, where mean increases in neck fluid were 7.5% (19.7 ml) with sham ES, and only 3% (8 ml) with active ES (Figure 1b).

**Conclusion:** Our preliminary results demonstrate ES as an effective means of reducing fluid accumulation in the legs while seated and subsequent rostral fluid shift into the neck when lying supine. Future work is focused on investigating the effects of this reduced leg fluid accumulation and subsequent rostral fluid shift on respiratory pathologies such as sleep apnea.

![Percent Change in Fluid Volumes during Sitting](image)

Funding: Ontario Graduate Scholarship; Mitacs Accelerate PhD Fellowship; Health Care, Technology and Place Fellowship

**SP146.5 - Surgical process analysis identifies lack of connection between sequential fluoroscopic 2D alignment as a critical impediment in femoral intramedullary nailing**

**Author(s):** Hamid Ebrahimi1, Albert Yee2, Carl Whyne3
1University of Toronto, Toronto/CANADA, 2University of Toronto, Toronto/CANADA

The current standard of care in lower extremity long bone fracture stabilization is closed intramedullary (IM) nailing. The surgical protocol associated with this surgery is well defined. Yet, challenges arise that impede the surgical workflow, add operative time and radiation exposure (to patients and medical staff), and lead to frustration in the operating room. Clear description and analysis of a surgical process can expose challenging steps and activities that can facilitate surgical workflow optimization, guide surgical technology development, improve surgical planning, and enhance surgical training and education. To date, a number of studies have presented methodologies to model individual surgical process models or to develop generic surgical process models. Comparisons between surgical process models have also been studied with respect to procedure parameters such as operating time, number of activities, etc., to evaluate the impact of surgeon experience or to understand
differences in terms of sequentiality of activities during surgeries. However, implementation of identified surgical models to optimize the surgical process has received little attention. Hence, the aim of this study was to map the IM nailing process, identify surgical challenges that impede the surgical process and elucidate their underlying causes.

This study consisted of semi-structured interviews and surgical observations. Eight surgeons from community (three) and teaching hospitals (five) were interviewed to identify the IM nailing surgical procedure, surgical challenges, and their use of adapted surgical techniques. During the eight IM nailing surgeries, information on the surgical procedure was grouped into activities (physical tasks), steps (sequence of activities) and phases (major events) to represent different levels of granularity in the surgical process. In steps identified as challenging or when barriers were encountered, individual activities were analyzed to elucidate underlying causes.

Seventy-five percent of surgeons identified reduction as the most challenging step of IM nailing, consistent with the surgical observations. The greatest challenges were manipulation of fracture fragments for realignment and identifying their 3D orientation using 2D x-ray images (where fragments aligned in one plane were misaligned out of plane). Adapted manipulation techniques used universal chucks with T-handles, mallets, wraps or Shanz screws. In one unsuccessful case the fracture was opened to allow realignment. The entry point step was identified as most difficult by 25% of surgeons, due to challenges in access and 3D K-wire orientation. Adapted techniques aimed to alter patient positioning (torso abduction and/or knee adduction) or eliminate the need for a straight access line through use of an awl. Lateral positioning was suggested to facilitate entry point access in obese or muscular patients.

In both the reduction and entry point steps identified as challenging by IM nailing surgical process analysis, 3D alignment was the critical barrier. Utilization of repeated 2D fluoroscopy without connectivity between sequential images to guide reorientation was a consistent impediment to 3D entry point guidewire positioning and femoral fragment realignment. These findings have important implications toward guiding technological improvements and competency based surgical training.

SP147 - Information Technologies in Healthcare Delivery and Management: Part 2

SP147.1 - The Electronic Medical Record: Can it be integrated with Treatment Delivery and Management?

Author(s):

In the United States (and other venues), there have been numerous efforts to promote an integrated Electronic Medical Record (EMR), one that will incorporate all (or at least key) aspects of the patient’s history (medical and social), diagnostic examinations, treatments, results, and follow-ups. The Meaningful Use (MU) program has as one of its goals to provide improved clinical decision support (CDS) to healthcare providers. The reality is that current EMR systems function more as data repositories, providing much improved access to clinical information, but not making the leap to true clinical decision support. There are many impediments to closing this gap, including the reticence of most EMR manufacturers to enter the realm of treatment delivery, which would likely result in significant changes in their FDA risk classification. This has been shown in Radiation and Medical Oncology Information Systems, some of the earliest EMR systems to be fully integrated into the treatment process, but not connected to ambulatory EMR systems due to the differences in FDA classification.

SP147.2 - AIM Quality Assurance Program Development for CT X-Ray Systems

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The University Health Network purchased Toshiba Aquilion CT X-ray systems that offer improved diagnostic image quality. It is clinically important to maintain good image quality on these systems. The problem that was addressed was how to develop and implement a comprehensive CT image quality assurance program at the University Health Network.

Important image quality parameters were identified using X-ray system specifications. An appropriate image quality test phantom was selected and evaluated using measured results. This topic deals with the technical problem of how to develop and implement an x-ray image quality assurance program for the Toshiba Aquillion CT systems at the University Health Network. This is a significant project because the outcome will assist both the technical and clinical staff to monitor and maintain the stability of the image quality of the CT system. Optimal image quality is essential for the clinical staff to view patient anatomy and perform an accurate diagnosis of the patient’s condition. The project will deal with the selection of an image quality phantom, establishing baseline data derived from the phantom and storing the data for future reference. An important objective is to provide a user-friendly interface for viewing the image quality data. Since the scope of the project deals with CT scanners across five hospitals, the process must be clear and concise to all clinical users of the image quality program. It was decided that the best way to implement a program like this was to develop a website interface to allow all clinical users to access the image quality data on the available desktop computers. This presented the problem of setting up a dedicated image quality server and creating software that will satisfy the needs of the image quality assurance program.
Another challenge of the project was to develop a quality assurance program that will satisfy the corporate vision of the University Health Network. This vision is concerned with achieving global impact. The work done in this report will be relevant to Canadian standards and incorporate global standards as well. These standards were used for building a formal AIM CT Accreditation Program. This internal UHN CT Accreditation program was developed to satisfy the needs for a standardized annual testing of CT dose and image quality parameters.

A comprehensive quality assurance program was then developed and implemented. The program was used to baseline existing system parameters and record variations in image quality. The AIM server provided an ideal centralized interface to store and display CT image quality data, CT Accreditation reports and CT clinical protocols. It is recommended that a CT image quality program be used at other hospitals to maintain and improve system performance and clinical protocol standards.

SP147.3 - Evaluation of Improved Automatic Speech Recognition Prototype for Estonian Language in Radiology Domain

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The aim of this study was to determine the dictation error rates in finalized radiology reports generated with a new automatic speech recognition (ASR) technology prototype for the Estonian language. Apart from a preliminary attempt, no Estonian language based ASR systems exist currently in radiology. Lack of a mother-language supported ASR system for under-resourced and agglutinative languages could be one reason. The scientists from Tallinn University of Technology in collaboration with radiologists from North-Estonian Medical Centre (NEMC), Tallinn, Estonia, took a step closer towards an ASR application in radiology for Estonian language by performing a study using Estonian based models.

The training of language model was performed in two steps. Firstly, for training a language model, 177 659 real radiology reports from different imaging modalities were used including 77 067 x-ray, 30 929 ultrasound, 29 825 computed tomography, 14 815 mammography, 12 082 endoscopic, 8 792 magnetic resonance tomography, 3 950 radiology consultation and 1 199 angiographic reports. Manually normalized versions of 1299 randomly selected reports were created to standardize the report corpus. The ASR prototype, incorporating the trained language and acoustic models, was tested in Radiology Department, North Estonia Medical Centre, Tallinn, Estonia, by 17 radiologists (11 female and 6 male). In total, 261 reports were dictated, including 13 x-ray, 12 ultrasound, 119 computed tomography, 37 mammography, 12 endoscopic, 66 magnetic resonance tomography, and 2 angiographic reports. Word error rates (WER) and report error rates (RER) were calculated for each speaker and modality.

Second phase, the model was improved by taking account the errors from the first test. Moreover, applying of deep neural network based acoustic model and adapting acoustic and language model based on dictated speech, an enhanced ASR prototype was achieved. Additionally, 500 000 real radiology reports from different imaging modalities were included into model training.

In the first ASR prototype, total WER over all material was 18.4% and total RER 93.1%, not sufficient for clinical practice. Live experiments with the ASR prototype showed differences between the users depending on their experience and speech characteristics. An improved ASR prototype was applied onto dictated records resulting total WER 5.0%, which is acceptable for real clinical use. In summary, the ASR prototype for Estonian language in radiology domain was the first time successfully applied and assessed in routine clinical practice. User feedback based automatic correction of language model is planned to implement into next ASR prototype.

SP147.4 - Usability engineering approach towards secure open networks in the integrated operating room of the future

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Nowadays, the number of technical systems in the operating room increases constantly. Besides improving the therapeutic quality, these changes may also lead to new human-induced risks for patients, therapists and third parties. In particular, within intra-operative activities requiring a safe and fast operation, surgeons and nurses rely on sophisticated and efficient solutions in terms of Human-Machine-Interfaces in order to perform their tasks effectively, efficiently and reliably [1]. Therefore, proprietary integrated workstations with a central user interface cockpit have been provided for the operating theatre in recent years. Risk management as well as usability validation have to be provided by the integrating manufacturer. However, these ‘monolithic’ solutions limit the flexibility of the operators and users regarding interoperability and integration of independent innovative devices in these integrated OR solutions. Against this background, the project OR.NET – Secure Dynamic Networking in Surgery and Clinic – funded by the Federal Ministry of Education and Research (2012-2015, overall budget 18,5 ME, www.ornet.org) is a national flagship project involving more than 50 partners from the fields of research, industry, clinical operators and standardization. The main objective of the OR.NET project is to develop the technological as well as legal and operational basis for an open platform and standards for the modular dynamic integration of medical devices and IT systems into the future operating room and its clinical environment. Regarding the aspect of usability engineering, open modular integration, a modular definition of workflows, contexts of use as well as device configuration scenarios seems to be mandatory. Whereas modular standardization on an abstract application specific level limits flexibility to a certain extend, it enables risk management and usability control of modular networks. In this context, we develop a concept of Medical Device Profiles (technical specifications) including Medical Devices User Interface Profiles (MDUIP) representing specifications of human resources required for the interaction with the specific device and related process-model dependent medical device functionality for the modular design of a central user interface in the integrated operating room. The use of standardized MDUI Profiles will allow the manufacturers to integrate their medical devices, respectively the provided functions in the OR.NET network, without disclosing the risk analysis and related confidential know-how or proprietary information and without explicit knowledge on the final configuration of the device set-up and combination in the integrated OR. The MDUI Profiles will allow both, an automated optimized selection and composition of various user interfaces, and implicitly an optimal design of a central GUI with respect to the criteria of usability and an integrated human risk analysis in terms of Human-Machine Interaction. The concept has been evaluated for neurosurgery. The overall OR.NET concept and the evaluation of the MDUIP approach for the integration of an ultrasound dissector and an OR microscope in a neurosurgical test scenario (navigated spinal decompression) will be presented.

Conclusion

This system introduces a careful redesign of information system architecture for the radiation oncology clinic. Motivation for this change comes from risk abatement due to unmanaged clinical subsystems and ad-hoc practice behaviors from care givers. By providing clinical workflow management, we aim to focus the clinician on patient care decision operations and automate the information gathering tasks, maximizing the strengths inherent in an electronic information environment.

Introduction

The practice of Radiation Oncology has evolved into a data dependent operation involving a diverse set of specialized subsystems whose interactions in the clinical environment require careful management. While much effort has been applied to the quality and efficiency of the operations themselves (e.g. dose calculation, delivery, image fusion, segmentation), the interoperability and data management of these systems has been of a secondary concern.

This work introduces a electronic service bus to improve data and workflow management infrastructure for the evolving radiotherapy clinic, we refer to as the MGH Radiation Oncology Whiteboard. Using a web-based architecture to maximize access, ideas such as data immutability, data availability and data-driven workflow management are directly addressed. This new system has been designed using DICOM 2nd Generation models, and implements IHE-RO standards in order to ensure interoperability between the multiple subsystems encountered in a radiotherapy clinic.

Methods

The intent of this system is to support ‘best-of-class’ technologies in a multiple vendor environment rather than reliance upon a single monolithic software implementation. In this implementation, all systems interact with a central patient context constructed from interactions with the service applications tasked with patient care operations.

Such a system allows for direct workflow management, where activities are orchestrated by a centralized workflow logic management system. Given the patient state from all proceeding states, the system is able to automate the next steps in the patient workflow sequence. Ideally this system shall integrate all clinical subsystems, including but not limited to; CT simulation, intake, PACS, treatment planning, treatment QA, image fusion and segmentation and treatment delivery.

Workflow management is implemented using the DICOM UPS pull model, where subsystems, corresponding to desired activities, are provided with worklists. These worklists defined and orchestrated by the workflow management system, define the tasks to be performed along with the corresponding data needed to accomplish this task. Extending the functionality, the system may then automate much of the information access requirements of the task, pushing the appropriate data as referenced by the patient model to the appropriate subsystem and initializing the task itself.

This design allows for the proactive design of clinically “safe” workflow models where the underlying workflow business logic may be interrogated to identify hazardous workflow operations. These clinical behaviors may then be mitigated before clinical implementation occurs.

Treatment session management is provided as a service in this architecture, where the IHE-RO IPDW (Integrated Position and Delivery Workflow) model is applied to a proton treatment facility. The system introduces management of imaging, registration, positioning and treatment activities, requiring a return from the positioning and delivery system a report regarding the performed procedures.
Cell culture is a process by which cells are grown under controlled conditions. Using artificial cell cultured medium/growth medium we wish to artificially culture different types of cells in the body. Apart from common salts, amino acids, sugars, vitamins and organic nutrients that are required, we also require catalysts which promote cell division. The artificial cultural medium will be contained in a specifically designed piezoelectric container. A piezoelectric container is a normal artificial cultural container but it will be connected to a piezoelectric crystal in one of its sides. As the cells in the cultural medium grow, the inner compartment gets filled. It applies pressure on the piezoelectric crystal which is measured using a sensitive device. We wish to use this mechanism on cancerous cells. Unlike normal cells, cancerous cells have different properties. Cancerous cells would not exhibit the property of contact inhibition and if the growth nutrients and catalysts in the cultural medium are sufficient, the cells would grow enough to exert more pressure on the crystal and therefore a high volatage would be generated.

Using the above results, we aim to build a simple device based on simple mechanisms which can detect cancer cells. The device will basically contain 2 compartments as shown in figure below. As shown above, the first compartment has a piezoelectric crystal on its boundary, the second one consists of an artificial cultural medium. A common movable wall in between will separate the 2 compartments. One side of the wall will have a protruding flat hammer head pointing towards the piezoelectric crystal at the boundary of the device.

When the cell sample will be given into compartment 2, cells would start dividing. However normal cells on account of their property of contact inhibition, would stop dividing after sometime without exerting sufficient pressure to move the inner wall. If the sample contains cancer cells, they would continue to divide and in sometime would create a mass of cancerous cells to exert pressure on the inner wall. The inner wall would move towards compartment 1 and strike the piezoelectric crystal. The crystal would generate voltage from the sudden pressure and the voltage output would be recorded. Sufficient experiments would be conducted to see the value of voltages, as well as time range of producing the voltage. Also, it will be taken care if practically normal cells produce miniscule voltages but then we would also note the differences of voltages produced. The voltage value would be recorded using a special circuit so that the output can be checked anytime who is using the device.

We wish to create a potable, home using cancer testing device.

**SP148.2 - Ways to outreach medical devices in low resource countries (LRC)**

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EGG and X-ray machines were invented more than one hundred years back, still almost 80% of global population living in the LRCs does not get benefits of these devices. We can easily visualise the situation with more modern equipment. This failure pains us as scientists or engineers. Some factors for this failure, particularly in medical devices, are: i) design and manufacture only in the developed countries of the world, ii) long periods of patent protection allows some people or group to monopolise, leading to technology disparity and the consequent economic disparity, which in turn caused unaffordability of medical devices in LRCs, iii) engineering education in LRCs not geared to design of devices. Because of manufacture in a remote developed country, the problems faced with the current medical devices in an LRC are, i) the procurement cost is very high, ii) the devices are not user friendly to people in different LRCs as they have different cultures and languages, iii) the devices do not suit local power line abnormalities and weather conditions resulting in premature failure, iv) the devices are not repairable in many instances. The last factor happens because of a) remoteness of manufacturer, b) unavailability and/or high price of spares, c) lack of manpower with adequate technological know-how and d) tendency of manufacturers to keep technology secret, which has increased in recent times with the advent of microcontroller based equipment where software can easily be kept hidden. Again one important point often unnoticed is that the technology innovator in an LRC has also to be the entrepreneur for commercial manufacture. In fact this happened during the industrial revolution in Europe which led to industries that can support R&D for manufacture of new products now. Unfortunately no industrial revolution happened in the LRCs and such R&D based industries do not exist.

Therefore, the single major solution to the unacceptable situation hinted above is empowering persons with engineering background in all LRCs in the design, manufacture and marketing of medical devices. With this aim we have recently initiated a ‘Centre for Technology Equalisation (CTE)’ in Bangladesh under a registered society. At CTE we are planning to organise a workshop where electronics engineers from the LRCs will be trained in the design, development and commercial manufacture of a computerised ECG machine that we have developed indigenously and which has performed well for more than a year of field trial. What WHO, UN and other world bodies can do is to provide support to such local initiatives for technology development and dissemination, which may have different characters in different countries depending on local situations and conditions. Based on the results of such initiatives, the better ideas and models can then be promoted in other LRCs through special educational, training and other supportive programmes.

**SP148.3 - South African – Swedish effort on pre-hospital diagnostics of stroke and traumatic injuries**

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Global health faces a number of unprecedented challenges that cannot be approached effectively from the perspective of a single discipline or a single country. During the last century many countries in the western world has undergone a transition in the spectrum of diseases away from communicable diseases towards chronic diseases often depending on considerable resources from society. The one billion people living in the world’s poorest countries have yet to make this transition and the burden of disease, which is already extremely high, is set to escalate.
Stroke care represents one of these major global unmet challenges of the global health care system. The human cost of stroke is horrific. Out of the 15 million people that suffer a stroke each year, 5 million die and another 5 million are permanently disabled. Among stroke survivors, 20% have serious remaining dysfunctions. A much larger proportion has less conspicuous, dysfunctions, which still seriously affect quality of life for the patient and relatives. In the western world, stroke is placed third among reasons for acute death, and first among reasons for neurological dysfunction, resulting in most days of hospital nursing and therefore the most costly disease within western world health care. In the developing world statistics are more uncertain. In South Africa, stroke was found to be the fourth most common cause of death, accounting for 6% of all deaths in 2000.

The purpose of the present project is to start the path towards implementation, of cost efficient, easy to use, diagnostic tools for stroke in the sub-Saharan Africa, where there are very limited resources in terms of medical personnel, hospitals and diagnostic devices. We have developed and tested a new diagnostics system for stroke intended for the around 200,000 ambulances and the 17 million yearly stroke patients, around the world. For the society this product will help reducing the large cost of stroke and traumatic brain injuries. While of uttermost importance for the western world, less developed countries may come to benefit even more due to the potentially low cost and easy handling of the technology used.

SP148.4 - A portable multi-frequency impedance measuring device for biodynamic analysis

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[Introduction]

We have proposed a biodynamic analysis method using bioelectrical impedance[1]. We developed a system to measure the frequency characteristics of bioelectrical impedances that have high time resolution[2]. The frequency characteristics obey the “Cole-Cole circular arc law,” characterized by four impedance parameters: \( Z(\omega) = R + jX \), \( \alpha \), and \( \beta \). Using the developed measuring system, we showed that the movements of the forearm and throwing motions in baseball were easily distinguished by the impedance parameters of the frequency characteristics[3, 4]. However, this system requires a wave generator driven by AC power, a high-speed A/D converter, and a desktop computer. Therefore, the system is large and has low portability, thus it is difficult to use the system in outdoor environments. In this paper, we propose a portable multi-frequency impedance measuring device.

[Materials and Methods]

The four-electrodes technique is used in the proposed device for the measurement of human body impedance. This device consists of five oscillators whose frequencies are 4, 10, 20, 40, and 100 kHz; a differential amplifier; analog switches for synchronous rectification; and low-pass filters. The voltage signal obtained by adding sine waves of the five frequencies is converted to constant current (RMS value: 250 μA). The current flows to the human body via two current electrodes and the voltage in the measured body part is detected. The current waves of the five frequencies is converted to constant current (RMS value: 250 μA). The current flows to the human body via two current electrodes and the detected differential voltage is amplified. The amplified signal is rectified for each frequency using analog switches and low-pass filters (cutoff frequency: 25 Hz). The output signals of this device are resistance \( R \) and reactance \( X \) for each of the five frequencies. This device is powered by USB mobile phone battery.

[Results and Discussions]

The measurement range of the device is 0–80 Ω. The errors in resistance and reactance were less than ±1% and ±2%, respectively. The impedance parameters are calculated from the five sets of resistance and reactance with a numerical optimization. For example, in a conventional system, when 200 sets of the impedance parameters every second need to be measured, the sampling frequency and data acquisition rate must be 2 MHz and 800 kS/s. In contrast, in the proposed device, a sampling frequency of 200 Hz and a data acquisition rate of 2 kS/s is sufficient.

[Conclusion]

The proposed multi-frequency impedance measuring device is sufficiently accurate for measuring bioelectrical impedance parameters. Further, it requires no external oscillator or high-speed A/D converter, and it is powered by a USB mobile phone battery. Therefore, the proposed device is easy to use, portable, and well suited for outdoor use. A future study will further develop the use of impedance parameters in biodynamic analysis.

[Acknowledgement]

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[References]


SP148.5 - A Study of the Challenges of Donating Medical Equipment to Developing Countries

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Previous studies conducted in the United States and Europe have shown that as much as 70% of medical equipment that is donated to low-income countries is never put into use in these countries [1]. As a result an unnecessary burden is created, and many of the recipients’ equipment needs remain unresolved. In this study, funded by the International Development Research Centre in Canada, we are examining the practices of Canadian organizations that donate equipment to developing countries. In addition, we plan to trace the path of shipments of donated equipment from their point of origin, to their ultimate destination. The goal is to better understand why so many organizations are still making inappropriate donations despite the existence of well-publicized guidelines promoting donation best practices [1]. To achieve the goals of the study, we are building on partnerships with the biomedical engineering community in Ghana, including their recently established Biomedical Engineering Association.

To date we have identified about 70 Canadian organizations that donate medical equipment and supplies to developing countries. We have contacted these organizations and asked them to answer a survey questionnaire; we received 43 survey responses. Based
on these responses, we approached the most active organizations and asked if we could visit their facilities and interview key staff so that we could better understand their processes. We have visited 12 of these facilities, and conducted telephone interviews with an additional 5 facilities.

We have also hired a research assistant in Ghana to collaborate with us and track down the ultimate destination of some of the shipments of donated equipment from Canada to Ghana. By doing this we hope to gain a better understanding of which shipments had the highest success rate in meeting the needs of the recipients, and what type of planning process was involved in preparing these shipments.

Through the survey, interviews, and shipment tracking, we intend to develop a number of case studies or ‘stories of unsuccessful donations’ in which we trace the path of a donation from the well-intentioned donor, through the hazards of international shipping and customs brokers, to the final destination – often in the hands of an unsatisfied recipient. We plan to use these case studies to promote as widely as possible a better understanding of the pitfalls of medical equipment donations, and educate Canadian donor organizations on best practices and the causes of unsuccessful donations.

In our presentation at the World Congress, we will present a summary of what we have learned to date, as well as future plans to continue this work. We also hope to make contact with recipients of donated equipment from developing countries other than Ghana, so that we can expand our study in the future.


**SP148.6 - The Clinicopathologic Characters and Activity Survey of Sudden Death of Infant in a Depressed Economy: South-Eastern Nigeria Experience.**

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Sudden death of infant (SDI) is among the clinical conditions called sudden infant death syndrome (SIDS) referred to as death situation in which all clinical causative factors play apparent and hideous roles within an hour of unexpected death of infant within one year of age. To ascertain SDI at ABSUTH, a 6 year study of all infant death cases in record books were searched and two types of questionnaires added. Medical officers and hospital staff involved in infant healthcare were 343, and 1400 mothers contacted were of age ranges 18-40 years. Causes of SDI were respiratory failure 107, RTA 4, circulatory failure 25, alimentary distress 103, trauma and domestic accident 10, and cardiac failure 70 cases. Highest Frequency of occurrence in the years was observed in 1999 and gave 104. Commonest clinical characters were anaemic heart failure, child neglect and abuse, drug toxicity, heamorrhage, and vagal inhibition. The rapidity with which SDI occurred in 25.2% of 107 respiratory failures was within 10 seconds to 5 minutes, and to 232 cases was within 24 minutes of hospitalization. Common clinical symptoms were mild to high fever, intermittent coughing and vomiting, malnourished body, respiratory distress, and apnea while 77.1% full term birth cases had body weight of 2100 to 2500g. Child neglect and abandonment were evident in 49.3% mothers of lean economies. SDI peak was from 5th to 8th months, at which periods 112 female and 168 male infants were wean to death by 280 mothers. Yearly highest incidence of SDI is 1999.
SP149 - Iterative Reconstruction

SP149.1 - Preliminary study on reduction of cartoon artifact in the iteratively reconstructed images from sparse projection views

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OBJECTIVES In this study, we developed an approach that can help reducing cartoon artifact in the reconstructed images from sparse projection views. Sparse-view CT has been actively investigated as a viable option for low-dose CT, and compressive-sensing-inspired image reconstruction frameworks have been developed accordingly. One of the problems in such algorithms is the over-smoothing in the reconstructed images often called the cartoon artifact. Sparsity of the transformed image is maximized during the iterative image reconstruction steps from the insufficiently sampled data, which helps preserve the edge information but may cause such an over-smoothing. The cartoon artifact not only degrades accuracy of the reconstructed images but also may confuse the clinician's interpretation. In this study, we analyzed the noise statistics of the reconstructed images and performed a preliminary study to reduce cartoon artifact.

METHODS Projection-Onto-Convex-Sets (POCS)-based Total-Variation (TV) minimization algorithm was employed for image reconstruction from sparse-view projection data set. We separated the noise image using a conventionally reconstructed image from full-views and examined the noise statistics. A random number generation following the investigated noise statistics was realized from Pearson type-4 Distribution and was added to the image pixel values during iterations. The frequency and amplitude of the added noise were empirically determined. We considered a case of using 25% sparse projection views compared to the full-view case, and applied the proposed method. The XCAT numerical phantom was used for simulating a male patient with his heart containing iodine.

RESULTS Kurtosis of the conventionally reconstructed images from full-views was relatively lower than POCS-TV reconstructed images from sparse-views. Accordingly, the textures of the two reconstructed images were different. Based on the findings in the noise statistics, the parameters in our noise addition module were determined. The reconstructed images using our proposed method visually appeared more similar to the conventionally reconstructed images, and the SSIM value has increased up to near 0.9. In other words, the cartoon artifact was much reduced in the narrow window setting.

CONCLUSIONS Reconstructed images using POCS-TV algorithm have shown severe cartoon artifacts in the reconstructed images from sparse-view data. The cartoon artifact reduction method was proposed to convert noise texture from a cartoon-like noise to a salt-and-pepper noise. Our preliminary study showed that the proposed method maintains the image quality and reduces cartoon artifacts in the reconstructed images. Although more investigation is necessary to optimize the condition of proposed method, the cartoon artifact reduction method seems to be potentially useful for clinical applications of low-dose CT.
contains cylindrical contrast targets with contrast levels of 0.3%, 0.5% and 1% and diameters ranging from 2 - 15 mm. The module contains a supra-slice set of contrast targets arranged in an outer circumference and a sub-slice set of targets arranged in an inner circumference.

The phantom was scanned at 120 kVp over a CTDIvol range of 1.3 – 19 mGy on 4 different scanners. Images were reconstructed using FBP and the iterative algorithms available on each scanner. We used the following scanners (iterative algorithms): GE DiscoveryCT750HD (ASIR™ and VEO™); Siemens Somatom Definition AS+ (SAFIRE™); Toshiba Aquilion64 (AIDR3D™); and Philips Ingenuity iCT256 (iDose4™). In total, 328 images were acquired.

Four experienced clinical physicists scored the visibility of the low contrast structures using the 1% nominal contrast supra-slice targets on a 6 MP Coronis Fusion Barco display. 82 images were selected for double rating to check inter and intra-observer reliability. Rater reliability was analyzed using the ‘irr’ package in the R statistical program using two-way intra-class correlation models. We used the Student’s t-test to compare average image scores for different scanners/algorithms.

Results and Discussion

The internal reliability of the rater scores was determined, using the Cronbach’s alpha with a value of 0.97. Using the two-way fixed effects model, the inter-rater coefficient was 0.87 while the intra-rater coefficient was 0.93, signifying good agreement and consistency between raters, respectively.

The mean rater scores over the entire dose range on all four CT scanners are as shown. (a) GE Discovery CT750HD: 6.6±1.1, 6.9±1.1, 7.5±1.1, 8.2±1.2, 7.6±1.2, 8.4±1.2, and 7.1±1.3 for FBP, ASIR20, ASIR40, ASIR60, ASIR80, ASIR100 and VEO respectively; (b) Siemens Somatom Definition AS+: 4.9±0.7, 5.2±0.7, 5.9±0.6 and 7.6±0.9 for FBP, SAFIRE-L1, SAFIRE-L3 and SAFIRE-L5 respectively; (c) Toshiba Aquilion64: 3.8±0.8, 4.6±1.0, 4.4±0.8 and 5.1±1.1 for FBP, AIDR3D-mild, AIDR-3Dstandard and AIDR3D-strong respectively; (d) Philips Ingenuity iCT256: 4.6±0.8, 4.9±0.8, 5.4±0.9, and 5.8±0.8 for FBP, iDose4-L1, iDose4-L4 and iDose4-L6 respectively.

The results showed that, generally, the highest levels of iterative reconstruction gave the highest mean score at all doses for the scanners investigated. The differences in the mean rating scores using iterative reconstructions are statistically significant (P < 0.05) for SAFIREL3 – SAFIREL5, ASIR40 – ASIR100 and all AIDR3D algorithms with respect to FBP, using the average inter-rater scores. In contrast however, the results obtained for ASIR20, VEO, SAFIRE-L1 and all iDose4 algorithms were not significantly different (P > 0.05) with respect to FBP.

Conclusion

Our results show that higher levels of the iterative reconstruction algorithms outperform FBP on GE, Toshiba and Siemens scanners. Lower levels of iterative reconstruction algorithms produce similar results to FBP on the GE and Philips scanners.
SP149.5 - Sparse-view image reconstruction with compressed sensing and its application in low dose CT myocardial perfusion imaging

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Computed tomography (CT) perfusion is a process by which perfusion to an organ is measured by CT images. This technique requires repetitive scanning together with injection of contrast agent resulting in high radiation dose (~5 to 20 mSv). We have developed a low x-ray dose method for quantitative CT perfusion imaging. It relies on reconstructing dynamic contrast-enhanced (DCE) CT images from sparsely sampled x-ray projections using a compressed sensing (CS) based algorithm. The feasibility of this approach is demonstrated in the myocardial perfusion imaging of a pig. For this purpose, we performed prospectively ECG triggered dynamic CT imaging on a 70 kg farm pig at 140 kV and 80 mA (28 mAs) with a GE Healthcare (GE) CT750 HD scanner with contrast injection (0.7 mgI/kg) at 3 m/s. DCE images were then reconstructed from all (984) and one-third (328) of available projection views with filtered backprojection (FBP) and CS respectively. Myocardial perfusion (MP) maps from full view FBP reconstruction and also with microsphere MP measurements from CS image sets were compared with those from full view FBP reconstruction and also with microsphere MP measurements. Compared with full view FBP MP measurements, CS maps had biases of -0.01 mL/min/g (95% CI -0.05 – 0.03). When measurements from CS MP maps were compared against ex-vivo fluorescent microspheres technique, the mean bias was -0.12 mL/min/g (95% CI -0.26 – 0.03). This animal study demonstrated that the proposed sparse view coupled with CS image reconstruction is able to generate MP maps with one-third of projection views (sparse-views) required in the conventional FBP technique, resulting in 66.67% reduction in radiation dose.

SP149.6 - Feasibility study for 3D cone-beam computed tomography reconstruction with few projection data using MLEM algorithm with total variation minimization

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Since, the CBCT (cone-beam computed tomography) was developed in 1967, it has been widely used in medical field. The CBCT has relatively simple geometry and less time consuming characteristics to obtain three-dimensional volume data. On the other hand, the major disadvantage of CBCT system is higher radiation exposure to the patient. Thus, it is necessary to apply proper reconstruction method to reduce patient dose.

In this study, simulated sparse projection data was obtained by GATE (Geant4 application for tomography emission) v6.0 simulation tool and those two dimensional projections were reconstructed by MLEM (maximum-likelihood expectation-maximization) algorithm. The total variation minimized image processing method was applied to improve the image quality. The images were evaluated by CNR and FWHM. Furthermore, absorbed dose in simulated phantom was evaluated by GATE v6.0 dose actor. The images reconstructed by MLEM algorithm and total variation minimized method result in high image quality despite of sparse of projection. Especially image obtained by 60 projections showed comparable image quality with that from 360 projections.

In conclusion, sparse-projection reconstruction with MLEM and total variation minimization is a useful approach to reduce radiation dose with maintaining quality of reconstructed images.

SP149.7 - A weighted stochastic gradient descent algorithm for image reconstruction in 3D computed tomography

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We present and evaluate an algorithm for image reconstruction from a small number of projections in 3D x-ray computed tomography (CT). The proposed algorithm is similar to the class of projected gradient methods. Because each iteration of these algorithms for large 3D CT reconstruction is very computationally demanding, our goal is to devise an algorithm with fast convergence. To achieve this goal, in the proposed algorithm the gradient descent for reducing the measurement misfit term is carried out using a stochastic gradient descent iteration and the gradient directions are weighted using weights suggested by parallel coordinate descent. To further improve the speed of the algorithm, at each iteration we minimize the cost function on the subspace spanned by the direction of the current projected gradient and several previous update directions. We apply the proposed algorithm on simulated and real cone-beam projections and compare it with a well-known accelerated projected gradient algorithm, Monotone Fast Iterative Shrinkage-Thresholding Algorithm (MFISTA). Evaluations show that the rate of convergence of the proposed algorithm is superior to that of MFISTA.

SP149.8 - Investigation of sparse-angle view in cone beam computed tomography (CBCT) reconstruction algorithm using a sinogrom interpolaton method

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Several methods for reducing patient dose have been widely studied in computed tomography (CT). The radiation exposure dose for patient can be decreased with sparse-angle view reconstruction in CT. In sparse-angle view reconstruction, limited projection images are taken around the object and these are incomplete projection data for obtaining the complete sinogram data. A sinogram interpolation method is the one of solutions to reconstruct the image in sparse-angle view. In this study, we applied a linear sinogram interpolation method in cone-beam computed tomography (CBCT) reconstruction. We simulated the CBCT system with the MATLAB R2012a program to obtain projection data and reconstruct images using three-dimensional version of the Shepp-Logan phantom. Root mean square error (RMSE) was measured in a sinogram interpolation method and normal Feldkamp-Davis-Kress (FDK) reconstruction. The lower RMSE factor means the reconstruction image was similar to the original image. In conclusion, our results demonstrated that the sinogram interpolation method can minimize the error with original image compared with normal FDK reconstruction.
X-ray scatter imaging is a novel radiologic technology which delivers increased soft tissue contrast. Multiple pencil beams are scanned over the object. The scatter image is built by extracting the low-angle scatter cross section integrated along each primary beam from the captured dataset of overlapping scatter patterns. The resulting image is much more sensitive to tissue composition than are conventional projection images which are based on the primary linear attenuation coefficient. In our work, a Maximum Likelihood-Expectation Maximization (ML-EM) iterative algorithm is used to disentangle the scatter patterns.[1]

Artefacts can arise from the signal disentanglement. E.g., when a bright scatter signal is adjacent to a dim signal, the algorithm generates ghosts of the signal from one pencil beam location to another. We investigate the reasons for this and possible improvements to the signal extraction algorithm. We used two categories of data: (i) experimental phantom data acquired previously at the Canadian Light Source synchrotron using five 33.2 keV beams of area ~0.6 mm² located approximately in a plane, and (ii) simulated data from a Matlab model, with scatter selectable to be from beams passing through muscle, fat, bone, and/or a minimally-scattering object such as air. Attenuation of the Laue scatter ring patterns can be selected to be azimuthally symmetric, or asymmetric, about the pencil beams. The scatter pattern data were input to the ML-EM algorithm and the sensitivity to the inputs studied. Furthermore, we modified the algorithm to segment the Laue rings in radial sectors.

Our results confirm that the ML-EM algorithm performs best when adjacent beams have comparable Laue ring intensity. For example, the algorithm is better at separating signals from two beams that passed through muscle and fat, than for two beams passing through muscle and bone, because of the greater attenuation for the latter. The cause of the ghosting artefact is established to be a fundamental limitation of ML-EM. In the first few iterations, low-spatial-frequency scatter signals are subdivided equally and assigned to multiple beam locations, swamping small signals. The global optimization minimum rectifies the problem, but ML-EM’s approach to the global minimum is unacceptably slow, requiring over 10,000 iterations. Azimuthal segmentation of the scatter patterns allows a closer fit to the measured scatter data but still does not reach the global minimum. We have increased the ML-EM convergence rate. In the algorithm, the ratio of measured to estimated scatter patterns is computed and used to correct the next update. By scaling the difference from unity by a factor of 2.0 every three iterations, the resulting rms difference between the estimated and measured scatter patterns can be reduced, for example, from 2.66% at the 16th iteration to 2.02%. The global minimum however is still not reached in reasonable time. We are also investigating the use of the primary pencil beam information from adjacent beams. Spatial interpolation of these data can give approximate transmission factors with which to correct the recorded scatter data for spatially-dependent attenuation.

SP150.3 - X-ray Phase-Contrast imaging: from mammography to breast tomodiagnosis using synchrotron radiation  
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In addition to absorption-based x-ray imaging, over the last two decades other techniques devoted to exploit the wave nature of x-rays were developed to enhance visibility of details and increase image contrast. These methods are called Phase-Contrast imaging (PCI) techniques and were developed in order to obtain high contrast and high spatial resolution images of biological samples. The first clinical study based on a PCI technique was performed at the SYRMEP beamline (Synchrotron Radiation for Medical Physics) of ELETTRA, the Italian synchrotron facility; the free space propagation approach was applied. The clinical study was based on 71 female patients that underwent digital mammography at hospital and, due to questionable or suspicious breast abnormalities not clarified at UltraSonography, underwent phase contrast mammography with synchrotron radiation (MSR). The study shows that Phase-Contrast allows improving the image quality and increases significantly the diagnostic performance of MS in comparison with digital mammography: difference between methods in the area under the ROC curve is 0.2 (p<0.001). The mean glandular doses (MGD) delivered during MS exams are, on the average, 42% lower than the ones delivered during DM exams, due to the properties of synchrotron radiation. Moreover the use of monochromatic beam, in the energy range 18–22 keV, allowed the direct measurement of the breast linear attenuation coefficients for each patient.

The new clinical project in breast imaging at the SYRMEP beamline, concerns breast tomodiagnosis and it is carried out by the SYRMA-CT collaboration, an interdisciplinary team supported by INFN, ELETTRA and the Trieste University Hospital. The SYRMEP mammography facility will be deeply modified to allow the acquisition of tomodiagnostic images, and the dosimetric and safety system will be upgraded too. A complete Monte Carlo simulation code has been developed and tested for dose evaluation and exam optimization. The detector selected for this application is PiXIRAD-8: a CdTe detector working in single photon counting mode. The active area is 25x2.5 cm², the pixel size is 60 micrometers in hexagonal arrangement, the frame rate is 14 frame/s and the pixel rate capability is 5 x 10^5 counts/pixel/s.

The aim is to acquire tomodiagnostic images of the breast delivering MGDs in the range 4–20 mGy. The beam energy will be in the range 38–40 keV, the upper limit is determined by the beam available at the SYRMEP beamline. To obtain high quality images at a clinical acceptable delivered dose new image reconstruction approaches will be explored, in order to reduce the number of necessary projections: simultaneous algebraic reconstruction tomography (SART) and equally sloped tomography (EST) approaches are under investigation. Moreover phase retrieval algorithms will be applied to the projection before the tomodiagnostic reconstruction in order to increase the image contrast.

In the present communication the results of the Phase-Contrast mammography clinical study will be summarized, in terms of image quality, delivered dose and linear attenuation measurements, the SYRMA-CT project will be presented and the preliminary Phase-Contrast CT images obtained at ELETTRA in clinical compatible condition will be discussed.

SP150.4 - 4 Years of X-ray Imaging at 05B1-1 Beamline at BMIT  
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The BioMedical Imaging and Therapy (BMIT) facility located at the Canadian Light Source, provides synchrotron-specific imaging and radiation therapy capabilities [1-5]. There are two separate endstations used for experiments, Bending Magnet beamline described here and Insertion Device beamline that started general user program in 2015.

The bending magnet beamline 05B1-1 was used to acquire first image in December 2008 and was officially opened for general user program in 2011. This endstation is designed for imaging and therapy research primarily in animals ranging in size from insects to mice to small dogs and cats, as well as tissue specimens including plants.

![Fig. 1 3D Model of the BM Beamline components](image)

Core research programs include human and animal reproduction, cancer imaging and therapy, spinal cord injury and repair, cardiovascular and lung imaging and disease, bone and cartilage growth and deterioration, mammography, developmental biology, gene expression research as well as the introduction of new imaging methods.

The monochromatic spectral range spans 15–40 keV, and the beam is more than 200 mm wide in the experimental hutch. Several different focal plane detectors (cameras) are available with resolutions ranging from 2 μm to 200 μm.
A bent Laue monochromator has been developed that has very good focal and energy dispersive properties for KES. Approximately 5% of the vertical beam profile is involved in “edge crossing” energies (Figure 1), thus no splitter is employed. The combination of good spatial resolution, energy dispersive properties, flux and a unique approach to data analysis make this system nearly ideal for KES.

Details of the monochromator will be discussed, especially the focal and energy dispersive properties. Example images (i.e. Figure 2) of the beam and the object images will be presented as well.
SP150.6 - An incoherent implementation of x-ray phase contrast imaging and tomography that maintains high sensitivity at low delivered doses

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X-ray phase contrast imaging (XPCI) has been one of the hottest topics in x-ray research over the last two decades, because of its potential to revolutionize diagnostic radiology and other medical applications of x-rays. Indeed, its ability to improve diagnostic potential in mammography is currently being demonstrated by the in vivo work on human patients underway at the Trieste synchrotron in Italy.

However, translation into everyday clinical use has proven very difficult, to the extent that part of the community is starting to doubt this will ever happen.

We argue that the main reason for the above lies in the fact that all implementations of XPCI proposed so far have been based on coherent approaches. While some of these are very promising, the need for source coherence prevented them from being usable in clinical practice, at least until a new generation of sources will become available that can simultaneously provide high x-ray flux and high coherence. Whenever incoherent sources have been employed, devices have been introduced to artificially increase their coherence (e.g. crystals or gratings). This resulted in a significant reduction of the x-ray flux, leading to excessive exposure time, as well as delivered dose whenever these devices are positioned after the sample.

This talk will present a solution based on a completely incoherent approach to XPCI, centred on the adaptation (through apertured masks) of the “edge-illumination” principle to polychromatic and divergent x-ray beams generated by conventional sources. This talk will show that:

1) The method is completely incoherent, but this notwithstanding provides a phase sensitivity equal to that of other coherent approaches while using unfiltered and uncollimated focal spots of up to 100 micron (compatible with e.g. current mammography sources). We will show that the coherence length is much smaller than both the size of the apertures in the used masks and the separation between them, and explain how phase sensitivity is measured. Based on recent experiments performed with energy-resolved detectors, we will also show that the method is completely achromatic.

2) In planar imaging, the delivered dose is lower or equal than in e.g. conventional mammographic examinations, and in CT it is well below the limits imposed by e.g. small-animal imaging.

3) The technique is highly flexible and can be easily adapted to tomosynthesis, microscopy and micro-CT, etc, and that “dark-field” (sometimes referred to as “ultra-small angle scattering”) images are also readily achievable, still within clinically acceptable dose limits.

After the technical excursus outlined above, we will show examples from recent applications in medicine and biology, including in mammography, imaging of cartilage and joints, use of new contrast agents and monitoring of regenerative medicine processes. Finally, we will provide an outlook on future technical developments of the method, which include options for “single-shot” retrieval of attenuation, phase-contrast and dark-field images, as well as strategies to reduce the exposure time (currently ~10s for planar imaging) and the overall dimensions of the imaging system, scale up the field of view, completely automatize the alignment.

SP150.7 - Indirect measurement of average alveolar size using dynamic phase-contrast imaging

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For some lung diseases, assessment of alveolar dimension could add critical information to inform patient care and disease progression. However, current clinical imaging techniques, such as computed tomography, lack the resolution required to measure these small structures in patients. While the gold standard imaging modality for measuring alveoli is micro-CT, this technique is not possible in clinical use due to the size of the patients and the radiation dose. An alternative imaging modality is phase-based contrast imaging, which would deliver a lower dose to patients and increase the size limit. Phase contrast X-ray imaging has previously been combined with particle image velocimetry (PIV) to measure lung motion, another indicator of lung disease. Thus it was hypothesized that average alveolar size could also be measured indirectly using PIV. In the work reported here, we show that average alveolar size shows a high correlation to the mathematical divergence of the velocity vector field that results from the speckle pattern produced by phase imaging of mouse lungs. This correlation is linear with p<0.006. If this correlation holds in human lungs, it could potentially be calibrated to indirectly measure average alveolar size in human patients using some of the grating-based phase-contrast imaging methods that are showing great promise in clinical use.

PCXI and μ-CT Results:

<table>
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</table>
**SP151 - Cardio Mechanics & Organs**

**SP151.1 - Biomechanics and artificial organs**

**Author(s):** Alexandros Repanas, Marc Mueller, Fedaa Al Halabi, Oleksandr Gryshkov, Michael Bode, Holger Zernetsch, Birgit Glasmacher

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**Introduction**

Tissue engineering is an interdisciplinary field that combines the principles of engineering and life sciences with the goal of restoration, repair or replacement of tissues and their functions. Bridging the gap between isolated cells and functioning tissue, the scaffolds become an instructive extracellular microenvironment that actively guides cells both locally and in time towards tissue formation and regeneration. Additionally, the mechanical properties and the micro-structure of the scaffolds play an important role to cell proliferation, differentiation and eventually regeneration of the damage tissue site. Electrospinning is a technique for the production of ultrafine polymer fibers from polymer melts or polymer solutions through electrostatic interaction. It is most often used as scaffold material in tissue engineering applications due to its similarity to the filamentous microenvironment in native tissues. This similarity often promotes a more positive cell response to the generated fibers than to the bulk material alone. Moreover, this method is also suitable to generate gellike 3D gel-structures for immunosolation and cryopreservation. Here, we describe the production of aligned fibers with different 3D structures such as mats and tubes, the incorporation of bioactive substances and their biomechanical evaluation.

**Materials & methods**

Different kinds of biodegradable polymers of natural and synthetic origin (polycaprolactone, poly-1-lactide acid, polyethylene glycol, chitosan etc) that have been approved for biomedical applications were dissolved inside organic solvents (chloroform, acetone, ethanol etc) at adequate concentrations for electrospinning. Single jet or coaxial jet electrospinning was used to create fibers gathered on the surface of collectors with different geometry (rectangular, rotating mandrel, tubular etc). Morphology of the fibrous scaffolds was examined by scanning electron microscopy (SEM) having a fixed power setting. This means that the power controller cannot be equipped with controllers that have this capability. Interests have been devoted to using the LVAD as a bridge-to-recovery technology or destination therapy treatments, in recent years considerable interest has been devoted to using the LVAD as a bridge-to-recovery device. These rotary pumps are implanted in patients awaiting heart transplantation. The Continuous flow total artificial heart (CFTAH) is a device consisting of two continuous ventricular assist devices that produce pulseless flow into both systemic and pulmonary circulation. Its utilization is not yet widespread. The Continuous flow total artificial heart has only been implanted in humans three times as an off-label use of a ventricular assist device. All three men have been supported by chronic pulseless flow. The issue of chronic pulseless vs. chronic pulsatile blood flow and its effects on organs and tissue perfusion has been debated in medical and biomedical scientific journals for decades. There are many animal studies, views of many scientists and many hypotheses, but no clear answer to the basic question: will a person be able live a quality life with pulseless flow for months and years?

**Results and Discussion**

Scaffold design via electrospinning resulted in versatile scaffolds made out of various polymers that exhibited different macroscopic and microscopic structures, various pore sizes and porosities. From aligned fibers that could be used in nerve tissue engineering, tubular scaffolds for vascular grafts and coaxially electrospun membranes with encapsulated pharmaceuticals, artificial scaffolds were created to fit the need of various applications. The mechanical properties of the scaffolds were in line with the need for each case, comparable with natural tissues. Electrospun scaffolds showed to address both controlled release and structural cues with adequate pore sizes and resulting porosity enabling cell proliferation.

**Acknowledgments**

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**References**


**SP151.2 - The Continuous Flow Total Artificial Heart in Clinical Practice**

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My minireview describes an inventive medical device for the replacement of pulsatile circulation by pulseless circulation for patients awaiting heart transplantation. The Continuous flow total artificial heart (CFTAH) is a device consisting of two continuous ventricular assist devices that produce pulseless flow into both systemic and pulmonary circulation. Its utilization is not yet widespread. The Continuous flow total artificial heart has only been implanted in humans three times as an off-label use of a ventricular assist device. All three men have been supported by chronic pulseless flow. The issue of chronic pulseless vs. chronic pulsatile blood flow and its effects on organs and tissue perfusion has been debated in medical and biomedical scientific journals for decades. There are many animal studies, views of many scientists and many hypotheses, but no clear answer to the basic question: will a person be able live a quality life with pulseless flow for months and years?

**SP151.3 - Power Control Range of Operation for the Left Ventricular Assist Device in Bridge-to-Recovery Treatment**

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Left Ventricular Assist Devices (LVADs) are mechanical pumps that may be used as an alternative to drug therapy for patients with congestive heart failure. These rotary pumps are implanted in patients to provide an alternative path for blood flow from the left ventricle to the aorta that supplements the natural blood flow through the aortic valve. Although the LVAD is used largely for bridge-to-transplantation or destination therapy treatments, in recent years considerable interest has been devoted to using the LVAD as a bridge-to-recovery device. This type of treatment is typically intended for patients whose heart condition may improve as a result of a limited time LVAD support. Candidates for this type of treatment may be weaned from the LVAD when their hemodynamic and physiological changes indicate recovery of the heart muscle.

The amount of blood flow supplied by the LVAD depends on the rotational speed of the pump which is controlled by the electric power supplied to the pump motor from the LVAD battery pack. Current LVAD technology allows for the option of operating the pump only at a fixed power setting. This means that the power controller cannot react to any changes in the activity level of the patient by automatically adjusting the supplied power. The next generation LVADs however, will be equipped with controllers that have this capability. The purpose of this paper is to address the important engineering challenge of determining the range of operation available to the
power controller within which it can: (1) automatically adjust the power so that the resulting total blood flow meets the physiological demand of the patient; and (2) promote recovery by maintaining normal operation of the aortic valve. Using a mathematical model, we have shown that if this power is increased beyond a certain critical value the aortic valve will close permanently due to the inability of the left ventricle to retain enough volume that can build pressure high enough to open the valve and let the blood flow through it. Permanent closure of the aortic valve may cause complications such as valve fusion or stenosis, stagnation of blood flow and/or thrombus formation, all of which may be harmful to the patient by delaying or preventing the recovery of the heart muscle. In this paper we investigate the effect of the power provided to the LVAD pump on the ability of the aortic valve to open and close regularly during the cardiac cycle hence avoiding all of the above mentioned complications. We derive a relationship between the critical value of power that causes the aortic valve to permanently close and the patient’s level of activity. We show that independent of the degree of severity of the heart condition, this critical value is directly related to the patient’s level of activity and that the more active the patient, the larger the range of operation available to the LVAD power controller. This means that increased activity reduces the possibility of exceeding the critical value and consequently increases the chance of faster recovery.

SP151.4 - An quantitative estimation method of peripheral perfusion by using a CCD camera during rotary blood pump support

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The rotary blood pump support for ventricular circulatory assistance has become a standard procedure as the bridge use or the destination therapy for the surgical treatment of severe heart failure in recent years. While the outcome of the long term support by the rotary blood pumps in the patients is excellent compared with the heart transplantation, the optimal driving condition of each pump still remains to be seen. It is anticipated that the pulsatile flow can be generated by the interaction between the native heart function and the pump which is to be contributing to maintain the peripheral perfusion. One of the definitive condition of the revolution number of the pump support is that of the native heart function and the pump to provide the native heart contractile function. Recently, a pulse detection technology by using CCD cameras has been represented for the diagnostic purpose of patients' hemodynamics. We also have applied and develop the noninvasive evaluation method for the investigation of peripheral perfusion during the rotary blood pump support in order to examine the pulsatile effects of the pump characteristics on peripheral organs. In this study, the brightness of color components derived from the CCD camera (NEX-FS100JK, Sony, Japan) under the different blood density conditions was examined in vitro by using an originally designed peripheral model made of open-foamed polyurethane sponge at the density of 1.7 x 10^2 g/cm³. After the static characteristic tests, the peripheral perfusion at a goat face was evaluated under the left ventricular assist condition using the centrifugal blood pump (Evaheart, SunMedical, Japan). The animal study was performed with the left ventricular assist using an adult healthy Saanen goat under the normal anesthetization using 2% isoflurane with remifentanil. All the animal experimental procedure was investigated and allowed by the Animal Experiment Committee in Tohoku University.

The results were as follows: In the static model study, the relationship between the brightness and the blood density in the sponge model was calculated. It was indicated that the brightness value calculated under the green color LED lighting condition was elevated by around 30% by the increase of sponge density by 3%. In the animal experiment, the peripheral perfusion could be obtained as the synchronous pulsation with the cardiac beats under the rotary blood pump support. The pulsatility calculated from the goat’s face perfusion indicated that the elimination of pulse might be caused by the increase of the revolution number of the pump. Consequently, the pulsation by the noninvasive CCD detection could be evaluated as the changes in peripheral blood flow based on these data.

SP151.5 - Mathematical Modeling of Left Ventricle Stroke Work Following Transcatheter Aortic Valve Replacement Associated With Paravalvular Leaks

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Objectives The objective of this study was to develop a lumped parameter model to evaluate the effect of paravalvular leaks (PVL) following transcatheter aortic valve replacement (TAVR) on the total load supported by the left ventricle (LV).

Background A significant number of elderly patients with severe symptomatic aortic stenosis are denied surgical aortic valve replacement due to its high operative risk. TAVR has recently emerged as an alternative solution for high-risk inoperable patients with aortic stenosis. However, TAVR is often associated with paravalvular leaks (PVL). PVL leads to left ventricular volume overload and increased stroke work of the left ventricle. Under such conditions it is difficult to evaluate the net benefit from TAVR since the benefit from the increase in valve area is damped by the presence of PVLs.

Methods A mathematical model was developed based solely on non-invasive data allowed for the description of the interaction between effective orifice area (EOA), PVL and the left ventricle work (LVW) pre and post- TAVR. The model was used to simulate different configurations in terms of valve areas and valve regurgitation/PVLs before and after TAVR. The following conditions were investigated: 1) Before TAVR: severe aortic stenosis with EOAs of 0.56 cm², 0.66 cm² and 0.76 cm² with no, mild, moderate and severe aortic regurgitation; 2) After TAVR: EOAs of 1.37 cm², 1.61 cm² and 1.90 cm² with no, mild, moderate and severe aortic regurgitation paravalvular leaks. For each case, LV stroke work has been computed as well as the net reduction/increase in LV stroke work as a result of TAVR.

Results and Conclusion The model was able to reproduce physiological waveforms found in patients with aortic stenosis and regurgitation. The results show that in several configurations, TAVR did not lead to a significant reduction in LV stroke work because of the presence of PVLs.

Defining a new parameter for evaluating TAVR success, as the ratio of the actual reduction in LV stroke work to the ideal reduction expected in the absence of PVLs, showed that in only 53% of cases TAVR was successful (>75% efficiency) in reducing LV stroke work. In 19% of cases the efficiency of TAVR was between 50-75%, in 18% of cases the efficiency of TAVR was between 50-50% and in 10% of cases TAVR led even to an increase in LV stroke work because the benefit of increasing EOA was damped by the negative impact of PVLs. In conclusion, TAVR is an effective option to reduce the left ventricle overload in high risk patients with severe AS. However, this is only true in the absence or mild paravalvular leaks. Severe or moderate paravalvular leaks significantly limit the benefit of TAVR and might even lead to an increase in the left ventricle overload.
In cases (b) and (c) an increase in $P_m$ gives new insight and better understanding of the mechanics of left ventricular function. A variety of clinical data taken from the medical literature and patient records can be used to distinguish three states for the operation of the left ventricle: (a) Normal physiological state, with $d_1$ nearly coinciding with the mid-point $d_5$. (b) Mildly depressed state, with $d_1$ and $d_5$ nearly coinciding. In this case we have $SV > (V_{ed} - V_{dm})/2$, with slopes $E_{max}/e_{am} > 2$ and $P_{isom}/P_m > 2$. Notice from Fig. 1 that when $d_1$ moves on the line $d_3V_{dm}$, the stroke work $SW$ reaches its maximum value $SW_x$ when $d_1$ coincides with the mid-point $d_5$. (c) Severely depressed state, with $d_1$ above $d_5$ on the line $d_3V_{dm}$. In this case we have $SV < (V_{ed} - V_{dm})/2$, with $E_{max}/e_{am} < 1$ and $P_{isom}/P_m < 2$ (see Fig. 1, right side). In cases (b) and (c) an increase in $P_m$ causes a decrease in $SW$, resulting in cardiac insufficiency. These results are confirmed by a wide variety of clinical data taken from the medical literature and give new insight and better understanding of the mechanics of left ventricular contraction.

**Figure 1:** (left) The ESPVR is represented by the line $d_3V_{dm}$ with midpoint $d_5$ and slope $E_{max}$. The pressure-volume relation is represented by the line $V_{ed}d_2d_1V_{dm}$ in a normal ejecting contraction. $P_{isom}$ is the peak active pressure of the myocardium. (right) Normal physiological case with $d_1$ below mid-point $d_5$ (solid line); abnormal case with reduced contractility with $d_1$ above mid-point $d_5$ (dotted line, top); abnormal case of hypertension with $d_1$ above mid-point $d_5$ (dotted line, bottom); notice that the three cases have the same $EF = SV/V_{ed}$.

The ventricular pressure $P_m$ is assumed constant during the ejection phase, $d_1$ is the corresponding point on the ESPVR. One can distinguish three states for the operation of the left ventricle:

- **a)** Normal physiological state, with $d_1$ below $d_5$ on the line $d_3V_{dm}$. In this case we have stroke volume $SV > (V_{ed} - V_{dm})/2$, with slopes $E_{max}/e_{am} > 2$ and $P_{isom}/P_m > 3$. This case corresponds also to maximum efficiency for oxygen consumption by the myocardium.

- **b)** Mildly depressed state, with $d_1$ and $d_5$ nearly coinciding. In this case we have $SV > (V_{ed} - V_{dm})/2$, with $E_{max}/e_{am} > 1$ and $P_{isom}/P_m > 2$. Notice from Fig. 1 that when $d_1$ moves on the line $d_3V_{dm}$, the stroke work $SW$ reaches its maximum value $SW_x$ when $d_1$ coincides with the mid-point $d_5$.

- **c)** Severely depressed state, with $d_1$ above $d_5$ on the line $d_3V_{dm}$. In this case we have $SV < (V_{ed} - V_{dm})/2$, with $E_{max}/e_{am} < 1$ and $P_{isom}/P_m < 2$ (see Fig. 1, right side).
SP152 - Special Treatment Techniques: Part 2

TRACK 04: RADIATION ONCOLOGY

SP152.1 - Optimal timing in concomitant chemoradiation therapy of colorectal tumors in nude mouse treated with Cisplatin and LipoplatinTM

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Background: Cisplatin is a chemotherapeutic agent, which under certain conditions can become a radiosensitizer. Cisplatin given concurrently with radiation enhance cell death by several mechanisms, including the inhibition of radiation-induced DNA damage repair and the induction of additional DNA damage or modification of radiation induced DNA damage. In recent fundamental investigations on cisplatin-DNA complexes, it was found that DNA damage induced by the low-energy secondary electrons, produced by ionizing radiation, was considerably increased when cisplatin was bound to DNA. This finding implies that the highest concomitant effect should be achieved, when the amount of cisplatin binding to DNA is highest.

Materials and Methods: Using an animal model of colorectal cancer, we determined the platinum window of maximum radiosensitisation and synergism, defined by studying the pharmacokinetics and time-dependent intracellular distribution of cisplatin and LipoplatinTM, the encapsulated form of cisplatin recently proposed to overcome its toxicity. In nude mice, bearing HCT116 human colorectal carcinoma treated with cisplatin or LipoplatinTM, the platinum accumulation in blood, serum, different normal tissues, tumor and different tumor cell compartments was measured by inductively coupled plasma mass spectrometry. Radiation treatment (15 Gy) was given 4, 24, and 48 h after drug administration and was correlated to the amount of platinum−DNA adducts in the cancer cells. The resulting tumor growth delay was reported and correlated to apoptosis analysis.

Results: The optimal treatment and highest apoptosis were observed when radiation was given at 4 h or 48 h after drug injection. These times correspond to the times of maximal platinum binding to tumor DNA. An enhancement factor (ratio of group treated by combined treatment compared to chemotherapy alone) of 13.00 was obtained with LipoplatinTM, and 4.09 for cisplatin when tumor irradiation was performed 48 h after drug administration.

Conclusion: The most efficient combination treatment with radiation and cisplatin or LipoplatinTM was observed when the amount of cisplatin binding to DNA is highest. These results improve our understanding of the mechanisms of platinum-induced radiosensitization and should have significant impact on the design of more efficient treatment protocols.

SP152.2 - Grid therapy: impact of radiobiological models on calculation of therapeutic ratio

**Author(s):** Somayeh Gholami1, Hassan Ali Nedaei2, Ali S. Meigooni3, Francesco Longo4
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Grid therapy, also known as Spatially fractionated radiation therapy, is a novel technique that has been introduced for treatment of patients with advanced bulky tumors. Several investigators have used linear quadratic radiobiological model to demonstrate the therapeutic advantages of the Grid therapy. Despite the success of the linear quadratic (LQ) model, for evaluation of the limitation of the Grid therapy with such large doses per fraction still there are challenges that need to be met. In this study we have applied both LQ and MQ radiobiological models to calculate therapeutic ratio (TR) of spatially fractionated radiation therapy. This evaluation is performed using Monte Carlo simulation.

In this study the Geant4 (version 9.6.p02) is used to simulate the photon spectrum of a 6 MV x-ray beam emitted by a Varian2100C linear accelerator, based on vendor detailed information. Percent depth dose (PDD) and dose profile of 6MV photon beam were obtained at 5cm depth for 10×10 cm2 open radiation field size in a water phantom. To verify Monte Carlo simulation calculations, these results were compared with the experimental measured data by a calibrated PTW 31010, 0.125 cc Semiflex chamber. The Grid block with hole-diameter of 1cm and a center-to-center distance of 1.8 cm at the isocenter was also simulated.

Therapeutic ratios of tumors with different histology (Melanoma, Squamous cell carcinoma (SCC), Adenocarcinoma and Sarcoma) have been calculated using both radiobiological models. Survival fraction of tumors at 2 Gy dose (SF2) and tumors cell lines radiobiological parameters were extracted from published data. In addition, various maximum doses are used to evaluate relationship between maximum dose and therapeutic ratio. Table 1 shows results for predicting TR at the different prescribed doses using LQ and MLQ models. The difference between the two models is less than 5% for the TR calculations.
Equivalent uniform dose (EUD) for all prescribed doses for both models has a value between 2.19 Gy and 3.87 Gy.

In this study, we have provided a dosimetric simulation and assessed the therapeutic ratio of four different types of tumor cells based on two LQ and MLQ radiobiological models for different doses. The results indicate that using radiobiological models that are more appropriate for high dose per fraction would not change the theoretical prediction of spatially fractionated radiotherapy. This is because the value of equivalent uniform dose (EUD) in Grid therapy is in the range that LQ model is valid.

### Table 1 - Results for therapeutic ratio (TR) calculations for LQ and MLQ radiobiological models at different maximum doses

<table>
<thead>
<tr>
<th>Tumor</th>
<th>SF2</th>
<th>TR (LQ Model)</th>
<th>TR (MLQ Model)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 Gy</td>
<td>20 Gy</td>
<td>30 Gy</td>
</tr>
<tr>
<td>Melanoma</td>
<td>0.485</td>
<td>1.22</td>
<td>1.37</td>
</tr>
<tr>
<td>SCC</td>
<td>0.483</td>
<td>1.21</td>
<td>1.37</td>
</tr>
<tr>
<td>Adeno.Ca</td>
<td>0.43</td>
<td>1.12</td>
<td>1.23</td>
</tr>
<tr>
<td>Sarcoma</td>
<td>0.42</td>
<td>1.10</td>
<td>1.21</td>
</tr>
</tbody>
</table>

SP152.3 - Will CyberKnife M6™ Multileaf collimator offer advantages over IRIS™ collimator in prostate SBRT?

**Author(s):** Vindu Kathriarachchi1, Charles Shang2, Theodora Leventouri1, Georgios Kalantzis1

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**Purpose:** CyberKnife M6™ InCise™ Multileaf collimator (MLC) has become a new modality in practice. Its ability of forming irregularly shaped beamlets offers a potential for more efficient dose optimization and treatment delivery in comparison with that by IRISTM dodecagon beams. This study is focused on quantification of such timesaving ability in prostate SBRT with comparable dosimetry plans.

**Methods:** Eight prostate cancer patients were planned in MultiPlan™5.1.2 respectively utilizing IRIS and MLC for 36.25 Gy in 5 fractions. PTV was outlined for treating prostate only. All plans were evaluated by dose conformity index (CI), homogeneity index (HI), new conformity index (nCI) and PTV coverage. In addition, maximum doses at the bladder and rectum, calculated treatment time per fraction and planned MUs were also compared and tested for significance with the Wilcoxon test.

**Results:** In both IRIS and MLC plan groups, PTV Dmax was scaled to 115% while the HI was maintained at 1.15. The mean V100 was 95.42% for IRIS, and 95.36% for MLC (p=0.48); mean CI: 1.08 vs. 1.05 (p=0.09); and mean nCI: 1.13 vs. 1.11 (p=0.11). Between the groups, the differences of Dmax for the bladder and rectum were found insignificant (p=0.4). Changing from IRIS to MLC, the average treatment time per fraction was reduced by 35% (43.5 ± 2.6 min vs. 28.3 ± 1.6 min, p<0.01) and the planned MUs were decreased by 40% (50318 ± 8976 vs. 30286 ± 2211, p<0.01).

**Conclusions:** This investigation demonstrated the ability of CyberKnife M6™ to produce prostate SBRT plans equivalent to those using IRIS in terms of target coverage, and dose sparing of critical structures. However, a significant 35% reduction in treatment time and 40% reduction in number of MUs were achieved by replacing IRIS with MLC without dosimetric compromise in planning quality.

SP152.4 - Retrospective analysis of treatment margins for stereotactic ablative lung cancer treatments based on 4D CBCT

**Author(s):** Sheeba Thenumpallil1, Jean-François Germond1, Nicolas Péguret2, Jean Bourhis2, François Bochud2, Raphael Moeckli2

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**Purpose/Objective:** The objective of this study was to evaluate treatment margins defined after the 4D CBCT off-line analysis and compare them with literature.

**Materials/Methods:** Thirty stereo-ablative T1-T2 N0 M0 lung cancer patients were analyzed (with a total of 229 fractions). All patients were treated in frameless and free breathing conditions. The treatment margins were defined according to van Herk recipe on Mid-Ventilation phase. The treatment margins before 4D CBCT off-line analysis were defined using the systematic and random components taken from literature (Sonke et al. IJROBP 2009). For each patient, we assessed the tumor motion amplitude and the intra-fraction variability from 4D CBCT images realized for tumor positioning (baseline shift), for couch correction verification and for intra-fraction motion (three 4D CBCT were performed for each fraction). From these data, we derived the resulting systematic and random errors for our patient cohort, leading to related margins for each patient.

**Results:** A summary of systematic and random errors are shown in the Table. When comparing the treatment margins applied to the patients (data from literature) and the margins retrospectively calculated from our patient cohort we observed that the margins applied to the patients should have been slightly larger (~1 mm 3D vector) (see Figure).

**Conclusions:** Tumor localization accuracy and intra-fraction motion uncertainties were assessed in our patient cohort by analyzing 4D CBCT images performed during each treatment fraction. We found that slightly larger margins should have been applied to our patients. According to the probabilistic approach of the van Herk recipe, a difference in the PTV margins as small as 1mm (3D vector) should not lead to a difference in tumor local control. However, the consequences of these differences should be evaluated in a dosimetric point of view in order to confirm that assumption. This is the object of an ongoing study.
Radiotherapy is still considered as a last resort treatment in liver cancer cases, when the patient’s condition doesn’t allow for more conventional treatment options. However, the same health factors that prevent the use of these methods also affect the risks associated with radiotherapy and further reduce the spectrum of treatment options that are available.

At the CHUM, liver tumors are treated using the CyberKnife system aided by the implantation of gold seeds as markers for tracking. However, some patients’ liver condition doesn’t permit the insertion of those markers. In these cases, we are left with the need for some other way to visualize the movements of the tumor during treatment. Surgical clips, which are already present in the liver of the patient, will then be used as surrogates to monitor the movement of the tumor. These clips have very different physical and radiological properties from gold seed markers and therefore their use needs to be investigated further to assess their relevance as markers and to optimize their use in the clinical context.

We have evaluated the in-treatment images taken at the CyberKnife for previous patient cases and using an anthropomorphic phantom for a more general outlook. It was then measured that, to maximize the contrast between the clips and the surrounding tissue, it is best to use both high kV and mA settings on the imager, as can be seen on figure 1. The capability of the CyberKnife’s algorithm to detect and track the clips was evaluated by comparing the calculated and real positions of the clips in the treatment images. The ensuing error on the position could then be analyzed and compared with the corresponding error in the case of gold seed markers and the recommended margins of error for radiotherapy treatments. This displacement was also assessed experimentally by using a moving phantom with inserted clips. The margin of error and any blurring effects on the expected dosimetric treatment map were measured using dosimetric film.

This research allows us to draw conclusions as to the utility of surgical clips in tracking liver tumors. Using our conclusions as well as those found in literature, we were able to make recommendations for good clinical guidelines for treating liver tumors using surgical clips as radiological markers for tracking.

SP152.6 - A Novel Couch-Gantry Trajectory Based Stereotactic Treatment Method
Author(s): Byron Wilson1, Karl Otto2, Ermias Gete1
1Medical Physics, BC Cancer Agency, Vancouver/CANADA, 2Physics And Astronomy, University of British Columbia, Vancouver/BC/CANADA

Introduction
We propose an inverse planning solution for trajectory-based stereotactic (SRS) treatments of small lesions in the brain with a c-arm linac. The beam trajectory is formed by simultaneously rotating the linac gantry and the treatment couch, thus enabling a wide selection of beam angles in a time efficient manner. Dose is optimized by dynamically varying the dose rate and the MLC leaf positions along the beam trajectory.

Methods
The trajectory-based inverse planning algorithm we propose is based on the VMAT technique developed by Karl Otto. The predefined beam trajectory (Figure 1) is formed by rotating the patient couch through 180° while the gantry produces a series of 6 to 8 partial arcs of +/-170° each. This trajectory allows delivery from a wide array of directions while the couch is constrained to move at a slow and constant angular velocity, thus ensuring patient comfort. Dose rate and MLC leaf positions are modulated.
An optimized beam intensity pattern is formed along this trajectory (figure1b), while the MLC aperture changes continuously. The optimization adds control points using the progressive sampling algorithm and varies each control points' MLC positions and dose rates with stochastic perturbations, keeping only the perturbations that lower the cost function. Since the default trajectory samples the entire phase-space, unwanted portions of the trajectory are removed by dose rate modulation. MLC aperture optimization is used mainly for target conformity. Therefore, our method emphasizes beam weight perturbation and we are able to speed up the optimization by adding momentum to beam weight perturbations.

We have tested our method on two cranial cases (acoustic neuroma (plan1) and brain mets (plan2)) that were previously treated with SRS using non-coplanar dynamic conformal arcs. Treatment plans were generated and compared to the original conformal plans. These plans were successfully delivered on the TrueBeam Linac using the Developer Mode.

**Results**
For plan1, there was a reduction of the mean dose to the organs at risk (OAR): brainstem (17%) and optic tract (51%). For plan2, dose to OARs were comparable to the original plan and were maintained at less than 2% of the prescription dose. Conformity to the PTV improved for both plans. Delivery time for a 15Gy fraction at the isocenter was approximately 6 minutes.

**Conclusion**
The method proposed will be achievable on current conventional linacs once concurrent couch and gantry motion are enabled. This technique produces high quality, reproducible and efficient treatment plans for SRS patients.

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**SP153 - Quality Assurance: Part 4**

**SP153.1 - Comparison of AAA and CCC Algorithms for H&N RapidArc pre-patient treatment QA**

**Author(s):** Thuso M. Ramaloko¹, John K. Bhengu²

¹Medical Physics, Addington Hospital, Durban/SOUTH AFRICA, ²Medical Physics, Inkosi Albert Luthuli Central Hospital, Durban/ SOUTH AFRICA

**Objectives:** Because adherence to quality assurance (QA) is important to patient safety, moving from gamma passing criteria to patient DVH-based QA won't be a bad idea. The aim of the study was to evaluate OAR dose difference for H&N between COMPASS and Eclipse.

**Materials and Method:** The Eclipse TPS, COMPASS software, 30 H&N RapidArc patient’s plans, 5 Prostate RapidArc patients’ plans, Delta-4, MatrixX and Varian trilogy Linac were used. All 35 plans were computed with eclipse TPS using 2.5 Arcs, 2.5mm grid size, 1.8-2Gy per fraction for 28-33 fractions and field size ranged from 5cm² to 12cm². The computed dose fluence(s) were measured with MatrixX and Compass software dose reconstruction was carried out using 2.5mm grid size. The maximum dose (D2%) as per ICRU-83 recommendations was used for comparison between Eclipse and Compass. The prostate plans were primarily used for checking field size dosimetric effect between the two systems.

**Results and discussion:** Table 1 summarizes the head and neck plans comparison between the Eclipse TPS and the COMPASS verification software for different organs.
SP153.2 - Tuning treatment planning system model parameters for accurate VMAT dose calculation using conformal arc plans

Author(s): Orest Ostapiak
Medical Physics, Juravinski Cancer Centre, Hamilton/CANADA

Machine models parameters within a treatment planning system (TPS) must be carefully tuned in order to accurately calculate dose due to VMAT plans. This is best achieved by comparing the results of calculations with those of measurements for VMAT plans that: deliver reproducibly; yield relatively homogeneous dose distributions; and, are sensitive to model parameters such as those characterizing the MLC. In Pinnacle version 9.2, creating deliverable VMAT plans requires first commissioning a candidate model, then running an optimization to generate a set of VMAT control points. These control points may have irregular shapes which complicate the analysis of discrepancies between calculated and measured dose.

The purpose of this work is to present a method for creating simple VMAT-like plans in a TPS that can be used to test and fine-tune MLC model parameters.

Plans were designed to irradiate a cylindrical phantom containing an ion chamber aligned along its central axis. A single voxel at the central axis in each slice comprised the target region of interest. Four conformal arcs beams spanning successive 45 degree sectors irradiated the target with a margin. Margins were tailored to create MLC slit fields of 1, 5 or 10 mm width. Each arc is created with the isocentre shifted 2 cm toward the mid-arc incident direction in order to force the MLC slit to sweep across the field. Control points were defined every 2 degrees of gantry arc. The isocentre for each arc was then centered on the ion chamber using the same control points. Each arc delivers a narrow slit field that sweeps across the ion chamber as the gantry rotates. Since each arc is opposed, the dose varies by less than ±1.5% within 1 cm of the ion chamber cavity centre.

Doses measured using each of two chambers (A16 and PR06) agreed to within about 1% for all slit widths delivered by a single machine. Dose variation between two machines was 1, 2 and 5% corresponding to slit widths of 10, 5 and 1 mm respectively. Our clinical Eclipse model computes doses that are between 4 and 24% low compared to measurement. Adjusting the dynamic leaf gap from 0.08 mm to 1.6 mm brings computed doses within 3% of those measured. In Pinnacle, setting the MLC leaf tip radius to 12 cm and using the machine’s leaf offset table yields computed doses that are between 2.5 and 13.8% low compared to measurement. Increasing the leaf tip radius to 1000cm and setting all leaf offsets to -0.08 mm (to match the Eclipse dynamic leaf gap) yields calculated results that are within 1.2% of the measured values.

Plans that mimic VMAT delivery may be created within a TPS using standard forward planning techniques. While not clinically relevant, these plans are useful for model tuning since the calculated dose is sensitive to small adjustments in MLC model parameters but robust with respect to delivery and measurement.

The Delta-4 gamma index are 97.9±1.4% and 97.9±2.2% for H&N and prostate plans respectively, and Compass gamma index are 97.0±1.1% and 97.2±2.1% for H&N and prostate plans respectively.

Conclusion: The results were in agreement with Oncologist’s quantitative protocol and Physicists total dose gamma index criteria. The small volumes displayed high dose difference and were documented. The baseline values were established.
**SP153.3 - Prostate brachytherapy with Oncentra Seeds: Intra-operative planning and delivery software validation assisted by an FMEA**

**Author(s):** Benee X. Larouche, Yannick Hervieux, Dominic Béliveau-Nadeau, Jean-Francois Carrier, Daniel Taussky, Guila Delouya

**Radio-oncologie, CHUM - Hôpital Notre-Dame, Montreal/CANADA**

**Introduction:** For the past 9 years, our center has been treating patients with prostate cancer with permanent seed implant prostate brachytherapy. This has been done using a Nucletron intra-operative planning and delivery system (FIRST®). We have now changed to a new Elekta Brachytherapy software (Oncentra® Seeds 4.2 (OCSSe)). The goal of this study was to validate the new software for clinical use. Published guidelines from the AAPM and CPQR as well as a Failure Mode and Effect Analysis (FMEA) were used to review software and process.

**Methods:** We reviewed and implemented applicable guidelines from TG-43, TG-53, TG-56, TG-59, TG-64, TG-128 and TG-137. We also followed CPQR standard for Low Dose Rate Permanent Seed Brachytherapy. In total, over 60 tests were done to validate the new software. A FMEA was also performed.

**Results:** Using the tests, we identified weaknesses in the software:

- Discrepancy between software indication of ultrasound (US) imaging plane and the actual US imaging plane due to latency of the US image stream;
- Contour displacement when switching between modes;
- Line source dosimetry at 0 and 5° does not meet accuracy criteria;
- Poor robustness to system crashes. Over 10 min required to reboot system;
- The system does not force acknowledgement of error messages;

Some of these weaknesses were due to connectivity issues with third party equipment (US scanner). Following communication with the vendor, some issues were addressed through workarounds. The FMEA (see Table 1) lead to discussions with the vendor regarding workflow. In order to make our institution’s process more robust and less vulnerable to failures, planning system settings were customized to our needs.

**Table 1:** Top 5 Failure modes identified during the FMEA

<table>
<thead>
<tr>
<th>Step</th>
<th>Failure modes</th>
<th>S</th>
<th>F</th>
<th>D</th>
<th>C</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Accidental needle update</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Error in needle position due to frozen US image</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Mismatch between re-constructed needle and software needle “cartoon” used for positioning</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Wrong US scanning parameters</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Plan transfer not possible due to empty needles</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

Over twenty-five patients have now been treated using OCSSe. Issues not identified during the pre-clinical testing were encountered, most notably surrounding corrections for prostate motion. Our process was reviewed and adapted taking into account these issues.

**Conclusion:** Based on data gathered so far, our results show that the extensive testing done before clinical implementation was valuable. These tests served to identify problems in the software and improve our process. Proper software validation in the context of the whole clinical process is very important and strongly recommended in assuring quality treatments.

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**SP153.4 - Investigation of predictive parameters for pre-treatment measurement pass rates in hypo-fractionated volumetric arc therapy (HF-VMAT) plans of single brain metastasis**

**Author(s):** Young K. Lee¹, Matt Wronski², Anthony Kim³, Mark Ruschin²

¹Department Of Radiation Oncology, University of Toronto, Toronto/ON/CANADA, ²Department Of Medical Physics, Sunnybrook Health Sciences Centre, Odette Cancer Centre, Toronto/CANADA

**Purpose:** HF-VMAT planning for brain metastases can be complicated, as these cases often involve small treatment volumes (planning target volumes (PTV)<25cm³) in close proximity to critical organs-at-risk (OAR). Pre-treatment dosimetric verification for such cases often yields sub-optimal pass rates. The purpose of the present study was to investigate the combined effects of OAR-to-PTV distance, as well as the differential between OAR tolerance dose and PTV prescription dose, in predicting what measurement pass rate is achievable.

**Methods:** Twelve single lesion brain HF-VMAT cases were planned using Pinnacle v9.2 with 6MV Elekta Agility (Crawley, UK). The prescription doses ranged from 25 to 35 Gy in 5 fractions. All plans were recalculated and measured using an ArcCHECK diode phantom (SunNuclear Corporation, Melbourne, USA) employing Gamma analysis with criterion set at dose agreement of 3% and distance agreement at 2 mm. The predictive value, PV, investigated in the present study was as follows:

\[
PV = \frac{dcco}{\Delta D/G}
\]

\(\Delta D\) is the difference in dose between the prescription dose and dose-limiting OAR dose in Gy, G is the nominal dose gradient (150 and 400 cGy/mm for in-plane and out-of-plane of PTV, respectively), and \(dcco\) is the distance calculated using overlap-volume-histogram to the closest critical OAR in mm, where negative \(dcco\) indicates overlap between the expanded PTV and OAR. Smaller or increasingly negative values of \(PV\) were expected to predict increasingly modulated plans and hence lower measurement pass rates.

**Results:** Median (range) of PTV was 11.5 (4.1 - 24.7) cm³. The closest critical OAR observed in 8/12 cases was brainstem and for 10/12 cases the OAR was in the same plane as the PTV. Figure 1 shows the \(dcco\) and \(PV\) plotted against the ArcCHECK measurement pass rates. PV<10 mm show pass rates of <90% for Gamma analysis with the criterion set at 3%/2mm. A stronger correlation was observed between \(PV\) and pass rates than \(dcco\) and pass rates.
Discussion: We show a relationship between PV and pre-treatment verification pass rate. Though the PV was calculated using a small dataset, it can be used to predict if a complicated VMAT plan may be required at the planning stage. This may allow the planner to decide if another planning methodology can be used to avoid pre-treatment verification failures that can cause problems in the planning process.

SP153.5 - Inter-centre comparison of dose delivery accuracy for six different linac-planning system combinations for SBRT lung cancer treatment using FFF beams.

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Purpose: Flattening filter free (FFF) beams are being rapidly adopted for stereotactic body radiotherapy (SBRT). Compared to conventional flattened beams (FF), they have higher dose rates, lower lateral beam hardening changes, lower leakage and lower out-of-field doses. Together these provide the potential to improve treatment plans. Elekta and Varian have implemented FFF beams using different energy definitions and have different MLC designs; both of which might influence the achievable plan quality. In addition the MLC segmentation, IMRT optimisation and dose calculation engines employed in the various treatment planning systems (TPSs) may influence performance. This multi-centre, multi-system study compared plans and delivery accuracy of FFF lung SBRT treatments across six different linac-TPS combinations.

Materials and Methods: Ten lung patient cases were provided to seven different radiotherapy centres for SBRT planning with FF and FFF beams. Linac/TPS combinations included are: Varian-Eclipse, Varian-Pinnacle, Novalis/Varian-Eclipse, Elekta-Pinnacle, Elekta-Monaco and Tomotherapy-Tomoplans. The planning protocol was common for all. Prescribed minimum doses were 48Gy/4fr for tumours located <1.5cm from the thorax wall, 50Gy/5fr for those within 2cm of the main bronchial tree and 54Gy/3fr elsewhere in the lung. 180°-200° VMAT arcs were used for all standard linac plans, avoiding the contra lateral lung. Relevant DVH metrics were tested for significant differences, using a paired two-sided Wilcoxon-signed rank test and 5% significance. Plans were delivered to a Sun Nuclear ArcCheck phantom, where planned and measured doses were compared using a 3%/3 mm gamma analysis with a 10% threshold, and global normalisation. Beam on times were recorded.

Results: In the preliminary analysis, high quality dose plans and good delivery accuracy were observed for all the linac-TPS combinations across these ten plans. Mean gamma pass rates of 98.1% (FF) and 97.4% (FFF) were observed (Table 1). For Elekta-Pinnacle, FFF plans have lower pass rates than FF plans, but the relative calibration of the ArcCheck phantom (performed in low dose rates) may be a factor in this and is being investigated. FFF plan MU are higher in Varian/Novalis-Eclipse, but not for Elekta-Pinnacle. Eclipse generally used more MU than Pinnacle. Beam-on times are significantly reduced, with largest gains observed for Elekta-Pinnacle.

Conclusions: FFF beams produce acceptable plan quality and high dose delivery accuracy for SBRT lung treatments, across a range of linac-TPS combinations and representative tumour positions. Each combination has specific issues, which indicate further investigation possibilities. The TomoTherapy-Hi Art combination data is still to be fully evaluated.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>FF</th>
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<tr>
<td><strong>All</strong></td>
<td>mean</td>
<td>SD</td>
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<tr>
<td>Beam on [sec]</td>
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<td>77</td>
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<tr>
<td>MU</td>
<td>2912</td>
<td>732</td>
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<tr>
<td>Pass rate [3,3mm]</td>
<td>98.0</td>
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<td><strong>Elekta-Pinnacle</strong></td>
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<td>Beam on [sec]</td>
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<td>72</td>
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<td>MU</td>
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<td>653</td>
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<td>Pass rate [3,3mm]</td>
<td>98.9</td>
<td>1.9</td>
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<tr>
<td><strong>Varian/Novalis-Eclipse</strong></td>
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<tr>
<td>MU</td>
<td>3040</td>
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<tr>
<td>Pass rate [3,3mm]</td>
<td>97.6</td>
<td>1.8</td>
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</table>

SP153.6 - A pilot study investigating the impact of treatment delivery uncertainties for lung SABR using step and shoot IMRT and VMAT

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Purpose: Advanced RT techniques require conservative approaches to planning, e.g. safety margins added to target volumes and the level of
QA performed. This is partly due to a lack of detailed knowledge about the uncertainties involved in treatment delivery. The optimization and application of advanced techniques would benefit from a better understanding of such uncertainties and their impact on treatment effectiveness. This study investigates how delivery uncertainties affect target coverage for step-and-shoot IMRT (ssIMRT) and VMAT in SABR patient treatment plans.

**Methods**

6 MV ssIMRT and VMAT reference plans for three lung SABR patient datasets were created using the Pinnacle3 TPS (version 9.8) for an Elekta Synergy linac. Copies of these plans were modified using in-house code to generate a series of systematic ‘error-introduced’ plans, where the values of three beam delivery parameters were altered across all control points for each plan (gantry angle, collimator angle and MLC leaf positions). Gantry and collimator angles were changed from their reference values by +/- 1 or 2 degrees; MLC leaf positions by shifting each leaf from its reference position by +/- 1 or 2 mm. Error-introduced plans were read back into Pinnacle and dose calculations were performed on the reference patient anatomy. Target DVH metrics, including the volumes of PTV receiving 95% and 100% of the prescribed dose (VPTV95 and VPTV100, respectively) and the 50%, 100% and 105% isodose volumes (V50, V100 and V105, respectively) were extracted from each plan. The conformity index, high dose (105%) and low dose (50%) spillage were also quantified. Percentage differences between values for the error-introduced plans and their respective reference plan were calculated to quantify the impact of varying each delivery parameter. Results were compared between the ssIMRT and VMAT plans to consider dependencies on delivery technique.

**Results**

For all DVH metrics considered, increasing the magnitude of the introduced error generally resulted in larger percent deviations from reference plan results. The VPTV95 and VPTV100 consistently decreased with increasing magnitude of MLC leaf shift. A maximum decrease in VPTV100 of approximately 5% was observed for MLC shifts of 2 mm in both the ssIMRT and VMAT plans. Collimator and gantry angle variations typically resulted in VPTV95 and VPTV100 deviations of <1%. Of the DVH metrics investigated, high dose spillage was the most sensitive to introduced errors for both treatment techniques. When collectively considering all beam delivery parameters investigated in this study, high dose spillage increased on average by between 12 and 27% for the ssIMRT and VMAT plans, respectively.

**Conclusion**

The impact of treatment delivery uncertainties on ssIMRT and VMAT patient dose distributions was investigated with an initial pilot cohort of lung SABR plans. Target coverage was typically compromised more by changes in MLC leaf positions than gantry or collimator angle. Of the DVH metrics and delivery parameters considered, high dose spillage was the most sensitive to treatment delivery uncertainties. The study is being extended to a wider set of plans with the aim of quantifying site- and technique-specific treatment delivery uncertainties in advanced RT techniques.
Table 1. Differences in dose volume parameter calculated with MC using PlanCT and PlanCT for one daily treatment

<table>
<thead>
<tr>
<th>Plan</th>
<th>Structures</th>
<th>Dmean (%)</th>
<th>Dmax (%)</th>
<th>V95% (%)</th>
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<tr>
<td>PTV</td>
<td>98.9</td>
<td>103.7</td>
<td>97.7</td>
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<tr>
<td>Bladder</td>
<td>53.6</td>
<td>102.0</td>
<td>11.6</td>
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<tr>
<td>PlanCT</td>
<td>49.8</td>
<td>101.8</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>L Fem Head</td>
<td>19.6</td>
<td>42.1</td>
<td>1.0</td>
<td></td>
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<tr>
<td>R Fem Head</td>
<td>16.6</td>
<td>46.3</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>PTV</td>
<td>95.3</td>
<td>103.5</td>
<td>65.5</td>
<td></td>
</tr>
<tr>
<td>PlanCTFinal</td>
<td>Bladder</td>
<td>48.1</td>
<td>96.1</td>
<td>1.5</td>
</tr>
<tr>
<td>(one fraction)</td>
<td>Rectum</td>
<td>58.3</td>
<td>103.5</td>
<td>22.8</td>
</tr>
<tr>
<td>L Fem Head</td>
<td>20.3</td>
<td>45.8</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>R Fem Head</td>
<td>14.9</td>
<td>39.3</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

Discussion: Significant differences in dose volume parameters are calculated when using daily CBCTs. Note the large difference in V95% due to inter-fraction prostate movement. Preliminary results highlight the need for more sophisticated QA procedures, including adaptive dose accumulation over the entire course of treatment. This technique is intended to complement daily in vivo dosimetry using EPID-based techniques.

SP154 - Developments in Radiation Protection

SP154.1 - Out-of-field radiation dose to critical organs due to radiotherapy for testicular seminoma with modified dog-leg fields: is there a risk for stochastic effects?

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Purpose: Modern radiotherapy of stage II seminoma involves the use of modified dog-leg fields with reduced dimensions compared to conventional portals. The objectives of this study were to (a) calculate the out-of-field dose to critical organs from irradiation with modified dog-leg fields using a Monte Carlo approach and (b) estimate the associated risk for stochastic effects.

Methods: The Monte Carlo N-particle transport code was used to simulate the head of a linear accelerator generating 6 MV X-rays. The model was validated against in-field dose measurements performed on a water tank and out-of-field thermoluminescent measurements generated on a humanoid phantom. A mathematical phantom representing a typical adult patient was implemented into the Monte Carlo environment. Radiotherapy was simulated with a pair of anteroposterior and posteroanterior modified dog-leg fields covering the para-aortic and ipsilateral iliac lymph nodes. Radiation dose calculations were made for all critical organs that defined by the ICRP publication 103 and located outside the simulated treatment fields. The calculated organ doses were combined with the appropriate risk factors to estimate the probability for developing secondary malignancies and heritable effects.

Results: The measured and calculated in-field radiation doses were in an excellent agreement with a difference of less than 2 %. A small mean difference of 9.6±5.3 % was also found between out-of-field Monte Carlo dose calculations and experimental measurements. Simulated radiotherapy with modified dog-leg fields delivering 30 Gy to the tumor site resulted in an out-of-field organ dose range of 31.4-830.1 mGy. For a testicular cancer patient subjected to radiotherapy at the age of 30 years, the radiation doses received by non-targeted organs may increase the lifetime risk for second cancer development up to 2.2 %. The risk for heritable effects in future generations was estimated to be 0.2 %.

Conclusions: Radiotherapy with modified dog-leg fields may result in a relatively increased risk for second cancer induction. The probability for developing hereditary disorders is low compared to the natural incidence of these effects.

SP154.2 - Peripheral photon dose in organs

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There are an increasing number of RT patients who survive for periods comparable/larger than the latent period of a second cancer.
Additionally, new techniques provide a better dose conformation at the cost of higher doses in organs outside the treatment field. That makes mandatory to compare the benefits (TCP) and the risks (NTCP and second cancer risks SCR) of the patient exposure. And yet, in spite of the treatment planning systems (TPS) providing accurate calculations of the dose delivered to the target, organs placed at a distance are no considered. Consequently, TPS only generate information regarding tumour control and radiation toxicity of neighbouring organs. The lack of algorithms to estimate equivalent dose to peripheral organs, together with uncertainties on risk factors, make the estimation of SCR not trivial.

Equivalent dose in organs can be calculated as the sum of equivalent doses for each radiation quality. We proposed a methodology to estimate equivalent neutron dose in organs for RT treatments (E>10MV) [1, 2] and developed an algorithm to calculate photon doses (to be submitted) for conformal radiotherapy -3DCRT- and IMRT [3].

The aim was to propound a methodology to calculate the mean absorbed photon dose in peripheral organs for individuals from a point-based algorithm requiring steadily available patient parameters.

Organs’ lengths for individuals are calculated by using a scale factor (patient’s/Cristy phantom’s lengths). It is assumed that the organ photon dose is the integral of doses along the organ as follows:

\[
Dose_{organ,x} = \frac{1}{l_{organ}} \int_{x_{organ}}^{x_{organ} + l_{organ}} Dose(c, f, z, x') \, dx'
\]

\(L\) is the organ length and \(X\) the distance from the most cranial point to isocenter. Our model [3] established an expression for point dose calculation as the sum of the transmission and leakage (constant) and a second exponential term depending on the distance to a virtual scattering source (calculated from the isocenter depth –z- and \(x'\)). The fitting parameters, obtained for 3DCRT treatments, were modified to account for other treatment efficiencies (\(C = \) prescription dose/ MU) and field sizes, both relatives to 3DCRT. This algorithm was built into Matlab through a Graphical User Interface and was validated [4] and used for calculations on how moving from 3DCRT to IMRT may result in an increase in peripheral organ doses [5].

From equivalent dose in organs, SCR estimations can be made for comparison to epidemiological data on induced RT cancer rates.


SP154.3 - Gamma Radiation Dose-Response Relationship of Human Thyroid Follicular Cells

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**Introduction:** Thyroid gland is sensitive to gamma irradiation. Thyroid follicular cells produce the hormones T3 (triiodothyronine) and T4 (tetraiodothyronine or thyroxine) which play vital role in our lives. During radiotherapy (Co-60 teletherapy) in head-neck region, patients’ thyroid gland is exposed to high level gamma irradiation. The exact dose on thyroid depends upon the tumor site, stage and overall total radiotherapy dose.

**Aim of the work:** In this research, an attempt had been made to find the relationship between gamma radiation dose to thyroid gland and the consequent response of its follicular cells.

**Methodology:** A total of one hundred and eighty head-neck cancerous patients of Chittagong Medical College hospital and Sylhet MAG Osman Medical College Hospital who had to be treated with radiotherapy (Co60Co) were selected in the present research. The patients’ hormones T3, T4 and TSH (Thyroid Stimulating Hormone or thyrotropin) had been measured six times for each patient. The measurement times of which were before the beginning of their radiotherapy course, immediately after the radiotherapy, six weeks after the radiotherapy, twelve weeks after the radiotherapy, twelve months after the radiotherapy and finally twelve months after the radiotherapy for individual patients.

**Results and Discussion:** Thyroid follicular cells’ response had been estimated by the percent of decrease in secretion of hormones T3 and T4 in spite of increased secretion of TSH by the pituitary gland. Graphs had been plotted by keeping the dose to thyroid (from 0 to 66 Gy) of patients (due to head-neck cancer) as abscissa and the percent of reduction of T3 and T4 hormones after one year of completion of radiotherapy as ordinate. For T3 hormone, the most fitted graph had been found to be an exponential one satisfying the equation, \(y = y_0 + Ae^{-x/b}\) where, \(y_0, A\) and \(b\) are constants. The analyses had been done by the software OriginPro 7.5. For the T4 hormone, similar graph and equation had been found with slightly different parameters. For TSH, the corresponding relation had been found to be somewhat linear. No significant response had been observed unto twelve weeks after the completion of radiotherapy. At six months after the completion of radiotherapy, significant change in hormone levels had been observed. However at one year after the completion of radiotherapy course, drastic change in hormone levels had been observed. The more the level of exposure to thyroid, the more reduction in hormone T3 and T4 levels had been observed. For the exposure level of 66 Gy, graphs had also been plotted to find the role of time in the manifestation of radiation-response (reduction in the levels of T3 and T4) of thyroid follicular cells. Linear relations had been observed for T3 and T4 and for that 365 days time period.

SP154.5 - Aligning the ALARA principle with FFF treatment modalities

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The recent popularity of flattening filter free (FFF) treatment beams featuring high dose rates has created some new radiation safety considerations. The softer FFF beams are less penetrating than their counterpart flattened beams (FF) of the same nominal energies. Thus in replacing FF treatment units the existing shielding is usually...
A Varian TrueBeam featuring four energy modes of 6-MV and 10-MV with FF and FFF was to replace its decommissioned predecessor, a Varian 21EX 6MV and 10 MV accelerator. The shielding design and previous radiation survey for the existing treatment bunker was analyzed to assess radiation safety for the new unit, focusing on beam quality, elevated dose rates, and an increased workload. This led to modifications of one existing primary barrier to reduce the IDR. The calculated IDR beyond this barrier for the FFF quality beam at the highest dose rate was 41 mSv / h, above the threshold for a controlled area at 25 mSv / h.\(^1\)\(^2\)\(^3\) Thus extra shielding was required because of the increase in the dose rate from 6 Gy / minute to 24 Gy / minute at 100-cm SAD, not because of beam quality for the 10MV FFF beam.

A lead wall approximately 1 TVL thick covering this projected field plus margin was constructed at the primary barrier. Radiation survey results using an ion chamber survey meter yielded 28 mSv / h and 7.7 mSv / h for the unmodified and modified barriers respectively. Corresponding calculations were 41 mSv / h and 5.7 mSv / h.

The room beyond the modified primary barrier is an adjacent treatment bunker and thus already a controlled area with the appropriate posting of radiation warning signage. Because the IDR without barrier modification was high, it was reasonable to reduce the exposure for that room by adding the shielding. Thus we used the ALARA principle to further protect our staff.

We have modified a primary barrier for a treatment unit with a FFF beam with high dose rate capabilities. The ALARA principle was used to justify reducing the exposure to further protect staff. The increased exposure was due to the increase in maximum dose rate even though the FFF beams are softer and less penetrating. Hypothetically, situations can arise from a combination of workload, occupancy factors, and existing shielding that not only could cause increases in IDRs, but also the annual equivalent doses. Thus care should be taken in shielding design to deal with the high dose rates.

References:


NCRP REPORT No. 151.(2005)


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**SP155 - Characterization of Detector Systems for Therapy Dosimetry: Part 3**

**TRACK 05: DOSIMETRY AND RADIATION PROTECTION**

**SP155.1 - Ferrous - methylthymol blue - gelatin gel dosimeter with improved auto-oxidation stability**

**Author(s):** Kailin I. Peney, Kibret Mequanint

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The ferrous sulfate – methylthymol blue – gelatin (FMG) dosimeter is a recently-developed modification of conventional ferrous xylenol orange – gelatin (FXG) dosimeter that allows optical scanning with red light (615 – 635 nm), as opposed to amber light (580 – 590 nm). Scanning at the higher wavelength is beneficial as: optical scatter in the gelatin matrix decreases, and these wavelengths can be used for other optical dosimeters, allowing for simpler scanner design. It has previously been shown that the dose sensitivity and diffusion for both FMG and FXG are similar due to equivalency of the signal generation processes. Radiation-induced oxidation of ferrous iron (Fe\(^{2+}\)) in the acidified gel produces ferric iron (Fe\(^{3+}\)) in proportion to the delivered dose; and an intensely-coloured complex is formed between Fe\(^{3+}\) and either xylenol orange (OX) or methylthymol blue (MTB). Unfortunately both gels are prone to autoxidation. We propose decreasing the auto-oxidation in FMG gels by adding phenanthroline-type ligands.

In preliminary experiments 5-nitro-1,10-phenanthroline (Nn) and bathophenanthrolinedisulfonic acid (BD) were tested as stabilizing agents for Fe\(^{2+}\) with MTB in sulfuric acid (SA) solutions at 25 to 40 mM SA. Heating at 72 °C for one hour was used in lieu of a longitudinal study of autoxidation. Relative to Nn, the addition of BD had a very stable, low background optical density and adequate dose response. Unfortunately the diffusion coefficient was relatively high but addition of glyoxal (5 mM) decreased the diffusion by 10% without significantly affecting the sensitivity and stability (results not shown). In our opinion this FMG composition provides a viable alternative to FXG gels dosimetry.
SP155.2 - The dosimetric property of TLD2000 thermoluminescent dosimeter

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Purpose: To study the dosimetric properties of TLD2000 thermoluminescent dosimeter (TLD), including repeatability, linearity of dose response, energy response and dose rate effect.

Materials and Methods: 1300 TLD2000 TLDs were read out after exposure to a dose of 1 mGy of 65 keV x-ray, then were sorted out to have the same sensitivity within ±0.3%. TLDs were irradiated to a dose of 120 MU using 6 MV x-ray then irradiated to the same dose after 24 h. TLDs were irradiated by two ^125I seeds with the same activity for 24 h, and the interval time was 24 h, to study the repeatability of TLDs for 6 MV x-ray and ^125I seed. TLDs were irradiated to different doses using ^137Cs (662 keV γ-ray), ^125I seed and 6 MV x-ray, to study the dose response of the TLDs. TLDs were irradiated to a dose of 1 mGy using ^137Cs, 48 keV, 65 keV, 83 keV, 118 keV and 250 keV x-rays, to study the energy response of the TLDs. TLDs were irradiated to a dose of 120 MU using 6 MV x-ray with different dose rates of 37 MU/min, 75 MU/min, 150 MU/min, 300 MU/min and 600 MU/min; TLDs were irradiated to the same dose using three ^125I seeds with different activities of 0.739 mCi, 0.675 mCi and 0.559 mCi, and the irradiated time were 24 h, 26h 17 min and 31 h 48 min, respectively, to study the dose rate effect of TLDs for 6 MV x-ray and ^125I seed.

Results: 350 TLD2000 TLDs were selected with the sensitivity within ±3.0%. The maximum deviations of the repeatability were 2.7% and 4.0% for 6 MV x-ray and ^125I seed, respectively. The dose response of TLDs for ^137Cs and ^125I seed were linear. For 6 MV x-ray, the linear response range were 0.74 Gy-10.0 Gy, beyond 10.0 Gy the dose response became supralinear but proportional to the absorbed dose to TLD. The energy response for 48 keV, 65 keV, 83 keV, 118 keV and 250 keV x-rays, relative to the energy response of ^137Cs, were 1.25, 1.08, 0.99, 0.91 and 0.96, respectively. There were no dose rate effects in the dose rate range of 37 MU/min to 600 MU/min for 6 MV x-ray and 0.66 cGy/h to 0.87 cGy/h for ^125I seed.

Conclusions: TLD2000 TLD has good repeatability and linear dose response for ^137Cs, ^125I seed and 6 MV x-ray without dose rate effect, but the dose response is energy dependent.
experiment simulates the case of a PRESAGE® dosimeter scanned in a 60% (by weight) glycerol in water, which we found to be sufficiently low in viscosity for optical CT. The fiducial method was used to measure ray paths in order to re-sort the sinogram into parallel beam geometry, and a basic SIRT[5] algorithm was used for image reconstruction.

Results: The reconstruction shows uniformity within 3% for 84% of the radius, beyond which incomplete radial sampling leads to inaccurate values. The reconstructed attenuation coefficient of $0.342 \pm 0.004 \text{ cm}^{-1}$ within this region agreed with a central-axis measurement of $0.34 \pm 0.02 \text{ cm}^{-1}$ using the known phantom diameter.

Conclusions: With 6% refractive index mismatching, approximately 85% of the radius of a uniform object was reconstructed within 3% accuracy. This suggests that it should be possible to scan the PRESAGE® solid dosimeter in a 60% glycerol solution and accurately reconstruct the dose map within 85% of the radius. In future work we will image PRESAGE® samples with deposited dose distributions to determine if this approach enables practical clinical dosimetry.

References:


SP155.5 - Development of a Novel Linear Energy Transfer Detector Using Doped Plastic Scintillators and Monte Carlo Simulation

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In radiotherapy, absorbed dose is a common quantity used to measure the amount of delivered radiation; however, dose is not a good indicator of actual biological damage. Linear energy transfer (LET) is the energy deposited per unit length along a charged particle’s pathway; studies have shown that LET correlates well with relative biological effectiveness. This research seeks to design and develop a portable, clinically-suitable LET detector. According to Birks’ law, light output of plastic scintillators is stopping power dependent. This dependency can be varied through doping by various high Z elements.

By measuring light output signals of differently doped plastic scintillators at a given point (represented by column vector S, where each row corresponds to a different scintillator material), fluence of charged particles of a given LET (represented by column vector φ, where each row corresponds to different LET bins) can be unfolded by $S = R \cdot \phi$, where R is system response matrix. Hence, the higher the resolution of LET fluence required (i.e. increased rows of matrix φ), the higher the number of distinct scintillating materials that must be used. Moreover, φ can only be solved if R is invertible, and the unicity of φ is given by the rank of matrix R.

Monte Carlo GEANT4.10.1 was used to determine optimal doping of polyvinyltoluene (base scintillator) to ensure distinctness of detector response, and invertibility of R. Various dopant materials (W, Pb, Mo) at several concentrations (1%, 10%) were simulated, FIG 1A. Preliminary results show doping with 1%Pb caused energy deposited to increase by 8.8%+/−0.07%; for 10%Pb this increased to 41.5%+/−0.07%.

GEANT4 was also used to evaluate R; each row represents a differently doped scintillator, each column corresponds to different electron LET. R was further corrected for signal loss in various connections used to transfer light from scintillator to PMT (i.e. housing, fiber). This was done experimentally using an integrating sphere and calculating the ratio of light transfer in presence/absence of connection assembly (FIG 1B).

Experimental setup shown schematically in FIG 1C was used to measure light output from scintillating materials. In-house code was written to integrate the PMT signal over time. Initial measurements were done using commercially available undoped polyvinyltoluene scintillator and a 1%Pb-doped scintillator.

![Diagram of LET detector setup](attachment:image.png)
SP155.6 - Reduction of residual signal in LiF:Mg, Cu, P thermoluminescent material.

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**Purpose:** LiF: Mg, Ti (TLD-100) is a well-established material for medical dosimetry over the past forty years since its development in the 1960s due to its tissue equivalence, negligible fading over lengthy periods, reasonable radiation sensitivity and relatively low minimum radiation detection level. However recently LiF: Mg, Cu, P has become a popular TL dosimeter in routine applications of personal, environmental and clinical dosimetry due to its high sensitivity, almost flat energy response, linear dose response, and the shorter annealing procedures. The main drawback of the LiF: Mg, Cu, P based dosimetry is the significant residual signal due to the presence of a high temperature peak in the temperature range of approximately 270°C - 300°C. Considerable effort has been invested in the development of a LiF: Mg, Cu, P material with a greatly reduced residual signal. However, the integrated processes of sintering and microstructure development in a crystalline compound remain complex even after many years of research. The purpose of this work was to explore the possibility of using a low heating rate and longer TL signal integration time to reduce the residual signal in LiF: Mg, Cu, P (TLD100-H) dosimetry material.

**Materials and Methods:** TLD100-H material in the form of chips of thicknesses 0.9 mm (thick) and 0.4 mm (thin) were used. The chips were annealed at 240°C for 10 minutes after each irradiation and prior to next use. Irradiation was carried out in a solid water phantom at 5 cm depth using 6 MV x-rays. A dose of 0.5 Gy was delivered for each irradiation. Three readout cycles were tested, and repeat readouts were carried out immediately after the first readout, using the same parameters. The three heating rates used were 1°C/sec, 5°C/sec and 1°C/sec. The signal was integration time was 30 seconds, 60 seconds, 60 seconds and 300 seconds, respectively. The residual signal was calculated as a ratio of first readout TL signal over the second readout TL signal.

**Results:** The mean residual signal for thick TLD chips was 6.1% and that from thin TLD chips was 7.5% when the heating rate was 15°C/sec. When the heating rate was reduced to 5°C/sec, the mean residual signal for thick TLD chips was 1.9%. For thin chips the residual signal was negligible (<0.1%) when the heating rate was 7°C/sec. At the heating rate of 1°C/sec, the residual signal was practically removed and was less than the background noise of the TLD reader.

**Conclusions:** The present study shows that a slow heating rate reduces the residual signal in TLD100H dosimeters. The effect is more pronounced in thinner TLD chips. When low dose measurements are performed using TLD100-H material, thin chips with a heating rate of 7°C/sec should be used. A heating rate of 1°C/sec would be ideal for 0.9 mm thick TLD100-H chips; however a heating rate of between 1 and 5°C/sec would achieve a good balance between low residual signal and a practical overall readout time.

SP155.7 - Application of dose gels in HDR brachytherapy

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Normoxic gels are frequently used in clinical praxis for dose assessment or 3D dose imaging in radiotherapy due to their relative simple manufacturing process, well expressed radiation induced modification of physical properties and well defined spatial shape of the polymerized gel part in the irradiated volume. Normoxic polyacrylamide (nPAG) gels were irradiated in high dose rate (HDR) after loading brachytherapy system MicroSelectron v2 with 192Ir source. The source was inserted into 6 Fr catheter which was fixed at the axial position of the gel filled beaker during gel preparation phase. Varying composition and manufacturing process conditions free standing polymerized gel shapes were produced around a catheter as polymerization center. Dose and dose rate related properties of the free standing polymerized gel shapes were evaluated using Raman spectroscopy and were compared to those of in the gel volume located polymerized gel regions of usual nPAG gels. Analysis of the obtained results is provided and possibility to pre-assess special dose distribution in the prescribed irradiation target using these free standing polymerized gels is discussed.

SP155.8 - Practical 3D QA for Radiation Therapy Based on High-Resolution Laser CT of Reusable Radiochromic Polymer-Gel Dosimeters in Dedicated Phantoms

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Current quality assurance measurements are not sufficient to detect fine structure errors from complex plans. Treatment delivery methods are becoming more complex with higher doses and fewer fractions. A high resolution technique is needed to account for the subtle errors which combine resulting in a treatment plan which is ultimately inaccurate. Presently water phantoms are used for measuring and determining the dose distribution of radiation produced by a particle beam or photon radiation beam. The standard dosimetry system is comprised of: a water tank, an ionization/diode detector positioned in a fixed position and software used to control the motion of detector and analyze data. It is not possible to use the water tank system for advanced delivery techniques such as Arc Therapy or IMRT. Due to the point-by-point measuring concept this system cannot quantify the effect of modulated beams. 2D detectors such Matrixx or Mapcheck are used for quality assurance measurements but are limited to measuring one plane at a time. This information is adequate for QA test, but with the advancement of treatment planning techniques and treatment machines that deliver highly conformal dose; it’s impossible for a 2D detector to capture all the subtleties in the treatment plan. The promise of the clinical benefits of intensity modulated particle therapy (IMPT), for example, will only be achieved by having adequate 3D dosimetry and QA tools. Clinical 3D dosimetry will be critical in keeping pace with the rapid advancements in present day technology.

Our system offers reusable dosimeters which we have demonstrated the feasibility of the signal decay correction and the response signal decay rate; that ranges from hours to days depending on the formulation. The VOLQA™ software is capable of image reconstruction, DICOM import, 3D registration using orthogonal projections,
A practical 3D QA for modern radiation therapy has been developed and tested for clinical QA applications. High resolution and dosimetric accuracy is combined with minimum time required on the part of physics staff. Widespread use in both radiosurgery and particle therapy QA is anticipated. This system has the potential to improve quality assurance of radiation therapy treatment of cancer and other diseases by the introduction of fast, accurate, high-resolution, three-dimensional dosimetry based on laser CT of soft-tissue-equivalent polymer dosimeters whose local optical density changes in proportion to local dose. The new technology could potentially be used in acceptance and commissioning testing for all existing treatment modalities.

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In order to investigate the influence of sinotubular junction and sinus diameter on the aortic valve closure, numerical simulations were performed. Models of neo-aortic root for arterial switch operation to the patient with complete transposition of the great arteries were established. The 3-dimensional geometry of a reference aortic valve model A, with the aortic annulus diameter (DAA) = 9.70 mm, the diameters of sinotubular junction (DSTJ) = 9.70 mm and the diameter of sinus (DS) = 12.30 mm, was built. Then the DSTJ and DS were modified to create four geometric models with different dimensions, named as B (DSTJ = 11.60, DS = 12.30), C (DSTJ = 7.76, DS = 12.30), D (DSTJ = 9.70, DS = 14.76), and E (DSTJ = 9.70, DS = 9.84). The mechanical behavior of the aortic root on the closing diastolic phase was simulated. The performance of the aortic leaflets was assessed in terms of stress of neo-aortic root, change of the aortic annulus diameter as well as leaflet contact force during closing phase. The reference model A showed a maximum leaflet stress of 96.29 kPa. For models B and C, leaflet contact forces are respectively increased by 43.33% and decreased by 10.00% with the sinotubular junction diameter respectively increased by 1.2 times and decreased by 0.8 times compared with reference model A. Compared with model A, leaflet contact forces in models D and E are respectively increased by 6.67% and decreased by 23.33% with sinus diameter respectively increased by 1.2 times and decreased by 0.8 times. It is evident that increasing the sinotubular junction and sinus diameter within a range of 20% can increase the maximum stress and the leaflet contact force for aortic root and vice versa. It may be the reason why neo-aortic valve insufficiency occurs after a long period of time for patients with arterial switch operation.
SP156.3 - Preoperative in silico analysis of atherosclerotic calcification vulnerability in carotid artery stenting using Finite Element Analysis by considering Agatston score

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The role of calcification inside fibroatheroma during carotid artery stenting operation is controversial. Cardiologists face a major problem of "plaque vulnerability" during the placement of both balloon and stent, with stiff plaques containing advanced calcifications that break the arterial wall or give rise to unstable thromboembolic stroke. The aim of this work is to evaluate the role of calcification (in terms of material and mechanical properties) in plaque vulnerability and wall rupture and to find plaque maximum resistance before breaking. Image-based models of carotid artery stenting were used and Finite Element Analysis (FEA) was performed to simulate the impact of balloon and stent expansion in the presence of calcified plaques. In detail, a nonlinear static structural analysis was performed on 20 patients acquired using in vivo MDCT angiography. The Agatston Calcium score was obtained for each patient and subject-specific local Elastic Modulus was calculated. The in silico results showed that by imposing maximum ultimate external load of 1.2MPa and 4.2MPa on balloon and stent respectively, average ultimate stress of 55.7±41.2kPa and 171±41.2kPa as well as average Plaque Wall Stress of 19.03±6.05kPa and 64.3±63.3kPa were obtained on calcifications, respectively. Elastic and plastic strain average values of 0.03±0.02 and 0.006±0.01, respectively, were obtained on the calcified plaques after stent expansions. These average data are in good agreement with results obtained by other research groups relative to the values of compressive Elastic Modulus of atherosclerotic plaques and its ultimate stress, strain values after performing carotid artery stenting. Even if our findings are markedly influenced by local geometry and plaque shape, this study enriches the literature in pre-operative prediction of ultimate mechanical parameters in stenting operation to prevent rupture before balloon/stent expansion.

SP156.4 - Biomechanical modeling for foot inversion

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Foot inversion was the most common injury of lower limb injury, it seriously affected the foot balance and posture control during standing and walking. The purpose of this study was to describe the rationality of biomechanical modeling for foot inversion. Plantar pressure measurements and foot roentgenogram had been reported. However, direct measurement of the internal tissues stress was difficult. A three-dimensional finite element model of foot inversion was developed to investigate the region of foot inversion injury. Compared with normal foot, the results showed that subtalar joint region was mainly weight-bearing region. Peak von Mises stress of the internal bones was transferred to the lateral longitudinal arch. The simulation in this study would provide the suggestion of therapeutic planning to foot inversion.

SP156.5 - Deformation Method and 3D Modeling of the female body to simulate Core Biopsy procedure

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Core biopsy is an invasive surgical procedure that collects the tissue samples to be evaluated by an expert. The withdrawal of samples is performed with large-caliber needles, attached to a special pistol. It is a technique conducted by an imaging equipment to guide the procedure. Usually consists of ultrasound guided core needle biopsy or stereotactic mammography.

This procedure can be used in the investigation of various diseases and through it, you can identify precise information on the nature of the injury or the degree of impairment of the tissue for diseases. For breast cancer, the results with the biopsy are essential to set an appropriate treatment, and may this be a surgical intervention or not. Thereby, it is guaranteed greater effectiveness in the final results.

Thus, the simulation modeling of surgery and examination has an elastic deformation behavior of human skin through the puncture. It is used physical and mathematical methods to describe computationally this imputed deformation on the skin in a mammory biopsy procedure. Thus, the deformation of Infinite Elements is characterized and justified for such a technique. The method chosen features complex structures with a greater realism, which is ideal for the representation of the breast. And to improve the results obtained on deformation, it is used Fuzzy Logic for the interpretation of the output data.

With the aim of providing the medical students and other health professionals greater dexterity in performing breast biopsy, it was developed the project: 3D Anatomical Atlas Applied to Mama, in order to develop a learning environment using virtual reality precepts. The project is divided into five modules: three-dimensional (3D) modeling, ontological modeling, development of an Intelligent Tutor System (ITS), deformation and pathology. This paper presents the 3D modeling in conjunction with the deformation. The 3D modeling is responsible for creating 3D structures of the female body and its internal composition being used in virtual simulation of surgical procedure Core Biopsy, illustrated by Fig. 1. Thus, professionals can train your skills and, at the same time, using the modeling tools to make them more didactic, so that a student can assimilate the precepts.

Fig. 1. The simulation of Core Biopsy procedure
SP156.6 - Effects of Band Position on Hemodynamics of Pulmonary Artery: A Numerical Study of Patient-specific Virtual Procedure

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Hemodynamics of pulmonary artery flow after different strategies of pulmonary banding (PAB) was not well understood. By using computer-aided design (CAD), three PAB models were devised and numerical study was done by computational fluid dynamics (CFD). The results indicated that whirling flow was formed in all the PAB models, which is more significant in that with proximal PAB, leading to unbalanced perfusion of lungs. While in distal PAB models, the flow disturbance is relatively mild and unbalanced flow to left pulmonary artery has decreased. Integrated CAD and CFD study can be applied to predict and optimize the surgical outcomes of PAB.


SP156.7 - Experimentally validated Biomechanical Model of in vivo Lung under EBRT considering Diaphragm motion hysteresis

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Lung cancer is by far the most common cause of cancer death in both men and women. Both small-cell and non-small cell lung cancers are frequently treated with radiation therapy, which is often combined with chemotherapy, surgery or both. However, External Beam Radiation Therapy (EBRT) may lack desirable dosimetric accuracy because of respiration induced tumor motion. Recently, biomechanical modeling of the respiratory system has become a popular approach for tumor motion prediction and compensation. This approach requires reasonably accurate data pertaining to lung geometry, thoracic pressure variation, diaphragm position and tissue biomechanical properties in order to predict tumor motion. However, given the pleural pressure nonuniformity on the lung’s surface and contact between the lung, diaphragm and heart, modeling the lung loading is cumbersome. A simple approach frequently used in lung models applies uniform negative pressure on the lung’s surface at the end exhalation phase to simulate the inhalation phase [1,2,3]. The negative pressure’s magnitude is obtained either from reported pressure-volume curves in the literature or from 4D CT data. Other approaches include modeling the thoracic pressure and diaphragm motion separately [4,5].

To our knowledge, none of the existing lung biomechanical models account for respiratory cycle hysteresis. The lung hysteresis results from surfactant action during inhalation and tissue recoiling during exhalation. In this paper, we present preliminary results obtained from lung 4D CT image processing which indicate that the human diaphragm motion’s hysteretic nature. This hysteresis further contributes to the lung hysteresis. To track the diaphragm motion, 22 points located on its surface were tracked in a set of 4D CT images using Free Form Deformable registration. The displacement values in the superior-inferior direction were normalized between 0 and 1 for all the points. The average curve depicted in Figure 1 indicates that the diaphragm motion has similar pattern to the lung compliance curve. These results suggest that, to achieve desirable accuracy with lung biomechanical modeling, this strong diaphragm motion hysteresis should be considered. This was done by modifying the model we presented in [4], leading to significant improve-
**SP157 - Biochips and Blood Analysis**

**SP157.1 - On-chip blood Plasma separation using vacuum-assisted micropumping for point-of-care application**

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**Introduction:** To become useful diagnostics tools in global mobile health point-of-care (POC) settings, a disposable biosensor will require further improvement by integration of sample preparation, which has been troublesome due to incorporation of external active valves and pumps [1]. Our approach aims to simplify the on-chip blood plasma separation required to perform specific sensing of biomolecules, all without compromising biosensor functionality. Without any of the requirements of sophisticated equipment or dilution techniques, we could extract the plasma from the whole blood, which is suitable for point-of-care applications. This talk will cover a selected example in the emerging POC applications, such as hemolysis-free on-chip blood plasma separation by using a simple hand-held power-free vacuum-assisted pumping method.

**PRINCIPLE/DESIGN:** Pneumatic chambers, A and B, are neighbouring with the separation chamber and the dead-end ring channel, respectively, which are physically disconnected each other through a thin air-permeable PDMS wall (separation chamber/PDMS wall/pneumatic chamber A and ring channel/PDMS wall/pneumatic chamber B). Each pneumatic chamber is connected to a hand-held syringe. By pulling the plunger of the hand-held syringe, a vacuum will be generated inside the pneumatic chambers (due to the volume change from 2 μL to 2 mL). This will indirectly withdraw the blood sample in the separation chamber through the are-permeable PDMS wall. Flow rates can be tuned by adjusting the PDMS wall thickness and overlap area between the pneumatic chamber and the separation chamber. Meanwhile, by gravity, blood cells will sediment at the bottom of the separation chamber therefore plasma could be separated from the whole blood. Moreover, phaseguides are employed at the bottom of the separation chamber (1) to prevent air trapping inside the separation chamber and (2) to increase the plasma separation efficiency by avoiding the slide of blood cells that are already sediment down.

**EXPERIMENTS/Results:** The secret is to indirectly and slowly pump the whole blood into a dead-end chamber/channel embedded with smart microstructures (e.g., phaseguides in order to both enhance the separation efficiency and reduce the separation time) by well-controlled air-diffusion through the thin PDMS wall, due to the syringe-generated pressure difference (atmosphere in the dead-end chamber/channel vs. vacuum in the pneumatic chamber/syringe). This allows fast sedimentation of blood cells and thereby filter-free and hemolysis-free plasma separation. Through the experiments, we found the followings: (1) Pinning time due to the phaseguides was in inverse proportion to the separation efficiency. By adjusting the design parameters of the neck structure in the phaseguides, pinning time could be reduced. (2) The ratio between the height of the phaseguides and the separation chamber was proportional to the separation efficiency. (3) Flow rates were also in an inverse relationship to the separation efficiency. Similar results were also verified by a set of straight channels.

**Conclusion:** We have investigated a simple hand-held power-free vacuum-assisted pumping method, its application for hemolysis-free on-chip blood plasma separation, and the key parameters that would affect the separation efficiency. The present device is expected to be an effective tool for blood separation, especially for point-of-care applications.


**SP157.2 - Multi-Functional Platform for Blood Group Phenotyping using Surface Plasmon Resonance**

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Accurate and reliable phenotyping of blood groups is of the utmost importance prior to transfusion. Mismatching of incompatible donor and patient blood types could potentially lead to a haemolytic transfusion reaction, which can be fatal. Currently, there are many well established blood typing methods available, such as the column agglutination test (CAT), however methods quantifying these antibody-antigen interactions are limited. This is particularly important to identify and characterize weak interactions between weak subgroup variants, which are often difficult to determine by the naked eye and have the potential to be overlooked. The biosensing system, BIACore, relies on surface plasmon resonance (SPR) detection to quantify interactions between biomolecules. Previous studies have shown the use of SPR for blood group antigen detection and antibody detection; however, these methods showed poor regeneration and loss of functionality after a single use due to the inability to fully desorb bound material. Each chip (~AUD200) was also limited to a single blood group. A fully regenerable, multi-functional platform for quantitative blood group phenotyping via SPR detection can be achieved by covalently immobilizing an antibody, anti-human IgG, to the chip surface. Anti-human IgG is able to recognize and bind to the Fc region of human IgG antibodies for detection. The surface can therefore be used as an interchange platform capable of quantifying the blood group phenotyping interactions between RBCs and IgG antibodies. Much like the Indirect Antiglobulin Test (IAT) used to detect blood groups using IgG antibodies with the CAT, the blood group IgG antibody is incubated with RBCs, and the cells become sensitized, which allows them to bind to the anti-human IgG on the chip surface. This test has potential to quantitatively detect any blood group with a corresponding IgG antibody. A clear distinction between positive and negative results has been achieved using anti-D IgG and reagent red cells, as well as complete regeneration of the anti-human IgG surface. Very little degradation, if any, of the immobilized surface has been observed after over 100 regenerations. Consecutive testing of different blood types has also been successful, allowing multiple blood groups to be detected using a single chip. This multi-functional platform presents potential for quantifying antibody-antigen interactions for blood group phenotyping.
SP157.3 - Harmonic generation microscopy investigation of human pathological samples for automated cancer differentiation

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Nonlinear harmonic generation microscopy was used to investigate human pathological samples revealing quantitative differences between tumor and non-tumor regions in the extracellular matrix of several tissues including breast, lung, pancreas and thyroid. During tumor initiation and progression, alterations to the structure of collagen inside the extracellular matrix of different tissues can occur, which can be used for developing new biomarkers in cancer diagnosis. Second harmonic generation (SHG) is a spectroscopic nonlinear optical signal that is sensitive to changes in the ultrastructure of collagen, such as the organization of collagen into fibers, and the distribution of collagen fibers within a femto-liter laser focal volume, and therefore, SHG can be used as a biomarker for cancer diagnosis. The novel technique, polarization-in, polarization-out (PIPO) SHG microscopy was utilized, which is an accurate way to extract the second-order nonlinear optical susceptibility ratio component, \( \chi^{(2)}_{zzz}/\chi^{(2)}_{zxx} \), which is related to the ultrastructure of collagen at each pixel. The PIPO SHG technique requires measuring the SHG intensity at each pixel of the image, at different orientations of the linear polarization of the outgoing SHG as a function of the linear polarization orientation of the incident laser radiation. A MATLAB based fitting routine is used to deduce the \( \chi^{(2)}_{zzz}/\chi^{(2)}_{zxx} \) value at each pixel. Additionally, the average orientation of the fibers is also deduced at each pixel of the image revealing long range collagen organization in the tissue. The \( \chi^{(2)}_{zzz}/\chi^{(2)}_{zxx} \) maps reveal areas of altered collagen structure within tissue sections, and are independent of collagen concentration. Statistically-significant differences in \( \chi^{(2)}_{zzz}/\chi^{(2)}_{zxx} \) were found between tumor and non-tumor tissues, which varied from organ to organ. Therefore, PIPO SHG microscopy has the potential to be used as a high throughput pathological sample pre-diagnosis system, aiding pathologists in cancer diagnostics. Additionally, PIPO SHG microscopy could also visualize and characterize the structure of collagen in vivo without staining which may aid in the study of collagen-related biological processes such as wound repair.

SP157.4 - Protein Patterning: An investigation on the use of different protein deposition techniques and parameters to transfer proteins onto various surfaces.

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Protein microarrays are used to develop tools in various research areas including drug discovery, diagnosis, and protein-ligand interaction analysis. Their efficacy depends on a well-defined pattern of immobilized proteins that have retained their bioactivity. Protein microarrays are most commonly made via pin or inkjet printing that can lead to spots having uneven protein adsorption within the spotted area. Although automated, these processes have been shown to lead to inaccurate readings. Alternative techniques exist, including microcontact printing (μCP) with a poly(dimethylsiloxane) (PDMS) stamp that produces protein patterns on surfaces, while maintaining bioactivity for a wide range of proteins. In previous work we have qualitatively compared the distribution of deposited proteins via pin printing versus μCP with both flat and pyramid-shaped posts. Here we propose to quantitatively compare these two methods, in addition with inkjet printing, to produce an even fluorescent signal within a defined area. Variation of the protein solution and surface properties, in addition to the deposition method, will also be studied with respect to fluorescent signal production.

Investigation into the experimental parameters used in protein patterning to produce an even protein adsorption pattern will enable reliable assay readings by increasing the signal to noise ratio in printed protein microarrays.
SP158 - Educational Activities and Training in Medical Physics

**SP158.1 - Medical Physics Residencies-101: The What’s, Where’s, and How’s**

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Medical physics residencies serve as an excellent bridge between putting together the didactic knowledge obtained from a graduate program with practical experience in a Medical Physics sub-specialty. Most residency programs are within the Radiation Therapy sub-specialty, although Diagnostic Imaging-based residencies are slowly starting to become more prevalent over recent years. Residency programs prepare one to take a board examination in order to become a Qualified Medical Physicist. The boards which an individual can apply to are the Canadian College of Physicists in Medicine (CCPM) and the American Board of Radiology (ABR). Residencies can be accredited by the Commission on Accreditation of Medical Physics Educational Programs (CAMPEP) body, but this is not essential. Since CAMPEP states minimum requirements to be met in order to ensure adequate coverage of residency program content, there is a continual push for an increase in the number of CAMPEP-accredited residencies. CAMPEP also accredits Medical Physics graduate programs. Enrolling in an accredited graduate program ensures that the individual graduating obtains a minimum standard of didactic knowledge, which will serve him/her for successful completion of a residency program. This talk will serve to inform the individual of how to prepare for applying to a residency program, what one may expect from a residency program, and where one can apply to residency programs. Participants will also be exposed to how one can prepare for taking a board examination, as well as the general scheme of how the board examinations are administered. CAMPEP requirements for residency and graduate programs will also be introduced.

**SP158.2 - Education and Clinical Training of Medical Physics in Thailand**

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There are 5 education programs for medical physics in Thailand. The first was started in 1972 at Ramathibodi Hospital, Mahidol University. Followed In 1990, the M.S. in Radiological Science program was started at Siriraj hospital, Mahidol University. Then in 2001, the second medical physics program was established at Chiang Mai University. The M.Sc. program in Medical Imaging was started at Faculty of Medicine Chulalongkorn University in 2002. The fifth program has been started at Naresuan University, Phitsanulok in 2014. The major problem in medical physics was the shortage of clinically qualified medical physicists. The situation was improved when IAEA started clinical training for radiation oncology medical physics (ROMP) in 2005, diagnostic radiology medical physics (DRMP) in 2009 and nuclear medicine medical physics (NMMP) in 2010.

**Objective:** To report the education and clinical training of medical physicists in Thailand with the cooperation of Thai Medical Physicist Society (TMPS), the International Atomic Energy Agency (IAEA) and Chulalongkorn University.

**Method:** All educational programs are two-year program of the didactic lecture, laboratory, on-the-job training, clinical practice and research. The clinical training using IAEA training guides, self-assessment, progress report, external visit and external assessment by IAEA experts were obtained under the Regional Cooperative Agreement (RCA) for Asian and Pacific Region. Thai Medical Physicist Society is processing on licensing for qualified clinical medical physicist after the document submission to the committee of Ministry of Public Health.

**Results and Conclusions:** Even though the number of the medical physicists graduated from all programs is over 300, the lack of qualified medical physicists is still the problem. The success of the ROMP, DRMP and NMMP serves the needs at major university hospitals and the cancer centers. The clinical training was officially accepted by Chulalongkorn University for the Higher Graduate Diploma of Clinical Sciences Program in Medical Physics and started in 2011. The final medical physics education program of Ph.D. in Medical Physics will be started at Chulalongkorn University in August 2015. This program should support the need for medical physicist position in the university.

**SP158.3 - Radiation Protection in Medical Imaging and Radiation Oncology**

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Radiation protection is one of the leading and fastest developing areas of medical physics and society as evidenced by the emphasis hospitals and medical organizations are placing on radiation protection culture. The interdisciplinary nature of radiation protection makes it a key discipline in ensuring safety of the public.

Safety and quality assurance in the use of radiation in medicine aims to reduce unnecessary radiation risks while maximizing the benefit. Improvements in quality and safety in radiation medicine require a strong radiation safety culture. To better achieve the goal of strengthening radiation safety in healthcare and better protection of the patients from excessive or unnecessary radiation exposure, a concerted effort by all the role players together with the radiologists, referring practitioners, technologists, professional organizations, international bodies and regulators is essentially needed.

The International Organization for Medical Physics (IOMP) and the International Radiation Protection Association (IRPA) have worked together to produce a book on Radiation Protection in Medical Imaging and Radiation Oncology, intended for use both in countries that have well developed medical and health physics disciplines and in developing countries.

The International Organization for Medical Physics (IOMP) represents over 16,000 medical physicists worldwide and 81 adhering national member organizations. The mission of IOMP is to advance medical physics practice worldwide by disseminating scientific and technical information, fostering the educational and professional development of medical physicists, and promoting the highest quality medical services for patients.
The International Radiation Protection Association (IRPA) represents some 18,000 members from 50 associate societies representing 63 countries. IRPA’s vision is to be recognized by its members, stakeholders and the public as the international voice of the radiation protection profession in the enhancement of radiation protection culture and practice worldwide.

Awareness of the need for emphasis on radiation protection contributes significantly to the safety of healthcare providers, patients, and the public. Contributions are most evident in facility design, in monitoring of personnel and the patient care environment, and in development of procedures and practices for proper handling and limitation of radiation exposure. Medical health physicists are often challenged to maximize protection of personnel while minimizing the cost of resources necessary to keep radiation doses ALARA. Advances in medical health physics will continue to be based on evidence gathered through basic and applied research. Periodic review of the evidence will help medical health physicists to focus on the issues and to advance the science.

The book Radiation Protection in Medical Imaging and Radiation Oncology, focuses on the professional, operational, and regulatory aspects of radiation protection covering virtually all regions of the world. The theoretical background is complemented by detailed practical sections and professional discussions by the world’s leading medical and health physics professionals. Information is well organized into discreet chapters from basic protection to advanced imaging and treatment modalities. This book is a valuable source of information for the medical physicist and related specialties targeting a reading level of MSc and above.

SP158.4 - It’s a Medical Physics World! Presenting the Official Bulletin of the International Organization for Medical Physics

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Medical Physics World (MPW) has been the official bulletin of the International Organization for Medical Physics for over 30 years. The first issue of the bulletin was published in 1982 presenting a challenge to the IOMP and the medical physics societies around the world: “...to make ‘Medical Physics World’ worthy of its title”.

Ever since then the IOMP’s leading professionals have chaired and contributed to the development of MPW.

Medical Physics World Editors 1982-2015

Prof. Lawrence H. Lanzl
Prof. Colin Orton

Richard L. Maughan
Dr. Bhudatt R. Paliwal
Dr. Azam Nirooomand-Rad
Dr. E. Ishmael Parsai
Dr. Virginia Tsapaki

The last several years mark a great progress in Medical Physics World. The new style and layout introduced in 2012 increased the interest towards MPW not only among our professional society, but also among corporate members and professionals from other disciplines. MPW is now regularly distributed on all major professional events – AAPM meetings, RPM, ICMP, many regional events.

Medical Physics World has always been in-line with IOMP’s initiatives and hot topics. Besides providing the regular organizational reports, we have actively supported some of the IOMP’s most successful activities – IOMP’s 50th anniversary, the foundation of the Medical Physics International Journal (MPI), the International Day of Medical Physics (IDMP) and the formation of the IOMP Women subcommittee (IOMP-W).

During this 3-year period we successfully conducted a dissemination campaign that resulted in MPW’s wide recognition among world’s leading institutions. The journal is now regularly delivered to the European Congress of Radiology (ECR), the UNESCO International Center for Theoretical Physics (ICTP) and to the US Library of Congress.

The latest achievement of MPW’s editorial team is including Medical Physics World in the International Standard Serial Number registrar.

With all the contemporary technology our world turned into an electronic world, so did Medical Physics World. We often call it eMPW now, but we are still devoted to the very first promise “... to make ‘Medical Physics World’ worthy of its title”.

SP158.5 - The new IOMP Professional Journal - Medical Physics International - first results

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The medical physics profession is served by a collection of outstanding journals, each distinguished by its content, method of publication, geographic coverage, and organizational affiliation. The new IOMP journal, Medical Physics International (MPI), joined this group in 2013, filling a specific niche, not as a competitor, but as an active supporter and collaborator with the other journals. MPI is the official journal of the International Organization of Medical Physics (IOMP) and is with fully open access on Internet (www.mpijournal.org), providing information at no cost to the global medical physics community. The mission of MPI is to publish articles that contribute to medical physics education, professional development, communication about international medical physics activities, and to preserve the history and heritage of the profession. The Journal is peer reviewed and publishes also approved abstracts from Medical Physics Conferences.

A distinguishing feature of Medical Physics International is that it does not publish manuscripts reporting on research and development. For these we recommend the other established Journals as: Physics in Medicine and Biology (the first journal to be designated as an official journal of IOMP in 1969), Medical Physics, Journal of Applied Clinical Medical Physics (the AAPM journals), PhysicaMedica (the European Journal of Medical Physics) and other regional journals.
and careers in medical physics will be highlighted. Finally, based on its success and the growing interest in this conference, we will discuss the future of Canadian Conferences for Undergraduate Women in Physics and the potential and efforts in making the CCUWiP an official, annual event.

References:

SP158.6 - Two First Years of Reuniting, Engaging and Discovering: The Canadian Conference for Undergraduate Women in Physics

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A first Conference for Undergraduate Women in Physics was hosted by the University of Southern California in 2006. A few years later, six regional conferences were being held simultaneously and annually throughout the United States [1]. Inspired by this successful model centrally coordinated by the American Physical Society, McGill University hosted a first Canadian Conference for Undergraduate Women in Physics (CCUWiP) in January 2014, with 54 participants from Ontario and Quebec universities [2]. On 9-11 January 2015, a second, bilingual edition of the CCUWiP was hosted by Université Laval, which welcomed 75 undergraduate students from Eastern Canadian universities [3]. The goal of the CCUWiP is to give undergraduate women studying in a physics-related field the opportunity to experience a professional conference and discover a variety of career paths in academia, industry and health sectors. Moreover, this conference encourages the development of a national network of women in physics and promotes the accomplishments and leadership of women in STEM (Science, Technology, Engineering and Mathematics) fields. In light of having organized the two first Canadian editions, the organizational details involved in providing a student-accessible conference and the typical program of a CCUWiP will be introduced. We will describe the importance of the CCUWiP as a training and career development experience for women at the undergraduate, graduate and professional levels. As a student initiative sponsored by the Canadian Organization of Medical Physicists, the methods of promoting graduate studies, research

Currently MPI has 4 issues published, which include 260 pages with original papers on education and professional issues, history of the profession, new innovations from the medical physics industry, tutorials and abstracts of PhD theses. Additionally MPI has published 840 pages of approved abstracts from the International Medical Physics Conference ICMP2013 (Brighton, UK) and the International Conference on Radiation Protection in Medicine 2014 (Varna, Bulgaria).

The results are very encouraging - from its first issue MPI Journal has a steady number of about 1000 readers per week (see the statistics attached here). Its web site is designed in a way to allow both download of individual papers and whole PDF issues. Many papers have hundreds of downloads, what is a clear reflection of the need of such a Journal.
SP158.7 - Students’ perspective on studying online at Heidelberg University, Germany (UHD)

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**Purpose:** UHD established two postgraduate MSc programs in Medical Physics. In 2010 the English speaking Master Online “Advanced Physical Methods in Radiotherapy” (APMR) started as first distance learning online program at UHD comprising three mandatory attendance phases (duration from 4-14 days) in Germany during the two years of study. Furthermore, since 2012 the International Master “Clinical Medical Physics” (CMP) is on offer in cooperation with Pontificia Universidad Catolica de Chile (PUC). CMP combines two on-site semesters in Chile taught in Spanish by PUC with a third online semester held in English by UHD. The students terminate their studies with a Master Thesis, written either at PUC or UHD.

After five years’ experience in online teaching and learning we would like to present a first result of undertaken evaluations emphasizing on the importance of an ideal curriculum design for postgraduate students working in Medical Physics.

**Material and Methods:** The CMP program is designed for students from Latin America and it introduces the basics (such as Anatomy and Physiology or Physics of Radiation and Dosimetry) and advanced topics in Medical Physics (such as IMRT or IGRT) to students at the beginning of their professional career. In contrast the APMR program is dedicated to students with a clear background and professional experience in Medical Physics. Thus, it only concentrates on advanced topics such as IMRT, IGRT, Ion Therapy or Advanced Dosimetry and Quality Assurance to educate professionals from all over the world.

The modules of each program adopt the so called “blended learning approach”, a combination of online and on-site learning settings. Interactive synchronous online sessions, recorded video lectures and problem based discussions make effective use of emergent internet technologies for its learning objects while offering opportunities to practical skill and network with peers and teachers in hands-on attendance phases at modern radiotherapy facilities in Heidelberg for APMR students and in Chile for CMP participants.

At the end of each semester the students are asked to join formative anonymous online surveys as part of the evaluation system of UHD. Furthermore, during each attendance phase the students have feedback sessions with the program coordinators in order to discuss the last online modules without teachers. This allows students to give positive or even negative feedback in a private and secure setting.

**Results:** The qualitatively and quantitatively reviewed results of the surveys and the intensive face-to-face discussions represent the students’ perspective of the e-learning approaches of both programs and allow us to deepen our understanding of special needs of professionals in the field of Medical Physics. The students reported their satisfaction about the curriculum design in the frame of a permanent supervision by both the teaching and coordinating team.

**Conclusion:** In conclusion both discussions and survey results helped us to improve our curriculum design. Our continuous modifications seem to be the key for our low drop outs during the last 4-5 years.

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SP158.8 - Launching of the ASEAN College of Medical Physics

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Medical physics is rapidly advancing in the world and the situation is the same in South East Asia. There is an acute need for both qualified and experienced medical physicists to work in hospitals throughout the region.

The Association of Southeast Asian Nations commonly known as ASEAN is a geo-political and economic organization of 10 countries located in Southeast Asia, which was formed on August 8, 1967. The member countries are Brunei, Cambodia, Indonesia, Laos, Malay-sia, Myanmar, Philippines, Singapore, Thailand and Vietnam. The motto of ASEAN is “One Vision, One Identity, One Community”. Its aims include the acceleration of economic growth, social progress, cultural development among its members, and the promotion of regional peace.

The spirit of ASEAN resonates in the South East Asian Federation of Organizations for Medical Physics (SEAFOMP). The idea of setting up an organization for Southeast Asian medical physics societies was first mooted in 1996. During the International Organization of Medical Physics (IOMP) World Congress at Nice, the formation of SEAFOMP was endorsed by member countries and it was officially accepted as a regional chapter of the IOMP at the Chicago World Congress in 2000. SEAFOMP congresses have been held regularly since its inception and these congresses have stimulated much growth and progress in medical physics in the region.

After a long gestation period, another regional entity, the ASEAN College of Medical Physics, was born in October 2014 at the 12th Southeast Asian Congress of Medical Physics held in Ho Chi Minh City. The founding president of the College is Professor Kwan- Hoong Ng, president-emeritus of SEAFOMP. The secretariat is located in Indonesia.

The vision is to make the ASEAN College of Medical Physics (ACOMP) the premier education and training centre for medical physics in the ASEAN region. To achieve the vision, members will galvanise their talents to develop sustainable activities, and will take advantage of information and communications technologies to achieve their goals.

Some future activities being planned include schools on Monte Carlo simulation, advanced radiation dosimetry, radiation emergency and disaster management, non-ionizing radiation protection, and a project on radiation dosimetric intercomparison.

Finally, official recognition is being sought from international organiza-tions such as the International Organization for Medical Physics (IOMP) and the International Atomic Energy Agency (IAEA). Endorsement and support from these bodies will be an added impetus to the success of the ACOMP.
SP159.2 - Improved temperature monitoring and treatment planning for loco-regional hyperthermia treatments of Non-Muscle Invasive Bladder Cancer (NMIBC)

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Introduction—Hyperthermia is a cancer treatment that increases the effectiveness of radiotherapy or chemotherapy by heating the tumor area to 41-43°C. Recently, a multi-center phase III randomized clinical trial comparing adjuvant treatment of NMIBC using Mitomycin C with and without loco-regional hyperthermia has started. This invites careful consideration of the bladder as a treatment site. Optimal treatment and quality control requires reliable thermometry and accurate hyperthermia treatment planning. This study aims to improve the current standard in both areas.

Materials and methods—We developed a novel multi-sensor ‘umbrella probe’ with five thermocouple probes to measure the bladder wall temperature, and a central probe measuring in the bladder center (Fig.1). We extended our treatment planning system with a fluid model computing the convective heat flow within the bladder. The umbrella probe was tested using phantom experiments comparing temperature measurements on the interior and exterior of a porcine bladder placed in tissue equivalent gel, and heated to reach a 4°C temperature rise. The experiments were simulated using both the new convective model and the standard treatment planning system.

Results—The umbrella probe temperature measurements at the interior bladder wall were comparable to temperatures measured on the bladder exterior but differed 0.5°C from temperatures in the bladder center. The temperature distributions computed by the convective model and by the current treatment planning system showed good agreement within the phantom’s gel regions; temperature differences between the models exceeded ±1°C inside the fluid and in neighboring tissue regions, i.e. the bladder wall (Fig.2).
Conclusions— The umbrella probe reliably measures the clinically relevant bladder wall temperature. The convective model is a marked improvement over the current treatment planning system in the region of interest. Explicit modeling of fluids is particularly important when the bladder or its direct vicinity are part of the hyperthermia treatment target area.

SP159.3 - A Full 3D CFD Model Coupled with an Outflow Lumped Boundary and Inflow Total Pressure Formulation to Estimate Human Cardiac Perfusion

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There is discordance between the anatomic severities of the coronary narrowing and their corresponding functional significance, i.e. how much this narrowing is truly causing ischemia in the downstream perfused cardiac tissue bed. Fractional flow reserve (FFR) is among the physiological parameters invasively measured to assess the hemodynamic significance of a stenosis during maximal hyperemia with values ≤0.8 indicating vessel at risk for ischemia. Recently, noninvasive prediction of FFR was shown to be possible from noninvasive comprehensive predictive techniques involving computational fluid dynamics (CFD). In this work, a boundary condition formulation is suggested and coupled with a full 3D CFD model to estimate cardiac perfusion. The modeling process starts by truncating the domain of interest at a specific location and separating it from the vascular beds. A lumped dynamic model is considered and coupled to the 3D domain outlet boundary to account for the downstream effects from the vascular bed resulting from truncating the 3D domain. A generalized algorithm is established to handle the dynamic model at the outflow boundary to avoid/damp spurious numerical reflections. On the other hand, the inlet section of the domain is modeled with a total, rather than static, pressure formulation. The developed inflow and outflow boundary formulations coupled to the 3D CFD model allow characterizing the myocardial perfusion of the modeled vessel (i.e. determine the % loss in blood volume flow rate in stenosed arteries). The method is tested on idealized healthy and stenosed arterial branches and single segments under rest and hyperemic conditions. Results have revealed promising indications towards translating the developed methodology into clinical practice.

Materials and Methods: This study was carried out using Finite Element Analysis software (Comsol Multiphysics 4.3, COMSOL Inc, USA) to simulate a spherical tumour of 2 cm diameter and a radiofrequency ablation (RFA) needle from the Cool-tip RFA system (Covidien, Massachusetts, USA). Clinical margin of 0.5 cm surrounding the tumour was applied. Common points of intersection of axial, sagittal and coronal planes within the tumour volume were assigned as target sites for needle tip placement. The RFA needle was modeled to pass through the target sites with different angles before advancing it to the edge of the tumour margin. The target sites and the angles of needle insertion were considered as optimal approach if no missed ablation volume was observed within the tumour and its clinical margins.

Result: According to the simulation results, the target site at the epicenter of the tumour was identified as optimal location for needle tip placement despite any variations in needle angulations (Figure 1). Hence, identifying the epicenter of the tumour on the central slice of the axial images is essential for increasing the success rate of complete tumour ablation. Despite the epicenter, complete ablations are also possible by placing the needle tips at several sites as shown in Figure 2.

Conclusion: Complete ablation of the tumour can be constantly achieved by passing the needle through the epicenter of the tumour before advancing it to the edge of the tumour margin, regardless of the angles of the needle insertion. As the needle trajectory deviated from the epicenter, the risk of incomplete ablation increased with increasing angles of insertion.

SP159.4 - Simulation Model of Image-Guided Percutaneous Thermal Ablation in the Assessment of Optimal Approach for Complete Tumour Ablation

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Purpose: To develop a 3D simulation for imaged-guided percutaneous thermal ablation of the liver tumours based on a geometrical model to investigate the ablation versus tumour volumes with varying needle position and angulations.

Conclusion: Complete ablation of the tumour can be constantly achieved by passing the needle through the epicenter of the tumour before advancing it to the edge of the tumour margin, regardless of the angles of the needle insertion. As the needle trajectory deviated from the epicenter, the risk of incomplete ablation increased with increasing angles of insertion.
SP160 - Neuroengineering, Neural Systems / Biophysics And Modelling

SP160.1 - From “Fracking” and “Macrovoids” to the Onset of Cancer Metastasis: A Mechano-Metabolomics Model of a Plausible Fluid-Solid Network Instability in Tumors
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Based on analogy and inductive reasoning, we postulate that a malignant tumor (carcinoma) grows in size until the “de-percolation” threshold of its encapsulating basement membrane (BM) which undergoes proteolysis during oncogenesis. Typically, BMs are composed of tri-continuous hydrogel networks of collagen-IV, laminin, and interstitial fluid, with connector proteins such as nidogens, and perlecans. The aforementioned threshold is determined by the mechanochemical state of the tumor-membrane complex vis-à-vis its microenvironment and, herein, conjectured to synchronize with the tensile yielding/rupture of the BM. Thereupon, peripheral cells of the tumor undergo epithelial-to-mesenchymal transitions (EMT), becoming motile, and migratory.

We test this postulate by formulating a mathematical model based on continuum fluid-solid mechanics, diffusion, and cell bioenergetics theories. This approach may be characterized as “mechano-metabolomics” modeling at the continuum scale and complements genomic, and proteomic approaches. In this model, a prototypical, viscous tumor spheroid grows radially, consuming metabolic nutrients (viz., glucose, oxygen, and lactate) while being constrained by an elastic BM ca. 0.5-2 microns-thick, and a network of linkages of cell adhesion molecules (CAMs), chiefly cadherins and integrins. A fundamental schema “induced” from geology and polymer physics is the fluid-solid mechanical network instability observed in rock formations during hydraulic fracturing (fracking) and during formation of synthetic asymmetric membranes (vis-à-vis large voids), respectively. Polymer physics also furnishes scaling concepts to develop equations of state for cells, and concepts describing cell and tissue rheology via gel poroelasticity theory. Besides, critical perspectives from other recent developments, viz., homeorhetic tumor pressures, mechanotransduction, and symbiotic glucose-lactate metabolism observed in cancer cells, are incorporated, to base the framework on well-grounds physicochemical principles in abiological and/or microbial systems. The nonlinear model is computationally analyzed via Comsol Multiphysics®.

The theoretical simulations (“in silico experiments”) lucidly support the a priori conjecture and are consistent with biological observations of oncogenesis in vivo, and physicochemical measurements in vitro. Computed stress-strain fields in the tumor microenvironment suggest that proteolysed BMs, quantified by decreased elastic moduli, participate in aberrant tumor growth dynamics and likely undergo tensile rupture and stress localization-induced cellular detachments, initiating EMTs, and metastasis. Subsequent crack-tip stresses may also shift strains on CAMs from compressive to tensile, suggesting mechanotransduced conformational switches, such as from non-invasive, adherent E-cadherins to invasive N-cadherin phenotypes.

The model also provides a rationale to detect metastatic potential of tumors via a convenient diagnostic imaging tool such as positron emission tomography (PET). PET locates abnormally-high glucose uptake rates in cells and tissues, which are related to the mechan-ical field evolution of the tumor microenvironment, and thereby, the likelihood of BM rupture. Complementarily, newer techniques that characterize tissue elasticity such as elastography may also be applied in concert with the developed framework.

A major conclusion of this research is that a hallmark of cancer may be a measurable, microscale “physical event” in contrast to nanoscale genomic or proteomic events. Besides proteolysis as a “proximal cause” to rupture, other cancer phenotypes such as higher proliferation rates, softer cells, fractality, etc., can also be incorporated into the model. Experimentation is required to verify the postulate.

SP160.2 - Surface electromyography in quantifying Parkinson’s disease and its treatment with deep brain stimulation
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Parkinson’s disease (PD) is a progressive neurodegenerative disorder that affects millions of people worldwide. The disease cannot be cured but the motor symptoms can be relieved with medication or with deep brain stimulation (DBS). However, there is a lack of objective and quantitative methods for monitoring PD and the efficacy of its treatment. Finding these objective methods is a global challenge.

Surface electromyography (EMG) and a principal component (PC)-based monitoring method was used here for quantifying PD-characteristic features in the EMG signals. The aim was to find the most effective combination of EMG signal features for characterizing PD and its treatment with DBS. It was quantified, if the EMG signals of PD patients change into more similar with the signals of healthy subjects with DBS.

Two groups of PD patients (9 patients with DBS ON and OFF, and 22 patients with medication OFF) and one group of healthy subjects (13 age-matched subjects) were measured during isometric contraction of biceps brachii (BB) muscles and during elbow flexion-extension movements. Surface EMGs were recorded from BB muscles. Several parameters were calculated from the EMG signals. The following parameters worked best in discriminating between healthy controls and PD patients: recurrence rate, correlation dimension, sample kurtosis and crossing rate variable of EMG during isometric contraction of biceps brachii (BB) muscles and during elbow flexion-extension movements. Surface EMGs were recorded from BB muscles. Several parameters were calculated from the EMG signals. The following parameters worked best in discriminating between healthy controls and PD patients: recurrence rate, correlation dimension, sample kurtosis and crossing rate variable of EMG during isometric contraction of biceps brachii (BB) muscles and during elbow flexion-extension movements. These variables were chosen to form feature vectors for each subject in the PC-based monitoring method. The analysis revealed clear differences in the EMG features between healthy controls and PD patients (see Fig. 1), and also between DBS OFF and ON. In eight out of nine patients, the surface EMG features changed into more similar with the features of healthy controls when the stimulator was switched on.

The results showed that surface EMG is capable of characterizing patients with PD and effects of DBS treatment. Surface EMG is therefore a potential method for monitoring PD and its treatment efficacy objectively and quantitatively.
To study the correlation of microelectrode recording with final tract chosen during bilateral STN DBS performed at a specialized centre in South India in 260 Parkinson’s disease (PD) Subjects (patients in disease states). In Parkinson’s disease there is a decreased dopaminergic output from the substantia-nigra, which changes the firing patterns of many neurons of the substantia nigra (SN). One of the consequences is an increasing firing from the neurons of substantia nigra (SN) which by stimulating to the neurons of globus pallidus interna (GPi) causes inhibition of thalamus and cortex causing slowing of voluntary movements. The STN is an almond shaped nuclei located in the midbrain, ventral to the thalamus, and bordered by zona incerta cerebral peduncle, medial lemniscus, SNpr,pc, red nucleus, etc. The simplistic view was supported by the fact that high-frequency current delivered to STN or GPi neurons or other neurons of basal ganglia (BG) which caused their inhibition improved indication of symptoms. It is now known that there is a significant change in the firing pattern and a reorganization of the entire basal ganglia with DBS. A retrospective study was carried out at a tertiary care NIMS - AP State University Super-specialized Hospital with a dedicated movement disorder unit from south India. 260 subjects (patients) with diagnosis of PD as per United Kingdom Parkinson disease society brain bank criteria were included. All the subjects were willing to undergo the procedure and fulfilled the following criteria to be eligible for STN-DBS, i.e., they had a disease duration of more than 12 years, good response to levodopa, able to walk independently in drug ‘on’ state and had normal cognition. All the PD subjects who were wheelchair bound, had dementia or severe psychiatric disturbances were excluded. Surgery was performed in all by a qualified neurosurgeon. Stereotactic targets were acquired employing a specialized system with a specially designed stereotactic CRW frame which has a luminant MR localizer to directly target points within the STN of brain. The targeting was performed according to Lozano’s Technique – 2mm sections are taken parallel to the plane of anterior comissure –posterior commissure line and at the level with maximum volume of red nucleus, STN is targeted at 3mm lateral to the anterior lateral border of red nucleus. The MER itself is not a complete tool to clearly discriminate the optimal target as the line of the DBS lead may not correspond to the axis of the STN. Further the impedance of the microelectrode may vary as they may be influenced by the brain tissue and may not show a clear recording. However, MER definitely confirms the clear position of the electrodes and bolsters the confidence of the neurosurgeons that they are in the target. Further, the availability of MER recording results in a vast data in connection with the functioning on the neurons situated deep in the brain and may help in unraveling the mysteries of the brain. From our experience, we say that MER facilitates selection of the final electrode location in STN DBS.

**SP160.4 - Vortex of the Magnetic Field on the Growth Rate of Escherichia Coli**

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Microorganisms are widely used in large-scale production of industrial items; therefore the bacterial growth is a key point in this technology development. In this study it is shown a non-chemical
growth acceleration system by the stimulation of magnetic field
to the Escherichia coli (ATCC 9637). It was used a magnetic field
intensity from 1.13 to 4.13 mT, it was applied for 6 h, in cycles with
five different frequencies: 100, 800, 1500, 2450 and 2500 Hz, in the
sinusoidal signal, the sample was a temperature of 37 °C and 150
rpm constant stirring. The results shown that magnetic stimulation
has a proliferative effect when the effect when the stimulus is con-
tinuous comparing with either intermittent or un-stimulated samples.
Growth of Escherichia coli (E. coli) could be altered under magnetic
field induces effects. E. coli, so these cultures exhibited higher
changes in its viability compared to unexposed cells. The increase
in rates of microbial growth can accelerate some of the fermentative
processes in the food industry, or allow greater obtaining of biomass
of producer strains of molecules high biotechnological value as bio-
polymers, biopharmaceuticals and nanomaterials of biomedical use.

SP160.5 - Electro Magnetic Therapy and Laser in the Chronic
Pain Of The Woman.
Author(s): Manuel E. Zuniga
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Introduction: The medical Physics is the application of the physics
to the medicine. It is a branch of the multidisciplinary
physics. It applies the physical foundations in many therapeutic
techniques. Luis Galvani in the century XVIII, scientist and Italian
doctor discovered that the muscles and nervous cells were able to
produce electricity. In the century XIX he developed himself to
electromagnetism based on the relation electricity and human body,
being developed thus new contributions to the treatment. These
knowledge gave origin to new scientific areas like bio-electromag-
netism. German scientific Helmoltz, was the first to
demonstrate the electromagnetic action. In the Europe of century
XVI, Paracelso used magnets to deal with a variety diseases. Two
centuries later Mesmer became famous by treating many disorders
with magnets.

OBJECTIVES: To apply the electromagnetic therapy for the chronic
pain in the woman. To relieve the pain instantly. To suppress all
chronic gynecological such as the pelvic inflammation, pain breasts,
headache and others. To offer to well-being and satisfaction in the
woman in few minutes.

Methods: Reviewing a meticulous clinical history for the pain. De-
determining that an organic cause does not exist. Making a careful and
detailed physical examination. Determining the cause the pain.
Evaluating the scale of pain. Applying the electromagnetic therapy
related to laser. Applying (I10 N80) the suitable electrodes, at a fre-
quency of 80 Hz in one weekly session of 2 minutes and for 5 weeks
time. Obtaining of pressedmagnetic fields and application of laser in
the painful zone.

Results: In more than 20 years of treatment with electro-magnetic
therapy and laser, the result for the population of patients was highly
satisfactory with 90 % success. We have treated with patient with
diagnosis of inflammatory pelvic disease and chronic pain, patients
with mastalgia, migraine, fibromialgia, etc., all with excellent results.
Patients of all ages that goes from 20 up to 80 years old.
With this treatment of electro-magnetic therapy we stimulate the
own body with the production of substances with analgesic effect,
like the endorphinas and others.

Conclusions: We conclude with the high effectiveness of the
Electro-magnetic therapy and laser. The therapeutic answer
was outstanding and highly satisfactory. Valuing the subjective an-
swer as much as the objective one. Comparing the therapeutic
result of the pain before the electro-magnetic therapy and later of its
implementation, the suspension of the pain was excellent after. The
electro-magnetic therapy is an alternative medicine practice that
implies the use of magnetic fields on the human body.
the linear X-ray attenuation coefficient, rhenium (Z = 75) is deemed to possess superior X-ray attenuation properties than iodine (Z = 53). Herein, monozized, biodegradable rhenium-doped microspheres were produced using microfluidic technology. The size distribution (25.1 ± 2.6 μm, CV = 10.5%) was determined by bright-field microscopy and the external morphology by scanning electron microscopy (SEM). The potential application of this newly developed rhenium-based XCA was evaluated against iohexol, a clinically utilized iodine-based XCA. The formulations were normalized in molar concentration of the radiopaque element. The radiopacity utilized iodine-based XCA. The formulations were normalized in molar concentration of the radiopaque element. The radiopacity

This study demonstrated that the variation in radiopacity between rhenium and iodine is dependent upon the applied X-ray tube potential. Owing to the high K-edge of rhenium (71.69 keV) in relation to iodine (33.18 keV), rhenium absorbs high energy photons more efficiently. For instance, it was observed that rhenium displays a greater radiopacity than iodine at high X-ray tube potentials (>80 kVp). Although low and moderate X-ray tube potentials are frequently utilized in clinical practice, the soft region of the X-ray spectrum is absorbed by the patient. Therefore, longer exposure times are required, which contributes to an increase in radiation dose. On the contrary, high X-ray tube potentials require shorter exposure times. As most CT scanners can operate at up to 140 kVp, the utilization of high X-ray tube potentials in clinical practice is feasible. We hypothesize that the use of rhenium as a surrogate of iodine would lead to a reduced radiation dose per scan. Considering these experimental findings, we are currently working on the development of a rhenium-doped microsphere-based XCA with improved functionalities. This was validated. Whether follow-up measurements are performed by the same technologist on the same day—or different technologists on subsequent days—does not appear to have a clinically significant impact on PE or least significant change (LSC). Mixing beam types (i.e., fan and pencil) may affect lumbar PE and LSC measurements more significantly than those of the hip. The use of a single technologist may reduce the PE for the lumbar spine but appears to increase it for the hip. Restricting the patient population to the female gender has the apparent effect of narrowing the gap between lumbar and hip PE’s. Finally, the degree of BMD measurement accuracy can be affected by the type of phantom being used (e.g., European Spine Phantom vs Lunar phantom) and the faults in specific DXA edge detection algorithms.

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Author(s): Christiane Burton, Ian A. Cunningham, 3Health Sciences North, Sudbury/CANADA, 2Laurentian University, Sudbury/CANADA, 1Health Sciences North, Sudbury/CANADA

Cardiovascular disease (CVD) is the leading cause of mortality worldwide. In 2008, it was estimated that 17.3 million people died of CVDs, representing 30% of global deaths, and of those deaths 7.3 million are attributed to coronary artery disease. Various techniques are used for imaging blood vessels and assessing the location and severity of arterial narrowings. As an example, digital subtraction angiography (DSA) is a widely used vascular imaging technique that removes anatomic structures by subtracting an image with only the ground structure in ESA. We are currently in the process of developing a fast-kV switcher to demonstrate ESA in real time for cardiac imaging. Whether follow-up measurements are performed by the same technologist on the same day—or different technologists on subsequent days—does not appear to have a clinically significant impact on PE or least significant change (LSC). Mixing beam types (i.e., fan and pencil) may affect lumbar PE and LSC measurements more significantly than those of the hip. The use of a single technologist may reduce the PE for the lumbar spine but appears to increase it for the hip. Restricting the patient population to the female gender has the apparent effect of narrowing the gap between lumbar and hip PE’s. Finally, the degree of BMD measurement accuracy can be affected by the type of phantom being used (e.g., European Spine Phantom vs Lunar phantom) and the faults in specific DXA edge detection algorithms.

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Dual-energy X-ray absorptiometry (DXA) is the standard method of measuring bone mineral density (BMD) at highly trabecular bone, which can be statistically linked to the risk of fracture. For DXA, precision error (PE) and phantom-based accuracy studies are among the most important routine quality control procedures. A precision study was performed at our institution using the International Society for Clinical Densitometry guidelines. Comparing our results with those reported by other investigators, we draw the following general Conclusions: the PE was higher for the spine than the hip, which we attribute to the better geometric reproducibility at the hip. The hypothesis that the DXA calculates BMD relative to water was validated. Whether follow-up measurements are performed by the same technologist on the same day—or different technologists on subsequent days—does not appear to have a clinically significant impact on PE or least significant change (LSC). Mixing beam types (i.e., fan and pencil) may affect lumbar PE and LSC measurements more significantly than those of the hip. The use of a single technologist may reduce the PE for the lumbar spine but appears to increase it for the hip. Restricting the patient population to the female gender has the apparent effect of narrowing the gap between lumbar and hip PE’s. Finally, the degree of BMD measurement accuracy can be affected by the type of phantom being used (e.g., European Spine Phantom vs Lunar phantom) and the faults in specific DXA edge detection algorithms.
SP161.5 - Use of Conventional Regional DXA Scans for Estimating Whole Body Composition

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BACKGROUND:

Using soft-tissue composition in conventional regional dual-energy X-ray absorptiometry (DXA) scans of the spine and hip to predict whole body composition (whole-body fat mass, whole-body lean mass and trunk-fat mass) instead of a whole body DXA scan.

Methods:

We identified 143 adult patients who underwent DXA evaluation of the whole body. Anthropometric indices were also measured. Datasets were split randomly into two parts; the derivation set including a sample of 100 subjects, and the validation set including a sample of 43 subjects. Multiple regression analysis with the backward stepwise elimination procedure was used for the derivation set and the estimates were then compared with the actual measurements from the whole-body scans for the validation set. The R^2 (adjusted coefficient of multiple determination) and SSE (error sum of squares) criteria were applied to compare regression models.

Results:

Using multiple linear regression analyses, the best equation for predicting whole-body fat mass (R^2=0.945) included gender, height, weight, waist circumference (WC), spine fat fraction and hip fat fraction; the best equation for predicting whole-body lean mass (R^2=0.970) included gender, height, WC, spine fat fraction and hip fat fraction; and the best equation for predicting trunk-fat mass (R^2=0.944) included gender, height, spine fat fraction and hip fat fraction.

Conclusion:

The results of this study show that regional DXA scans of the spine and hip can be used to accurately predict body composition.

SP161.6 - Multiple Energy Synchrotron Biomedical Imaging System– Preliminary Results

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The drive to improve and expand the amount of information extracted from various imaging modalities has led to the use of multiple (usually two) x-ray photon energies in computed tomography clinical systems. With the use of a single photon energy, the ability to differentiate soft from hard tissues is a problem which multiple energy imaging can solve. The continuous spectrum available from synchrotron light facilities provides a nearly an ideal source for multiple energy imaging. For living biological subjects a multiple energy system that can extract multiple endogenous or induced contrast materials as well as water and bone images would be ideal. A novel bent Laue single crystal monochromator that has a wide angularly dispersed energy range (polychromator) has been developed to explore the use of multiple energies simultaneously for biomedical imaging at the Biomedical Imaging and Therapy beamline at the Canadian Light Source. Using the 311 reflection from a 511 silicon crystal wafer bent to a radius of 95 cm, the system prepares a 0.5 mm wide focused polychromatic x-ray beam with a spectral range of 27 keV to 43 keV, covering both the iodine and barium K-edges of 33.17 keV and 37.44 keV, respectively. As an example use, test objects with iodine and barium (common contrast agents used in clinical imaging) along with water and bone were imaged and successfully extracted independent quantifiable images of these four materials. The biomedical imaging system is presented with emphasis on the polychromator used to prepare the imaging beam.
SP162 - Ultrasound and OCT: Applications

SP162.1 - Endoluminal Ultrasound Biomicroscopy for in vivo detection of caustic esophagitis in rats

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Introduction: The ingestion of caustic substances constitutes a serious public health problem and a pediatric emergency that can lead to serious sequelae. The majority of these accidents occur in the home environment where children ingest cleaning products. Among adults, the caustic ingestion is usually intentional and related to suicide. The most serious complication in the short term following caustic consumption is the esophagus perforation, which can lead to mediastinitis and death. Therefore, a diagnostic technique to evaluate the damage to the esophagus wall is important and endoscopy is primarily employed. Nevertheless, it is a technique that does not provide visualization across the esophagus wall. Recently, a high frequency (40 MHz) minimally invasive imaging ultrasound technique, named endoluminal ultrasound biomicroscopy (eUBM), was implemented to diagnosis small animal digestive diseases. The eUBM has been used successfully in longitudinal studies to follow-up the growth and differentiation of colon tumors, or even in the diagnostic evaluation of inflammatory lesions in the digestive tract, of small animal models. So far, reports related to the use of eUBM in the evaluation of inflammatory and neoplastic diseases in rat esophagus has not been found.

Objective: to explore the use of eUBM as diagnostic technique at the acute phase of esophageal caustic lesions in rats.

Methods: eight Wistar rats were used and distributed into groups I (injured esophagus) and S (sham), of four rats in each. The animals in group-I received sodium hydroxide (NaOH) at 20%, to cause caustic injury, through a catheter inserted into the distal esophagus while those in group-S received saline. Twenty-four hours after caustic burn induction, the animals in group-I were examined simultaneously through endoscopy and eUBM. Prior to esophagus inspection, the animals were anesthetized with intraperitoneal administration of ketamine (50 mg/kg) and xilazine (5 mg/kg) and thereafter accommodated on an intubating rat platform and intubated. The eUBM system contained an ultrasound mini-probe catheter that rotated 360° around its axis, providing cross-sectional ultrasound images of the esophagus wall. The ultrasound mini-probe was inserted into the accessory channel of a flexible choledochoscope (2.5 mm outer diameter), allowing simultaneous acquisition of endoscopic and eUBM images. During the procedure, the esophagus was irrigated with saline, injected through a flush port on the mini-probe catheter that acted as the ultrasound coupling medium between the transducer and the esophagus wall. After inspection, the esophagus was removed for histological examination.

Results: eUBM images of all animals of group-I presented erosions and ulcers, which had correspondence with histological and endoscopic findings. Additionally, eUBM revealed thickened wall and ulcers reaching up to the esophagus muscle layer, which was not possible to observe from endoscopy. For the animals in group-S, eUBM revealed the esophagus wall without any change, with intact layers.

Conclusion: eUBM is an imaging method able to accurately assess the acute inflammatory lesions caused by caustic agents in the esophagus of rats.

SP162.2 - To tap or not to tap: A comparison of cranial 3D to 2D ultrasound in extremely preterm neonates with post-hemorrhagic ventricle dilation to predict the necessity of interventional ventricular tap

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Introduction

Preterm babies are at risk of post-hemorrhagic ventricle dilation (PHVD), which has been linked to brain injury and morbidities such as poor motor coordination and cerebral palsy. PHVD is currently monitored with 2D cranial ultrasound (US), though no consensus has been determined for when interventional surgical therapy is required. Patients with rapid PHVD will require interventions known as ‘taps’ to remove excess cerebral spinal fluid from the ventricles to prevent further brain injury through excess intracranial pressure. Ventricle volumes (VV) derived from 3D US will be able to distinguish neonates with rapidly increasing VV versus those with stable ventricles.

Methods

The novel 3D US system used in this study has been previously validated in the laboratory through phantom experiments as well as in an in vivo study. Neonates with PHVD were enrolled into the present study after informed parental consent following a protocol approved by the REB. Clinical 2D US and 3D US images were acquired within 10 minutes of each other 1-2 times per week throughout the patient’s stay in the Neonatal Care Unit (usually 2-4 months) and analyzed offline. Linear estimates of the ventricles’ size (Levene’s index (LI), anterior horn width (AHW), third ventricle width (3rd w), and thalamo-occipital distance (TOD)) were measured on the 2D images by a collaborating radiologist. Ventricle volume (VV) was measured from 3D US images by a trained observer and reviewed by a collaborating clinician. Changes in the measurements between subsequent image sets were recorded for each patient.

Results

162 imaging sets were collected from 19 very preterm neonates with PHVD. Strong correlations were found between VV and AHW, 3rd w, and TOD (R^2 > 0.71-0.78), while moderate correlations were found between VV and LI (R^2 = 0.60). No strong correlations were found between changes in ventricle volume and changes in 2D US measurements (R^2 < 0.50). The rate of change in 3D US VV were significant different (p < 0.001) between infants requiring an intervention and infants with spontaneously resolved PHVD. No such sig. difference was found using 2D US derived measurements.

Discussion/Conclusion

While 2D US measurements are reasonable estimates of VV, changes in the measurements are not good indicators of changes in VV. As such, clinicians cannot reliably use changes in 2D US based measurements to determine if a patient has dilating ventricles. This could lead to neonates experiencing dangerous increases in intracranial pressure to have a delay in treatment until more symptoms emerge causing further brain injury. 3D US VV enables better, more
confident monitoring of progressive ventricular enlargement, and seems to predict which patients could require interventional therapy, though a study on a larger cohort would be required to confirm.

SP162.3 - Endoleak and Thrombus Characterization with Dynamic Elastography after Endoleak Embolization following Aneurysm Endovascular Repair

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**PURPOSE**

Supersonic Shear Wave Imaging (SSWI) can be used to measure the tissue elasticity in real-time. Our goal is to characterize the mechanical properties of abdominal aortic aneurysm (AAA) after endovascular aneurysm repair (EVAR) in a canine model (endoleaks, thrombus, walls) and compare the results with CT-Scan, Doppler Ultrasound (DUS) and pathologic findings.

**METHODS AND MATERIALS**

EVAR was done with creation of type I endoleak in 18 aneurysms created in 9 dogs (common iliacs arteries). Two embolization gels, Chitosan (Chi) or Chitosan-Sodium-Tetradecyl-Sulfate (Chi-STS) were injected in the sac to seal the endoleak and promote healing. SSI and Doppler Ultrasound were performed at baseline (implantation, 1-week, 1-month, 3-months) whereas angiography and CT-scan were performed at sacrifice. Macroscopic and histopathological analyses were processed to identify and segment five different regions of interest (ROIs): endoleak, fresh or organized thrombus, Chi or Chi-STS. Elasticity modulus values were compared in these ROIs.

**RESULTS**

At sacrifice, 10 aneurysms had endoleaks, 9 had fresh thrombus, 15 had organized thrombus and 3 were completely sealed. At 3 months, elasticity modulus (in kPa) of 0.1±0.2, 9.2±3.5, 47.3±25.7, 55.9±21.7 and 69.6±29.0 were respectively found in endoleak, fresh and organized thrombus, Chi and Chi-STS regions. Elasticity values of endoleak and fresh thrombus areas were significantly lower than organized thrombus, Chi and Chi-STS areas (p<0.001). Elasticity values of fresh thrombus ranged between 3 and 19 kPa (8.7±3.6 kPa) at 1-week and 30.2±13.8 kPa at 3-months indicating that SSI can evaluate thrombus maturation. Aneurysm with fresh thrombus did not shrink as fast as aneurysm with only organized thrombus.

**CONCLUSION**

The results show that SSWI was able to characterize thrombus organization, embolization agents and healing over time after endoleak embolization following EVAR. The next objective is to evaluate in clinical study the feasibility and efficacy of this approach.

**CLINICAL RELEVANCE/APPLICATION, NEW OR BREAKTHROUGH WORK TO BE PRESENTED**

1. The Supersonic ShearWave Imaging was able to detect endoleak in real-time.
2. This technic has the potential to characterize thrombus organization within the aneurysm sac and in particular fresh thrombus which is associated with endoleak and endotension. The SSWI was able to distinguish fresh thrombus that cannot be detected on CT-scan (actual gold-standard).
3. The SSI can complement conventional DUS in post-EVAR surveil-

SP162.4 - Detecting lipid-rich artery plaque using a handheld photoacoustic imaging device

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**Objectives:** Carotid atherosclerotic plaque rupture is a cause of brain infarction. To prevent plaque rupture, it is important to detect the lipid-rich vulnerable plaque. However, it is not easy to evaluate such plaque by conventional medical imaging. Photoacoustic imaging is investigated as a novel modality of visualizing the difference of tissue characteristics. We have developed a handheld photoacoustic imaging device and tried to evaluate the possibility to detect lipid-rich artery plaque with it in phantom experiments.

**Methods:** Carotid artery plaque was modeled by injecting beef fat into a bovine aortic wall. The bovine aorta was submerged in saline. Light of a pulse-laser source is conducted to the measurement cross section of the ultrasound probe by holding a bundle of optical fibers close to the probe. Light at wavelengths of 800-1400nm was irradiated. The photoacoustic signal distribution was measured as photoacoustic images.

**Results:** In photoacoustic images at wavelengths where lipid absorbs light highly, strong photoacoustic signals were observed from the boundary between fat and the vessel wall. Figure 1 presents the spectrum of photoacoustic signals from the boundary. Although peak wavelengths subtly differ between the above spectra and the absorption spectrum of lipid, the shapes of the spectra are similar. At wavelengths of 1240-1300nm where the lipid spectrum shape differs, the similarity between the photoacoustic spectra and the absorption spectra was evaluated by calculating the correlation coefficient. As shown in Fig. 2, there is high correlation at the boundary between fat and the vessel wall.

**Conclusion:** The possibility of detecting lipid-rich plaque was confirmed based on an analysis of the photoacoustic spectrum. For future work, there are some issues to consider, such as experiments using more realistic models considering blood, its flow, and subcutaneous tissue; optimization of irradiated light intensity; selection of appropriate wavelength; and signal processing to improve SNR.
SP162.5 - Intersex differences in posterior eye chamber by spectral optical coherent tomography
Author(s): Karina Maciejewska, Iwona Pajonk, Zofia Drzazga
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Optical coherent tomography (OCT) is a modern, non-invasive interferometric imaging technique. In our research, it was used to scan retina in young, healthy group of students in order to investigate the intersex differences in the structures of retina layers and its elements. 24 healthy eyes with normal vision were examined using SOCT Copernicus HR device. SOCT scans were conducted for a fovea of retina and in region of optic disc with the use of 3D, Asterix and Circle modes. In general, 120 measurements were performed. In obtained scans, the distance between RPE (retina pigment epithelium) and choroid was smaller in women than in men group, what seems to be the reason of a thinner retina in women. Analysis of optic disc revealed significantly higher rim area in women group than in men, but a little lower cup/disc ratio. These findings may be of a great importance in diagnosis glaucoma and other eye diseases when comparing intersex results.

SP162.6 - Longitudinal Analysis of 3D Pre-Term Neonatal Ventricle Ultrasound Images
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Intraventricular hemorrhage (IVH) is a major cause of brain injury in preterm neonates. Measuring ventricular dilatation or shrinkage quantitatively is an important step in monitoring patients and evaluating treatment options. 3D ultrasound (US) has been developed to monitor ventricle volume as a biomarker for ventricular dilatation and deformation. Ventricle volume as a global indicator, however, it does not allow for the precise analysis of local ventricular changes, which could affect specific white matter bundles, such as in the motor or visual cortex, and could be linked to specific neurological problems often seen in this patient population later in life. In this work, we report a spatial-temporal nonlinear registration approach, which is applied to analyze the detailed local changes of the ventricles of preterm neonates with IVH from 3D US images. In particular, we employ a novel sequential convex/dual optimization to efficiently extract the optimal spatial-temporal deformable, which simultaneously optimizes the sequence of 3D deformation fields. The experiments with four patients with 4 time-point images for each patient showed that the proposed spatial-temporal registration approach accurately and efficiently recovered the longitudinal deformation of the ventricles from 3D US images, generating a Dice similarity coefficient (DSC) of 81.0±2.2%, a mean absolute surface distance (MAD) of 0.5±0.5 mm and a maximum absolute surface distance (MAXD) of 3.0±2.1 mm by comparing the registered follow-up image with corresponding baseline image. The obtained results suggest that the proposed approach may be potentially used to analyze the change pattern of cerebral ventricles of IVH patients, their response to different treatment options, and to elucidate the deficiencies that a patient will have later in life.
SP162.7 - Breast Invasive Ductal Carcinoma Assessed by Conventional Ultrasound and Contrast-Enhanced Ultrasound in Different T-Stages

Author(s): Yanchun Zhu1, Zhiyuan Wang2, Yaoqin Xie1

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BACKGROUND: Accurate assessment of tumor size is necessary when selecting patients for breast-conserving surgery. There was little evidence of an association between conventional Ultrasound (US) and Contrast-enhanced US (CEUS) in predicting T stage of Breast Invasive Ductal Carcinoma (BIDC).

OBJECTIVE: The purpose of this study was to explore the value of CEUS in measuring the size and predicting T stage of BIDC.

Methods: Conventional US and CEUS were performed before pathology examinations by using a Siemens-Acuson S2000 scanner. One hundred and six patients confirmed with nodules of BIDC were included in the study. Person's correlations, linear regression and Wilcoxon signed-rank test were used to evaluate the relationship between two methods.

Results: Among 106 nodules, there were 16 nodules in T1 stage, 71 nodules in T2 stage and 19 nodules in T3 stage. The results show that CEUS consistently enlarge tumor size measurement: the width differences were 3.11±1.34mm, 3.91±1.78mm and 3.16±2.56mm for T1, T2 and T3 stages, respectively; and depth differences were 3.11±1.34mm, 3.91±1.78mm and 3.16±2.56mm for T1, T2 and T3 layers, respectively. As shown in Figure 1, significant correlations were observed between size measurements of US and CEUS (width measurement: r = 0.908, r = 0.925 and r = 0.927 for T1, T2 and T3 stages respectively; depth measurement: r = 0.959, r = 0.971 and r = 0.976 for T1, T2 and T3 stages respectively; all P < 0.001). Linear regression models similar among different T stages.

Conclusions: In conclusion, this study suggests that larger size measured by CEUS than US. CEUS is a useful method for measuring the size and predicting the T stage of BIDC.

SP162.8 - Comparison of ultrasound systems in scoliosis measurement

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Introduction:

Idiopathic scoliosis is the most frequent spinal deformation presenting as a spatial deviation from the medial vertebral line. It is diagnosed in early adolescence and monitored until adulthood when surgical correction may happen. Patients are monitored by X-ray imaging every 3-6 months, exposing them to aggregating ionizing radiation, which increases the risk of cancer. Tracked three-dimensional ultrasound imaging allows for risk-free and accurate measurement of spinal curvature (Ungi et al. Ultrasound Med Biol, 2014). In this work, we compared the utility of inexpensive portable ultrasound with more expensive stationary ultrasound in spinal curvature measurement.

Methods:

An open-source tracked ultrasound based scoliosis measurement platform (Ungi et al. Ultrasound Med Biol, 2014) was utilised. This system is based on the SlicerIGT (www.SlicerIGT.org) open source environment that allows for seamless swapping among tracking devices and ultrasound scanners without requiring any programming or engineering development work. Two configurations of this system (Figure 1a) were compared: Interson USB ultrasound (Interson Corp, Pleasanton, CA, USA) with optical MicronTracker Hx60 (Claron Technology Inc., Toronto, ON, Canada); and Sonix Touch (Ultrasonix, Richmond, BC, Canada) with electromagnetic Ascension M180 (Ascension, Milton, VT, USA). In both configurations, a reference marker was attached to the patient and to the wall to compensate for gross body motion during ultrasound scanning. The intrinsic accuracy of SlicerIGT with both optically and electromagnetically tracked ultrasound was previously analyzed (Lasso IEEE TBME, 2014). This work focused on ultrasound image utility. Three human volunteers were scanned downward from the 7th cervical vertebra along the thoracic and lumbar regions. Two physicians experienced in spine ultrasound evaluated the visibility and clarity of the tip of transverse process, the anatomical feature that is necessary for curvature measurement.

Results and Conclusions:

For both physicians, in all patients and in all vertebrae, the transverse process tip (N=102) was clearly visible with both Interson and Ultraso

Figure 1. Comparison of CEUS and US measurements of all subjects and subjects with different T-stages.
SP163 - Primary Dosimetry Standards

SP163.1 - Candidate Technologies for Next-Generation Dosimetry Standards

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Primary standard instruments are broadly understood to be capable of realizing the unit of a physical quantity directly, according to its definition from basic physical principles, and because of their fundamental role in the calibration chain ideally possess the highest attainable accuracy and precision permitted by the state of the art. Because of its highly complex interactions with matter, however, ionizing radiation poses special challenges for its metrology and for the establishment of primary standards in which the measurand and the resulting units of measurement can be readily abstracted from the target material and physical attributes of the radiation source. This poses certain difficulties for advancing the state of the art in the quest for candidate technologies on which to base next-generation primary standards.

The extent to which this situation has inhibited the migration of technological advances from allied fields into radiation metrology may be difficult to ascertain, but is suggested by the resemblance of present-day water calorimeters to the earliest prototypes, developed decades ago, in which radiation-induced temperature rise is measured with thermistor probes sealed in a glass vessel. Heat transfer and scattering perturbations attributable to these components are well understood, however even when correction factors are readily obtainable the resulting instrument is still limited for use at fixed depth in static, flat radiation fields.

Remote detection of temperature rise by use of light or ultrasound is well established in non-destructive testing, but its use here, to detect the temperature field in an irradiated volume would seem to offer distinct advantages for the dosimetry of certain nonstandard beams and, more generally, for spatial mapping of dose distributions within matter. At NIST, both ultrasonic and optical techniques have been developed and exploited for high precision thermometry of water for purposes of radiotherapy-level dosimetry. In the case of ultrasound, work proceeds along two general lines, development of an imaging array for obtaining dose distributions in water and specialized studies with fewer transducers investigating detection limits and strategies for recovering faint signals. Parallel work using lasers in place of the ultrasound has yielded therapy-level dose measurements in both water and PMMA, and, via the use of sensitive interferometric techniques, shows considerable promise for exceeding the thermal sensitivity achievable with existing calorimetry systems.

Realization of an imaging calorimeter based on light or ultrasound remains a distant goal, however, with many technical hurdles yet to overcome, and thus work also continues on ways to adapt and improve thermistor-based systems for new primary standards for radiotherapy beams, and, most recently, for CT beams. A prototype calorimeter with thermistor beads embedded in a polystyrene core has been used in a HDPE phantom subjected to therapy-level radiation from a clinical accelerator and diagnostic-level radiation from a CT imaging system. With further refinements, the anticipated instrument would provide a calorimetry response to dose spanning over 3 orders of magnitude for beam energies ranging from keV to MeV, potentially making the system a portable “universal” primary reference standard that only requires electrical calibration of the thermistors.
SP163.2 - Absorbed dose to water measurements in a clinical carbon ion beam using water calorimetry

Author(s): Julia-Maria Osinga\(^1\), Steffen Greilich\(^2\), Oliver Jäkel\(^3\), Ulrike Ankerhold\(^4\), Achim Krauss\(^5\)

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\(^2\)Division Of Medical Physics In Radiation Oncology, German Cancer Research Center (DKFZ), Heidelberg/GERMANY,
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\(^4\)Division Of Medical Physics In Radiation Oncology, German Cancer Research Center (DKFZ), Heidelberg/GERMANY,
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Introduction: Until now, dosimetry of heavy ions with ionization chambers has not reached the same level of accuracy as dosimetry of conventional high-energy photons. The standard uncertainty associated with carbon ion dosimetry is about a factor of 3 higher as compared to high-energy photons [1]. This is mainly caused by the limited knowledge of the so-called k\(Q\),Q\(Q\) factor, which corrects for the different response of the ionization chamber to the actual user beam quality Q (here: \(^{12}\)C) compared to the reference beam quality Q\(O\) (here: \(^{60}\)Co). A significant discrepancy between fluence- and ionization-based dose measurements in carbon ion beams was shown in a previous study [2], which could indicate an inaccurate k\(Q\),Q\(Q\) factor. The k\(Q\),Q\(Q\) factor is, up to now, determined by calculations based on cavity theory and Monte-Carlo transport simulations and asks for experimental verification. This can be done by use of a primary standard for absorbed dose to water that allows for a direct calibration of the chamber in the user beam quality Q. Therefore, a project was initiated to perform absolute absorbed dose to water measurements in carbon ion beams by water calorimetry [3] to determine the k\(Q\),Q\(Q\) factor with a lower standard uncertainty.

Materials and Methods: The water calorimeter measurements at HIT had to be adjusted to the specific conditions, namely (1) the irradiation with a pulsed beam using the raster-scan method and (2) the off-isocenter position of the calorimeter. Therefore, a number of investigations were required prior to the calorimetric measurements to determine and optimize the beam parameters at the measurement position complying with the following requirements: Firstly, the irradiation time needs to be as short as possible to minimize heat conduction effects occurring during the calorimetric measurements. At the same time, a homogenous and reproducible dose distribution is necessary to achieve a low standard uncertainty in the subsequent calorimetric measurements. To perform the corresponding investigations, a water-equivalent slab phantom was designed to mimic the real measurement condition of the calorimeter offering high flexibility in measurement set-ups. Based on the optimal beam parameters found, a series of measurements (>100) with the water calorimeter and two Farmer-type ionization chambers were performed in the entrance channel of a 430 MeV/u carbon ion beam.

Results: Current results of the calorimetric and ionometric measurements performed over a time period of 6 months, including the experimental determination of associated correction factors as well as calculations of the induced heat transport effects for the water calorimeter, will be presented. Further, a preliminary estimation of the currently investigated k\(Q\),Q\(Q\) factor for both ionization chambers will be given.

Conclusion: We investigated optimized irradiation conditions enabling accurate calorimetric measurements in a scanned carbon ion beam. The latest results indicate that the experimental determination of the corresponding k\(Q\),Q\(Q\) factor for ionization chambers with a relative standard uncertainty below 1 % is achievable.

Literature


SP163.4 - Absorbed dose-to-water primary standard and traceability system for radiotherapy in China

Author(s): Kun Wang, Sunjin Jin, Jian Zhang
National Institute of Metrology, Beijing/CHINA

The absorbed dose-to-water was measured both by ionization and calorimetry method at radiotherapy dose levels in China. A graphite ionization chamber, based on the cavity theory and combined with Monte Carlo simulation, was developed to measure absorbed dose to water for Co-60 gamma radiation. With Townsend compensation method to achieve ionization current measurement, using EGSnrc package for graphite cavity ionization chamber to simulate water perturbation parameter, measured the ion recombination and radial inhomogeneity correction factor, the combined standard uncertainty to measure absorbed dose to water for Co-60 was 0.37%.

The standard based on a water calorimeter is designed to operate in Co-60 and megavoltage photon beams from a linear accelerator. The water calorimeter operated at 4°C to eliminate the problems associated with convection in water phantoms at room temperature. A low-noise temperature measurement circuit was able to resolve temperature differences at the μK level. With the bath and Peltier cooling system, the temperature of water phantom is stable at (±0.0001) °C. Using the cylindrical sealed glass vessel and bead thermistor of 10 kΩ, in the H2-saturated high pure water system, the resistance was measured by Wheatstone AC bridge. After calibrating thermistor and bridge separately, absorbed dose to water is absolutely measured with the combined standard uncertainty of 0.38%.

NIM participate in the comparison organized by Asia-Pacific Regional Metrology Programme (APMP), the differences with the reference value in APMP.RI (I)-K4 comparison was 0.04%, NIM finally had the ability for the traceability of absorbed dose to water.

The primary standard of water absorbed dose for photon radiation from 4 MV to 25 MV will be established and achieve the traceability of water absorbed dose for radiation therapy. This new standard will significantly reduce the uncertainty of ion chamber calibrations for Chinese radiotherapy centers and open up new areas of research for the NIM.

SP163.5 - Design of an MRI-compatible water calorimeter for use in an integrated MRI-Linac and Gamma-Knife

Author(s): Niloufar Entezari1, Davis Ly2, James Renaud3, Arman Sarfehnia4

1Department Of Physics, Ryerson University, TORONTO/ON/CANADA, 2Department Of Engineering, University of Waterloo, Waterloo/ON/CANADA, 3Medical Physics Unit, McGill University, Montréal/ CANADA, 4Department Of Radiation Oncology, University of Toronto, Toronto/CANADA

Purpose: The aim of this work is to present numerical design and optimization of a portable water calorimeter appropriate for dual use in an integrated MRI-linac and Gamma-Knife5, based on the concept of 4°C stagnant water calorimetry. In calorimetry, dose to water(Dw) is measured based on the principle that energy absorbed in a sensitive volume is completely converted to temperature rise(ΔT) using specific heat capacity of medium \(c_{P,D}=c_{P,W}k_{ht}\), where \(k_{ht}\) is heat transfer correction and compensates for heat gain or loss at point of measurement due to conductive and convective effects.

Methodology: The calorimeter dimensions, constrained by the size of an MRI-linac bore and Gamma-Knife collimator ring, were numerically optimized to maximize thermal stability. Several materials were investigated to be used for the calorimeter body, and thermal insulation.

A comprehensive numerical optimization study of four different calorimeter designs was undertaken using a commercial finite element method software package by accurately modeling heat transport inside a given geometry (FIG 1). For each design, thermal stability of system in presence of minor ambient thermal fluctuations was evaluated.

To study the effects of possible coolant temperature fluctuations (circulating in calorimeter to keep it at 4°C), several simulations were performed in which the temperature of coolant was kept either constant, slowly increasing, or fluctuating at a given frequency. The long term drift(48h) was simulated, and kht due to seven consecutive irradiation runs by a high energy beam was calculated.

Results and Conclusions: The calorimeter was designed to be used in upright position in MRI-linac with the radiation beam incident from the top, while it is rotated 90 degrees for use in Gamma-Knife. In the latter case, its semi-spherical end is placed at the isocenter of Gamma-Knife collimator ring, providing a constant depth of measurement for every incident beam angle.

Due to MRI-compatibility requirements, the calorimeter is to be rapid prototyped/built entirely out of plastic. Among all insulation materials tested, solid state aerogel-based insulation resulted in highest performance and thermal stability.

\[ k_{ht} \text{ was found to be } 1.002±0.014, 0.984±0.013, 0.986±0.029, 1.002±0.013(k=1) \text{ for designs in FIG1a-d respectively. The design in Fig.1d was chosen for prototyping, as it demonstrated the greatest long term stability (0.36μK/hr).} \]
In quasi-adiabatic mode, the radiation-induced temperature rise is measured in the sensitive volume (i.e., the core) while the outermost portion of the device is thermally stabilized by a software-based temperature controller. In isothermal mode, the entire device is subject to active thermal control and the quantity of interest is the electrical power necessary to maintain a stable temperature while irradiated.

An experimental characterization of the GPC repeatability, linearity, and dose rate dependence while operated in quasi-adiabatic mode was carried out in a water-equivalent phantom, under reference conditions, in a 6 MV photon field. Similarly, a characterization study of the GPC's isothermal mode was conducted by simulating radiation fields of various dose rate (0.5 – 11.8 Gy/min) and duration (10 – 180 s) by means of electrical power dissipation.

Results: For the quasi-adiabatic mode, a repeatability of 0.4% was established (n = 64), linearity was characterized by an adjusted $R^2$ value of 0.9996 (n = 40), and no statistically-significant dose rate dependence was observed.

For isothermal mode, differences between expected and actual GPC response ranged between 0.3 – 1.4%, and in general, agreement was superior for longer irradiations with dose rates greater than 2 Gy/min.

Discussion and Conclusions: This proof of concept points to the feasibility of operating the GPC in both quasi-adiabatic and isothermal mode for the purpose of absolute clinical dosimetry.

As expected from a calorimeter, the GPC is characterized experi-
SP164 - Adaptive Radiation Therapy (ART)

SP164.1 - Real-time dose reconstruction for adaptive radiation therapy

Author(s): Martin F. Fast, Cornelis Philippus Kamerling, Peter Ziegenhein, James L. Bedford, Simeon Nill, Uwe Oelfke
Joint Department Of Physics, The Institute of Cancer Research and The Royal Marsden NHS Foundation Trust, London/UNITED KINGDOM

Currently dose reconstruction can only be conducted after the treatment fraction due to its computational cost and missing real-time data interfaces. In future, real-time treatment interventions such as dynamic multi-leaf collimator (dMLC) tracking will require on-line dose reconstruction to ensure target coverage and organ-at-risk (OAR) sparing.

To facilitate this study, we have implemented on-line dose reconstruction by connecting our software for delivery & tracking (DynaTrack) and for dose calculation & planning (DynaPlan) through a TCP/IP network. DynaTrack is interfaced to our research Elekta Synergy linac/Agility MLC and controls treatment delivery and dMLC tracking via a real-time tracking interface. Actual MLC apertures and (simulated) target positions are reported to DynaPlan every 40 ms and 20 ms respectively. DynaPlan then relies on a set of pre-calculated dose influence matrices (Dij) with 5x5 mm² bixel resolution generated in research RayStation using its singular value decomposed pencil beam algorithm to calculate the actually delivered dose. To investigate the impact of dMLC deliveries on dose distributions, we generated two plans in Pinnacle: a lung patient (RTOG 1021, 54 Gy, 3Fx, 15-beam, PTV 34 cm³) and a prostate patient (RTOG 0938, 36.25 Gy, 5Fx, 7-beam, PTV 104 cm³). The dose was accumulated onto a voxel resolution of 1.95x1.95x3 mm³ (lung) and 2.3x2.3x1.5 mm³ (prostate). Three treatment scenarios were evaluated: a static delivery (no motion, no tracking), a conventional delivery (motion, no tracking), and an adaptive delivery (motion, tracking). Two motion trajectories were used to propagate the PTV contour within the planning CT (assuming static OARs).

We successfully implemented truly on-line dose reconstruction for experimental treatment deliveries on a linac. The dose reconstruction was updated at 25 Hz and took ≤30 ms (prostate) and ≤20 ms (lung) per MLC aperture. Dijdata of up to 1 GB per beam segment was handled at a memory throughput of ≤43 GB/s on a single workstation computer. The reconstructed dose distributions (see table) highlight the fact that target dose can be safely recovered using dMLC tracking for these patients and motion conditions.
**SP164.2 - Evaluation of unified intensity-modulated arc therapy (UIMAT) for the treatment of head-and-neck cancer**

**Author(s):** Michael Macfarlane¹, Douglas Hoover², Eugene Wong³, Jerry J. Battista², Nancy Read⁴, David Palma¹, Varagur Venkatesan⁴, Alex Hammond⁴, Jeff Z. Chen⁴

¹Department Of Medical Biophysics, Western University, London/CANADA, ²Department Of Oncology, Western University, London/CANADA, ³Department Of Physics & Astronomy, Western University, London/CANADA, ⁴London Regional Cancer Program, London Health Science Center, London/ON/CANADA

**Purpose:** Recently our group developed a unified intensity-modulated arc therapy (UIMAT) technique which combines IMRT and VMAT optimization and delivery in a single arc [1]. In this current study, we evaluated the potential benefit of UIMAT for the radiation therapy of complex head-and-neck cancers.

**Method:** A retrospective planning study was performed on 20 head-and-neck cases (13 treated clinically with VMAT and 7 with IMRT). These cases were re-planned using our UIMAT technique and the results were compared with the clinically delivered plans. Plans were assessed in terms of target coverage, target conformity, and sparing of organs at risk. The feasibility of plan delivery was verified with an ArcCheck phantom and a Varian TrueBeam linear accelerator operating in clinical mode.

**Results:** When compared to VMAT or IMRT alone, UIMAT plans maintained target coverage and conformity while significantly reducing the mean doses to organs at risk. This trend is summarized in Table 1. A comparison of dose-volume histograms between VMAT and UIMAT plans is also shown in Figure 1. In addition to its dosimetric advantage, UIMAT plans can be delivered with the same level of efficiency as VMAT.

**Conclusion:** Compared with IMRT or VMAT alone, UIMAT appears to offer dosimetric advantages for the radiation therapy of head-and-neck cancers.

**References:**


**Table 1:** Comparison of average dose-volume parameters between clinical (VMAT or IMRT) and UIMAT plans. The mean PTV dose and dose to 95% of the PTV volume (D95) is represented as a percentage of the prescription dose. All p-values were calculated using a paired, one-tailed t-test.

Real-time dose reconstruction is technologically feasible without compromising on resolution or accuracy. This is an important milestone towards the implementation of on-line replanning for adaptive radiation therapy and dose-guided dMLC deliveries. Future work will assess the impact of the motion model on the dose and use collapsed-cone Dij data for lung patients.

Disclaimer: Thanks to Elekta (research agreement on tracking) and RaySearch (support of Dij export).
### Planning Target Volume

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<td>Max (Gy)</td>
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<td>-9.1%</td>
<td>-6.4%</td>
<td>-4.8%</td>
<td>-31.0%</td>
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<tr>
<td><strong>p-value</strong></td>
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<td>0.189</td>
<td>0.001</td>
<td>0.011</td>
<td>&lt; 0.001</td>
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**Figure 1:** Comparison of dose-volume histogram between VMAT and UIMAT.

![Dose Volume Histogram](image)
SP164.3 - A Hybrid IMRT/VMAT Technique for the Treatment of Nasopharyngeal Cancer
Author(s): Nan Zhao, Ruijie Yang, Yuliang Jiang, Suqing Tian, Fuxin Guo, Junjie Wang
Radiation Oncology, Peking University Third Hospital, Beijing/CHINA

Purpose: This study is to investigate a Hybrid IMRT/VMAT technique which combines intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) for the treatment of nasopharyngeal cancer (NPC).

Methods: 2 full arcs VMAT (2ARC-VMAT), 9-field IMRT (9F-IMRT) and Hybrid IMRT/VMAT plans were created for 10 patients with NPC. The Hybrid IMRT/VMAT plans were combination of 1 full arc VMAT (Hybrid-VMAT) and 7-field IMRT (Hybrid-IMRT). The dose distribution of planning target volume (PTV) and organs at risk (OARs) for Hybrid IMRT/VMAT was compared with 9F-IMRT and 2ARC-VMAT. The monitor units (MUs) and treatment delivery time were also evaluated.

Results: For PTV70 and PTV95.4, the Hybrid IMRT/VMAT technique significantly improved target dose conformity compared with 9F-IMRT (0.62 vs 0.47, p=0.01; 0.64 vs 0.57, p=0.01) and 2ARC-VMAT (0.62 vs 0.43, p=0.00; 0.64 vs 0.60, p=0.01). For PTV84, the Hybrid IMRT/VMAT technique improved target dose conformity compared with 9F-IMRT (0.69 vs 0.63, p=0.00). The near maximum dose (D2%) and mean dose of mandible in Hybrid IMRT/VMAT were 5.2% (p=0.00) and 4.2% (p=0.03) lower than 9F-IMRT plans, respectively. The mean dose of TMJ, temporal lobe and unspecified tissue for Hybrid plans were 12.8% (p=0.00), 11.4% (p=0.01) and 4.0% (p=0.02) lower than 9F-IMRT plans, respectively. The V20 of right and left parotids for Hybrid plans and VMAT plans were 34.7% vs 35.7% (p=1.00) and 36.1% vs 37.1% (p=1.00), respectively. The mean dose of TMJ, D2% of mandible for Hybrid plans and 2ARC-VMAT plans were 37.4 Gy vs 39.3 Gy (p=0.34) and 63.7 Gy vs 64.7 Gy (p=0.06), respectively.

Conclusions: Hybrid IMRT/VMAT technique can be a viable radiotherapy technique with better plan quality.

SP164.4 - Interactive real time adaptation of IMRT treatment plans
Author(s): Cornelis Philippus Kamerling¹, Katrin Welsch¹, Peter Ziegenhein¹, Simeon Nill¹, Jamie McClelland², Uwe Oelfke¹
¹Joint Department Of Physics, The Institute of Cancer Research and The Royal Marsden NHS Foundation Trust, London/UNITED KINGDOM, ²Centre For Medical Image Computing, Dept. Of Medical Physics And Bioengineering, University College London, London/UNITED KINGDOM

Recently we introduced a software platform for IMRT treatment planning based on a sequence of local dose adaptations. These are facilitated by direct interaction of the planner with the graphical representation of the patient dose in a real-time feedback loop. Here we report on an extension of this interactive dose shaping (IDS) software for adaptive radiotherapy based on daily cone beam CTs (CBCTs).

The developed workflow consists of five essential components as indicated in figure 1. All related algorithms are integrated with our research TPS Dynaplan and optimized for speed to comply with the interactive planning paradigm. To facilitate deformable image registration (1a), the NiftyReg (UCL, London, UK) package was integrated.

As an example for the performance of the implemented workflow we report its application for a prostate patient aiming to re-establish the initially planned dose (based on planning CT) on a new patient geometry observed on a CBCT in fraction 5. The center-of-mass shift from PTV and rectum were 5.3 and 4.4mm respectively, mainly in posterior direction. The PTV dose prescription was 67Gy. Dose quality indicators were evaluated for (i) initial plan on initial geometry, (ii) initial plan on new geometry, (iii) adapted plan on new geometry and are reported in table 1. The recovered target dose indicates a successful restoration of the initially planned dose. The slightly higher rectum dose is the result of the decreased distance between PTV and rectum. The computations were performed on a low-end Intel i7 desktop PC with an image processing runtime of 2min, dominated by image registration (1a) with 84s. IDS recovery (5a) took 5s.

This work provides a first proof of concept study for the integration of an ART therapy workflow into an IDS TPS. Further validation aiming to optimize the image processing parameters and IDS recovery performance is in progress.
SP164.5 - A Hybrid IMRT/VMAT technique for the treatment of non-small cell lung cancer

Author(s): Nan Zhao, Ruijie Yang, Junjie Wang, Xile Zhang

Radiation Oncology, Peking University Third Hospital, Beijing/CHINA

Purpose: To investigate a Hybrid IMRT/VMAT technique which combines intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) for the treatment of non-small cell lung cancer (NSCLC).

Methods and Materials: 2 partial arcs VMAT, 5-field IMRT and Hybrid IMRT/VMAT plans were created for 15 patients with NSCLC. The Hybrid IMRT/VMAT plans were combination of 2 partial arcs VMAT and 5-field IMRT. The dose distribution of planning target volume (PTV) and organs at risk (OARs) for Hybrid IMRT/VMAT was compared with IMRT and VMAT. The monitor units (MUs) and treatment delivery time were also evaluated.

Results: Hybrid IMRT/VMAT significantly improved the target conformity and homogeneity compared with IMRT and VMAT. The V30 of normal lung for hybrid plans was significantly lower than IMRT plans (17.7% vs 18.7%; p<0.05) and VMAT plans (17.7% vs 18.4%; p<0.05). The V5, V10, V30 and mean lung dose (MLD) of normal lung for hybrid plans were 5.1%, 7.7%, 3.8% and 3.9% lower than those for VMAT plans, respectively (p<0.05). The maximum dose of spinal cord for hybrid plans was 5.6 Gy lower than that for IMRT plans (p<0.05). The dose received by esophagus and heart for hybrid plans were significantly lower than those for IMRT plans. The mean delivery time of IMRT, VMAT and hybrid plans were 280 s, 114 s, and 327 s, respectively. The mean MUs needed for IMRT, VMAT and hybrid plans were 933, 512, and 737, respectively.

Conclusions: The Hybrid IMRT/VMAT technique significantly improved the target conformity and homogeneity compared with IMRT and VMAT. It reduced V5, V10, V30 and MLD of normal lung compared with VMAT, and protected the OARs better with fewer MUs compared with IMRT. Hybrid IMRT/VMAT technique can be a viable radiotherapy technique with better plan quality.
deform the planning CT to the daily CBCTs, obtaining the anatomical information of the day with the electron density values of the planning CT. The deformed contours were checked for any discrepancies and Rapid Arc plans were calculated with fixed MUs on the deformed CTs. Based on the calculated plans, a cumulative DVH was generated and the variation in the parotid volume and the delivered mean doses of parotids were analyzed.

Results:

There was shrinkage of parotid volumes during the course of the treatment. In this study, the observed maximum, minimum and mean parotid volume reduction were 52%, 13% & 29% respectively. The mean dose of parotids varied from -3.6% to 17% from the planned doses. The parotid volume and dose variation for 10 patients are shown in the table below. It was observed that for parotids closer to high dose regions a small volume shrinkage causes a remarkable increase in mean dose due to more of the parotid volume inside the high dose region. Whereas for parotids closer to low risk nodal regions, there is no significant change in mean dose even for a volume shrinkage of 30%. Parotid mean doses were less than the planned doses for two patients due to shrinkage along cranio-caudal direction also.

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<th>PATIENT</th>
<th>VOLUME (%)</th>
<th>MEAN DOSE (%)</th>
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<tr>
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<td>10</td>
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</table>

Conclusion:

The results from the study showed that it is clinically feasible to estimate the parotid shrinkage and the delivered dose - volume relationship in VMAT using planning CT electron density mapping on daily CBCTs.

SP164.7 - Plan Optimization for a Lung Patient on a Parallel Linac-MR System

Author(s): Daniel Tamagi, Brad Warkentin, Amir Keyvanloo, B Gino Fallone, G. Colin Field

Medical Physics, Cross Cancer Institute, Edmonton/CANADA

Purpose: In a hybrid Linac-MR system, the magnetic field of the MRI produces a Lorentz force on charged particles that affects dose deposition. The resulting effects on patient dose distributions are expected to be most significant in low density regions such as lung, where the mean free paths of electrons and positrons are longer. This study uses a simplified (three-beam) Stereotactic Body Radiation Therapy treatment plan for a lung patient to investigate the importance of these dosimetric perturbations in the fluence optimization and dose calculation stages of the treatment planning process.

Methods: Modified versions of the EGSnrc Monte Carlo codes BEAMnrc and DOSXYZnrc were used to generate patient-specific beamlets in 1) the absence of a magnetic field, and 2) in the presence of a magnetic field (either 0.56T or 1.5T) oriented parallel to the beam. These beamlets were imported into a research version of the RayStation TPS (RaySearch Laboratories, Sweden), and were used: 1) to perform “forward” dose calculations of unmodulated beams, and 2) to optimize fluence patterns for modulated beams. Forward calculations using the kernels for 0T, 0.56T and 1.5T were performed for MLC shaped fields and were compared to determine the dosimetric effects of the magnetic field. The RayStation fluence optimization software was used to determine fluence patterns for each of the 3 fields to achieve clinical goals. MATLAB code was written to compare these optimized fluence patterns as a function of magnetic field strength. A forward calculation was performed for these optimized fluence patterns and the resulting dose distributions were compared for the 3 magnetic fields.

Results: As a function of magnetic field strength, fewer Monitor Units (max % differences of -0.9% for 0.56T, and -2.4% for 1.5T compared to 0T) were required to achieve equivalent target coverage, due to the confinement of scattered electrons by the magnetic field. We also observed more lung sparing (Mean dose of 0.8% less for 0.56T, and 9.5% less for 1.5T compared to 0T) as a function of magnetic field strength due to the scattered electron confinement, and the reduced MU’s. With identical optimization objectives, percent differences for fluence elements were within +5% between the 0T and 0.56T optimizations, but were as large as 60% for some elements between the 0T and 1.5T. We found that optimizing the fluence without the magnetic field being considered resulted in worse target coverage (DS 5% differences of 0.2% and 2.6% for 0.56T and 1.5T respectively compared to 0T). This effect is clinically negligible for the 0.56T case, but was more significant at 1.5T.

Conclusion: Our study suggests that modeling the magnetic field during fluence optimization and during the forward dose calculation is significant at 1.5T, but is clinically negligible at 0.56T. Our study also indicated that equivalent target coverage (compared to a conventional linac) can be achieved with better sparing of lung if the magnetic field is modeled during forward planning and fluence optimization. These results are for a lung patient with a simplified 3 beam treatment plan. More investigation is needed.
Several new procedures for efficient processing of long-term EEG recordings have been validated on long-term coma EEG data. The proposed solution is based on the use of cluster analysis over a set of various features derived from adaptively segmented EEG data. Special attention was given to utilization of clinically relevant information from multichannel EEG data. Methods for validation of the cluster analysis results were implemented and tested. Suggested algorithms speed up a subsequent evaluation of the data and simplify a tedious and time-consuming work of neurologists or sleep technicians, making the evaluation more objective, and represent results in an understandable form.

We propose a novel Real-Time Clustered MUSIC algorithm (RTC-MUSIC) that makes use of the advantages of the well-established MUSIC algorithm but can be applied to real-time data streams during the measurement. For this purpose, regional cortical activity is represented by a small number of dipoles based on a cortical atlas and a k-means algorithm, thus considerably reducing the size of the gain matrix. The computation of the subspace correlations between dipole pairs is highly parallelized. Moreover, performance optimization is achieved by employing Powell’s Conjugate Gradient Method [26] as the search algorithm to find the best dipole source combination without performing a brute-force calculation of all dipole correlations.

Our results show that the gain matrix clustering improves the condition of the underlying inverse problem. In addition, the reduction of the gain matrix to the most representative dipoles considerably reduces the computational effort. Performance optimization in RTC-MUSIC yields a further reduction of the required calculation steps by approximately 50 % for the same number of dipoles, sensors and independent sources, respectively, compared to the MUSIC algorithm. Moreover, the number of computational steps is exponentially decreasing with the number of parallel cores employed for the calculation.

Applying our novel RTC-MUSIC algorithm to single trial MEG data from an auditory task reveals similar localization precision compared to the original MUSIC algorithm. The real-time performance of our algorithm was confirmed in measurements with the Elekta Neuromag® MEG system.

We conclude that our novel RTC-MUSIC algorithm with gain matrix clustering allows for real-time localization of correlated sources of neuronal activity. It copes with the low SNR of single trial data and considerably reduces the computational time compared to MUSIC.

Magnetoeencephalography (MEG) and electroencephalography (EEG) provide information on brain function with a high temporal resolution. Recent developments in EEG allow for ubiquitous recording using dry electrodes. However, multichannel dry electrodes still suffer from higher channel dropouts compared to standard wet EEG.

We propose a new technique for interpolating EEG channels based on compressive sensing (CS). The complete signal is reconstructed from an incomplete set of measurements via convex programming. An adapted, convex optimization problem was designed to solve the interpolation problem. EEG is neither sparse in the canonical basis in the original time domain nor sparse in transformed time domains. Therefore, current CS algorithms cannot achieve good recovery quality. Consequently, we propose compressive sensing in the spatial domain. We use our recent spatial harmonic analysis (SPHARA) to decompose measured data obtained with a dry 97-channel EEG cap. SPHARA is based on the Eigenanalysis of the discrete Laplace-Beltrami operator defined on a triangular mesh. It allows a spatial Fourier analysis of the spatial potential distribution of EEG data. Pattern reversal visual evoked potentials (VEP) were measured using the dry electrode cap and a commercial amplifier (RefaExt, ANT B.V., Enschede, The Netherlands) for four healthy male volunteers. Channel dropouts were simulated for an increasing number of channels: 5, 10, 15, 20, 25, 30, 40 and 50%. Both, randomly chosen channels and channel patches were considered.

We propose a novel Real-Time Clustered MUSIC algorithm (RTC-MUSIC) that makes use of the advantages of the well-established MUSIC algorithm but can be applied to real-time data streams during the measurement. For this purpose, regional cortical activity is represented by a small number of dipoles based on a cortical atlas and a k-means algorithm, thus considerably reducing the size of the gain matrix. The computation of the subspace correlations between dipole pairs is highly parallelized. Moreover, performance optimization is achieved by employing Powell’s Conjugate Gradient Method [26] as the search algorithm to find the best dipole source combination without performing a brute-force calculation of all dipole correlations.

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We conclude that our novel RTC-MUSIC algorithm with gain matrix clustering allows for real-time localization of correlated sources of neuronal activity. It copes with the low SNR of single trial data and considerably reduces the computational time compared to MUSIC.
reconstructed using a CS algorithm, with compression ratio (CR) of up to 75%, remains at par with that for the original uncompressed signals. Whereas, the classification performance offered by the CCA method is reduced after the application of CS. Therefore, the MSI method can be more suitable for designing CS-based low-power wireless sensors for the acquisition of EEG signals in the SSVEP-BCI systems.

Method:

Five male subjects (29.8 ± 2.17 years) participated in this study. Initially, signals from three occipital channels (O1, O2 and O2) were extracted. Signals were compressed using CS with CR of 75%. Compressed signals were reconstructed using the -RLS, -RLS, and BSBL-BO algorithms. In the pre-processing stage, the data were segmented and windowed with window lengths (WL) of 1 s and 4 s, each one with an overlap of 50%. Then, the Common Average Reference (CAR) and band-pass filter in the range 3-60 Hz were applied. The CCA and MSI methods were applied independently, and the classification performance was evaluated.

Results and Conclusion:

The comparison of performance (mean and standard deviation) was tested in 50 repetitions of reconstructed Electroencephalographic (EEG) signals averaged for 5 subjects and different windows length. Finally, these results were also compared with the original EEG signals. From the results, we can see that generally the higher the window length of the data, the higher is the precision. As it can be noticed for all cases tested, the MSI technique surpassed that of CCA. The results regarding the reconstructed signals were slightly closer to the original signal: ≈72% (WL = 1 s) and ≈85% (WL = 4s). The three reconstruction algorithms showed results very similar to each other. For the proposed system, the MSI method can offer acceptable performance for high CR. The proposed system offers faithful detection performance and is suitable for the design of low-power wearable wireless electrodes. By using the stimulus frequency based on the MSI method, it is demonstrated that the proposed system can offer acceptable performance for a high CR compared to CCA technique. Consequently, the power-consumption in wireless EEG can be significantly reduced.
EEG channel. Continues Wavelet Transform (CWT) is conventionally used in literature which suffers from the lack of ability to exactly localize a single oscillatory event in time and frequency contemporarily. Motivated by the high-resolution capability of Hilbert-Huang Transform (HHT) in both temporal and spectral domain and its data dependent and adaptive nature, here we use HHT for TF representation. HHT consists of a combination of Empirical Mode Decomposition (EMD) and Hilbert Transform (HT). EMD is a fully data-driven technique for decomposing a non-stationary time series into a set of oscillatory and spectrally localized components called Intrinsic Mode Functions (IMFs). HT of the extracted IMFs, that reveals the non-stationarity of a signal through the computation of the instantaneous frequency and the instantaneous amplitude, is the second step of HHT. Furthermore, EMD-based TF representation enables us to embed the detrending of EEG signals by simply removing the corresponding IMFs. Results and Conclusion: Events in EEG can be uniquely characterized by a set of temporal, spectral and spatial signatures which their outer product makes a rank-one tensor. In a PARAFAC model, the observed EEG tensor is decomposed as a linear combination of rank-one tensors, each of them corresponding to an EEG event. Simulation results show that multi-way analysis of EEG greatly improve separation and localization of overlapping events in EEG and furthermore, the extracted signatures using PARAFAC decomposition of HHT-based EEG tensor, exploiting the merits of HHT, are more localized compared to CWT-based tensor analysis by having a higher Gini Index, which is used for measuring the sparsity and the concentration of energy in a signal. Removal of low frequency trends in EEG signal is essential and failure to do so can result in masking of the event of interest. Detrending of EEG is effectively embedded in HHT-based multi-way analysis.

SP166 - NeuroProstheses

SP166.1 - Enhanced Transcutaneous Electrical Nerve Stimulation (eTENS): A Novel Method of Achieving Posterior Tibial Nerve Stimulation Therapy for Overactive Bladder

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Overactive bladder (OAB) is characterized by symptoms of urinary urgency, frequency, and incontinence that can significantly affect quality of life. Posterior tibial nerve stimulation (PTNS) is an emerging therapy for OAB, where clinical efficacy has been shown as comparable to drugs and sacral nerve stimulation. PTNS therapy is delivered as periodic (e.g., weekly) stimulation sessions that result in improved bladder symptoms over a period of 12 weeks. While early studies attempted to use conventional transcutaneous electrical nerve stimulation (TENS) for providing OAB therapy, percutaneous stimulation using needle electrodes was subsequently found to provide significantly greater therapeutic effects. Despite the improved therapeutic outcomes however, percutaneous stimulation requires a trained clinician to deliver therapy and also entails repeated visits to the clinic. Furthermore, recent PTNS trials identify long-term compliance to therapy as a significant limiting factor for patients (i.e., annual drop-out rate > 12 %).

As a potential solution, we present a novel method of electrically stimulating peripheral nerves. Called enhanced transcutaneous electrical nerve stimulation (eTENS), this method achieves neural activation by coupling a conventional TENS electrode with an electrically-passive implant placed in close proximity to the target nerve. Using computational software (Comsol Multiphysics + Matlab), we implemented the eTENS system in a model of the rat posterior tibial nerve (PTN). The electrically passive element was modeled as a nerve cuff placed around the PTN trunk; while the TENS electrode was depicted as a monopolar electrode located on the skin surface. The level of neural activation achieved by current passing through the TENS electrode was quantitatively approximated by the activating function, i.e., the second spatial difference of the extracellular potential along myelinated PTN fibers (diameter = 10 μm).

The results of our computational simulations showed that neural excitability by surface stimulation – as predicted by the activating function – increased significantly when the target nerve was instrumented with an electrically-passive implant (e.g., nerve cuff). When compared to the case with “no implant”, our model predicted that the eTENS system can achieve activating function values that were up to 6.4 times greater. These results, in turn, suggest that electrical activation of a target nerve can be achieved with stimulation amplitudes 0.15 times lower than that required by conventional TENS. Our computational model further shows that this enhancement in neural excitability depends on several key factors: physical dimensions and conductivity of the passive implant, depth of the target nerve from the skin surface, and relative alignment of the passive implant with the surface electrode.

The results of our computational study support the idea of enhancing the effectiveness of TENS by coupling the stimulus with an electrically-passive element. We have characterized the role of individual model parameters with respect to neural excitability, and have thereby identified key design parameters critical for testing the eTENS system in vivo. Further long-term implant studies are required for clinical translation in OAB patients.
SP166.2 - Decreasing Upper Extremity Demands During Sitting Pivot Transfers for Individuals with Spinal Cord Injury by Utilizing Functional Electrical Stimulation

Author(s): Stephanie N. Bailey1, Scott W. Slivka2, Lisa M. Lombardo1, Kevin M. Foglyano1, Ronald J. Triolo3
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INTRODUCTION

The sitting pivot transfer (SPT) is a functional task performed by individuals with spinal cord injuries (SCI) that requires quick, intense forces on the upper extremities (UEs). Performed an average of 15-20 times/day [1], this repetitive task could be a contributing factor to the prevalence of secondary shoulder pathologies that develop in this population. Implanted functional electrical stimulation (FES) systems have been utilized in individuals with SCI to improve mobility, however, have not been evaluated in the ability to improve SPTs by reducing the demand to the UEs.

METHODS

A single subject performed SPTs between a standard wheelchair (WC) and modified chair, placing one hand on the WC armrest and the other on the seat of the chair, similar to the work of Desroches et al [2]. Using a Vicon MX system (Oxford UK) at 100 Hz, kinetics were recorded using an in-chair force plate, one in the floor, and a load cell attached to the armrest of the WC (AMTI, Watertown MA). Trials were randomized between two conditions: volitional and with stimulation to both quadriceps. The quasi-static peak and average moments were calculated about both shoulder joints during the lift pivot phase of SPTs. Paired t-tests (p<0.05) were performed to determine if there was a difference between stimulation conditions.

RESULTS AND DISCUSSION

There were many significant (p<0.05) decreases in average and peak moment about both shoulders when using stimulation (Table 1), which shows that both the leading and trailing limb can benefit from this transfer technique.

<table>
<thead>
<tr>
<th></th>
<th>Average Moment (Nm)</th>
<th>Peak Moment (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>StDev</td>
</tr>
<tr>
<td>WC to Chair (n=6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leading UE (L)</td>
<td>17.77</td>
<td>5.00</td>
</tr>
<tr>
<td>Trailing UE (R)</td>
<td>18.70</td>
<td>4.86</td>
</tr>
<tr>
<td>Chair to WC (n=12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leading UE (R)</td>
<td>26.84</td>
<td>3.44</td>
</tr>
<tr>
<td>Trailing UE (L)</td>
<td>23.76</td>
<td>3.51</td>
</tr>
</tbody>
</table>

Future research should focus on an improved set up that is able to detect moment during each phase of the SPT as well as including additional participants with various levels of paralysis to validate findings.

CONCLUSIONS

Utilizing FES in the lower extremities during SPTs has potential to decrease the moment about the shoulder joint bilaterally by shifting a portion of the weight-bearing to the lower extremities.

REFERENCES


ACKNOWLEDGEMENTS

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SP166.3 - Design of Orthotic Mechanisms to Control Stand-to-Sit Maneuver for Individuals with Paraplegia

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Individuals with paraplegia can use functional neuromuscular stimulation (FNS) to accomplish sit-to-stand, standing, and stand-to-sit maneuvers. Stand-to-sit (STS) requires eccentric contractions or lengthening of the active quadriceps muscle. However, eccentric contractions are not well controlled with FNS due to a lack of feedback to the extensor muscles during the maneuver. STS using only FNS results in large impact forces at initial contact with the seating surface, high accelerations at the impact, high knee angular velocities, and a heavy reliance on the upper limbs [1]. In this study, we design and evaluate two different orthotic approaches for controlling the stand-to-sit transition.

A hydraulic hip-knee coupling mechanism was designed to lock, unlock, or couple the ipsilateral hip and knee motion of a hip-knee ankle orthosis. Fluid flow is directed between cylinders at the hip and knee joints, where hip flexion causes the hip cylinder rod to extend and move fluid into the rod side of the knee cylinder, forcing the knee cylinder to retract. The blind sides of the cylinders are connected to move fluid from the knee cylinder blind side into the hip cylinder blind side during movement. A mechanical transmission is used to convert the retraction of the knee cylinder rod to a knee flexion moment. Since the ipsilateral hip and knee will be coupled, individuals with paraplegia can control their hip angle via the upper limbs and thereby control their knee angle.

A hydraulic knee damping mechanism was designed to lock, unlock, or damp knee motion for a hip-knee ankle orthosis. Fluid flow is modulated between rod and blind sides of the knee cylinder through a proportional valve. When the proportional valve is fully closed, the knee cylinder is unable to move and locks the knee. When the proportional valve is partially open, the knee cylinder provides a damping force to help slow the knee angular velocity during knee flexion of STS.

Both mechanisms are undergoing bench testing to ensure safety of the device before clinical evaluation in able-bodied volunteers and
subjects with paraplegia. The hip-knee coupling mechanism provides a consistent 1:1 coupling ratio, where one degree of hip flexion results in one degree of knee flexion. The 1:1 ratio will achieve hip-knee angle relationships as seen in able-bodied STS maneuvers and provide a way to better control the STS for individuals with paraplegia. The damping created by the proportional valve mechanism is in the process of being characterized in bench testing. The mechanisms will be implemented in STS maneuvers for recipients of implanted neuroprostheses with spinal cord injury to quantify the extent to which the mechanisms assist in reducing the impact force on the seating surface and in controlling the STS maneuver.

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SP166.4 - Improved Peripheral Nerve Recording with a Small Form-Factor Nerve Cuff Electrode: A Computational Study

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Electrical nerve stimulation has been successfully used to treat a wide range of neurological disorders (e.g., epilepsy, obstructive sleep apnea) by surgical implantation of nerve cuff electrodes. However, very limited progress has been made in the using these electrodes as part of closed-loop controlled neuroprosthetic systems. The current literature indicates that poor signal-to-noise ratio (SNR) of the recorded neural signal as one of the primary limitations of using nerve electrodes to measure peripheral nerve activity. To this end, we investigated the feasibility of improving signal fidelity by optimizing the design of a small form-factor, bipolar nerve cuff electrode.

A computer model – which combined the use of finite element software (Comsol Multiphysics) and Matlab – was implemented to simulate single fiber action potentials (SFAP) recorded by either a pseudo-tripolar or bipolar nerve cuff electrode. Our simulations showed that the inter-electrode distance (hence, the total length of the nerve electrode) significantly affects the peak-to-peak value (Vpp) of the simulated SFAP. The pseudo-tripolar electrode showed a 17.5-fold increase in Vpp as the cuff length was increased from 7mm to 33mm; whereas the bipolar configuration resulted in a 2-fold increase as the cuff length increased from 7mm to 20mm. Interestingly, at nerve cuff lengths below 13 mm, the Vpp of the SFAP recorded by the bipolar electrode was larger than that of the pseudo-tripolar electrode. Our model also revealed that the edge length (distance between the outer electrode contact and the edge of the insulating nerve cuff) had a significantly greater effect on the Vpp of SFAPs recorded from bipolar electrodes than that with a pseudo-tripolar electrode: 80% vs. 1% increases, respectively. Furthermore, simulations involving external noise sources and electrically-shielded nerve cuff electrodes showed dramatic (up to 99%) increases in the SNR of the recorded neural activity.

Concomitant experiments in 12 anesthetized rats confirmed our computational study. By recording stimulation-evoked compound nerve action potentials (CNAPs) from the sciatic nerve, we compared the Vpp value of the CNAP obtained from 3 electrode configurations: pseudo-tripolar (cuff length = 11 mm), bipolar (type A, inter-electrode distance=7 mm), and bipolar (type B, inter-electrode distance=3 mm). The type A (bipolar) electrode yielded the largest Vpp signal, which was 18% and 29% greater than pseudo-tripolar and type B electrodes, respectively. In 5 experiments, we also showed that electrically shielding the nerve electrode with a highly conductive material significantly increased the SNR by up to 65%.

The preliminary results of this study suggest that modifications to conventional nerve cuff electrodes can have significant effects on the fidelity of recorded neural signals. Both computational and experimental data suggest that design variable such as the edge length, inter-electrode distance and the presence of external shielding markedly improve the SNR. Further work is needed to test these ideas under more realistic conditions, such as spontaneous neural activity in either acute or long-term implant studies.

SP166.5 - Effect of stimulation on non-erect postures with a standing neuroprosthesis

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Neuroprostheses can enable individuals with spinal cord injury to stand erect from otherwise seated positions in the wheelchair [1]. To prevent collapse, current systems stiffen the lower extremities through continuous supramaximal activation of the knee, hip and trunk extensors. This approach does not allow for modulation of stimulation to enable users assume other than erect postures except by pulling or pushing against the continuously activated muscles with the arms. We hypothesized that appropriate changes in stimulation to ankle and hip muscles would decrease upper extremity effort exerted on a support device with changing posture. Preliminary experiments were performed to determine effects of altering stimulation on standing postures for one recipient of an implanted neuroprosthesis with motor and sensory complete paraplegia.

The limits of the postures achievable with upper extremity effort on a walker were defined with constant stimulation as the subject leaned as far as possible from erect in five different directions: forward, left, right, and diagonal (forward-right and forward-left) while center of pressure (CoP) at the extreme leaning positions were recorded. A subject-specific musculoskeletal model was used to generate optimal muscle activations required to maintain postures at the five extreme positions using inverse dynamics. Muscle activations were scaled to the threshold and saturation level pulse-widths (PWs) for each of the stimulated muscles. With real-time visual feedback, subject later adjusted her standing posture to move her CoP from erect to each of the 5 locations from the first experiment. After stabilizing at the new posture, stimulus levels were adjusted to coincide with the optimal values for the new CoP location as computed from inverse dynamics while the UE forces exerted on the instrumented walker were measured.

UE effort reduced by about 30% between left and right in the fore-aft direction and between 5%-10% in the diagonal directions (Figure 1). A relative increase (mean 20% between left and right UEs) was noted for movements to extreme left/right directions. The preliminary results indicate the potential for reducing UE forces (especially toward the forward direction) when optimal stimulus levels are applied. Future experiments will involve repeated trials on additional subjects. The ability to vary stimulus levels would enable users of standing neuroprostheses to vary their postures in a task-dependent manner to undertake activities of daily living which would otherwise be impossible from an erect posture.

Funding: NINDS Grant: R01NS040547.

References:
The number of wheelchair users and thus wheelchair related accidents in the United States is growing. There are an estimated 100,000 wheelchair related accidents a year in the United States, primarily resulting from tips and falls. Constant stimulation of the otherwise paralyzed core hip and trunk muscles can stabilize seated posture and return users to and maintain erect sitting positions in response to applied disturbances. The goal of this study is to automatically predict and detect potentially destabilizing conditions encountered by wheelchair users to control the actions of a neuroprosthesis to prevent falls and improve manual propulsion efficiency by appropriately modulating stimulation. Wireless inertial measurement units consisting of tri-axial acceleration and gyroscopic sensors were applied above the right caster of the wheelchair frame and on the sternum of 4 individuals with low cervical to low thoracic spinal cord injuries. Subjects propelled over level ground, ascended and descended 5 and 10 degree ramps, negotiated sharp turns and simulated rough terrain consisting of closely spaced and loosely spaced rumble strips, and completed simulated collisions such as sudden stops and a curb drop.

Methods

Wireless EMG (Delsys, Natick MA) from eight bilateral UE muscles were obtained at self-selected, fast (+20%) and slow (-20%) speeds. Methods of Orthopaedics, Case Western Reserve University, Cleveland/UNITED STATES OF AMERICA, 2Department Of Orthopaedics, Case Western Reserve University, Cleveland/UNITED STATES OF AMERICA

REFERENCES


FUNDING SOURCES

Rehabilitation R&D Service of the US Department of Veterans Affairs Merit Review I01RX001204 and Spinal Cord Research Program of the US Dept of Defense Grant SC090230.
Results

Right pectoralis major and right posterior deltoid muscles exhibited the largest statistical ranges and were best correlated with contact and recovery phases, respectively, for all propulsion conditions. Performance of a classification algorithm using this combination of muscles to detect contact and recovery states of wheelchair propulsion is currently being quantified in preparation for clinical testing of an EMG-based neuroprosthesis control system to modulate stimulation appropriately with the propulsion cycle and determine its effect on MWCP efficiency during challenging real-world conditions.

References


SP167 - GI and GU

SP167.1 - Medical Devices
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The continuous advances in technology and software, as well as their widespread use in diagnosis and treatment has provided new and transformative capabilities to physicians. The past 3 decades have witnessed revolutionary advances with the development and optimization of PET, CT, MRI and ultrasound imaging for diagnosis of a wide range of diseases. The next few decades are likely to bring advanced technologies to surgical and minimally invasive interventional methods to treat diseases. Advanced robotic systems have already had an important impact on surgical procedures as demonstrated by the da Vinci robotic system. While advanced tools and visualization software are continuing to be developed for robotic aided open surgical systems, many innovations are still required for image-guided minimally-invasive (i.e., percutaneous) interventional systems.

Many researches and companies have been focusing on developing a variety of novel robotic, navigation, guidance and visualization systems to be used for specific surgical/interventional indications. For example, revolutionary systems have been developed to be MR compatible (i.e., operate within or near an MR scanner), allowing accurate, precise and reliable minimally invasive MR-guided interventions such as prostate biopsy and therapy. Other systems have been developed that use 3D ultrasound fused with MR or CT images to guide biopsy and interventional tools. This approach makes use of the high quality images provided by MR and CT for identification of the targets together with the real-time ultrasound guidance of the interventional tools into the body. Examples of this type of systems include 3D ultrasound with MR fusion to guide prostate biopsy, as well as 3D ultrasound fused with CT images to guided focal ablation of liver tumors using radio-frequency or microwave energy delivery systems.

Innovations in robotics/mechatronics coupled to advanced software tools have resulted in complex and crowded surgical and therapy rooms. Thus, innovators have been developing a variety of virtual-reality guidance and navigation technologies making use of optical and electro-magnetics navigation systems. These systems are being developed and used in neuro-surgery as well as for focal liver tumor ablation. In addition, manipulation of tools and the complex set of images has required innovation in non-touch control as viewing and manipulating of tools and image display through use of a mechanical device such as a mouse, keyboard or touchscreen are problematic, requiring the physician to break the sterile field during surgery. Additionally, the surgeon’s hands are likely covered in bodily fluids, which could interfere with use of these devices. Thus, gesture-based systems allowing 3D control through real-time high-content virtual reality navigation would permit complex functions to be controlled without touching mechanical devices.

Clearly, we are in the middle of possibly the next revolution for medical imaging devices, which promise to integrate robotics, advanced software, virtual reality navigation with a variety of therapy/surgical tools. In this paper, we will focus on a survey of image-guided surgical/interventional medical devices and the potential direction this field will take over the next decade.
Learning Objectives:

1) Challenges facing developers of image-guided intervention devices
2) Current state of medical devices used in image-guided intervention.
3) Opportunities for development of new and transformative medical devices used in image-guided intervention.

SP167.2 - Dielectric Properties of Urine for Diabetes Mellitus and Chronic Kidney Disease between 0.2 GHz and 50 GHz
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1Department Of Biomedical Engineering, University of Malaya, Kuala Lumpur/MALAYSIA, 2Department Of Surgery, University of Malaya, Kuala Lumpur/MALAYSIA, 3Damansara Specialist Hospital, Petaling Jaya/MALAYSIA

This paper investigates the dielectric properties of urine among normal subjects, subjects with diabetes mellitus (DM) and subjects with chronic kidney disease (CKD) at microwave frequency between 0.2 GHz and 50 GHz. The measurements were conducted using open-ended coaxial probe at room temperature (25°C), 30°C and human body temperature (37°C). Statistical significant differences in dielectric properties were observed across temperatures among normal, DM and CKD subjects. Significant differences were reported across subject groups at 25°C, 30°C and 37°C respectively.

SP167.3 - Intraoperative Bioelectrical Impedance Measurement for Assisting Segmental Renal Artery Clamping Partial Nephrectomy
Author(s): Jun Du1, Yu Dai2, Qing Yang3, Jianxun Zhang4
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Critical procedures of segmental renal artery clamping partial nephrectomy (SACPN) includes segmental renal artery (SA) discrimination and ischemic area identification. Due to limitations of intraoperative ultrasonography, novel technique to facilitate SACPN is being needed. The aim of this paper is to explore whether intraoperative bioelectrical impedance spectroscopy (EIS) assessment could facilitate SACPN. Five domestic pigs were included in present study. The noninvasive electrical impedance sensor we developed consists of two stainless steel spherical electrodes, which are used to measure impedance spectra over the frequency range of 200 kHz to 5 MHz. EIS of renal artery and renal vein were assessed. After SA clamping, EIS of ischemic area, nonischemic area and ischemic-nonischemic boundary of kidney were examined. In porcine model, EIS of renal artery is significantly higher than renal vein (p<0.05). After SA clamping, EIS of ischemic area was significantly higher than nonischemic area (p<0.05). In addition, EIS of ischemic-nonischemic boundary was between that of ischemic and nonischemic area. The experimental results proved that the intraoperative EIS assessment could possibly facilitate SACPN through SA discrimination and renal ischemic area identification.

SP167.4 - Renal Volume Estimation by Ultrasound Parallel Scanning for Polycystic Kidney Disease Follow-up
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Renal size provides information for the diagnosis and prognosis of kidney diseases. Volume measurement is usually based on ellipsoid calculations derived from Ultrasound (US) imaging. Complex pathologies such as Polycystic Kidney Disease (PKD) require images obtained with contrast media or ionising radiations (X Rays), not suitable due to toxicity and radiation effects. We have developed NEFROVOL, a low cost, noninvasive solution to reconstruct renal structure and to estimate its volume, using parallel US scans (Figure 1).

Table 1 Test of NEFROVOL measuring KIDNEYS of volunteers

<table>
<thead>
<tr>
<th>Patient</th>
<th>Cuts</th>
<th>Dimensions</th>
<th>Real</th>
<th>NEFROVOL</th>
<th>Difference %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>10.74x4.99x6.56</td>
<td>184.08</td>
<td>138.05</td>
<td>-25</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>9.30x4.56x6.41</td>
<td>129.85</td>
<td>164.01</td>
<td>21</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>11.84x5.04x5.49</td>
<td>171.39</td>
<td>172.76</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>10.35x3.73x5.50</td>
<td>111.18</td>
<td>109.0</td>
<td>-2</td>
</tr>
</tbody>
</table>

Tests on geometric solids, fruit and patients yield estimates within 13%, 17% and 25% of the real volume, respectively. The volume of normal kidneys can be measured by conventional ellipsoidal formula and agrees with NEFROVOL calculation in patients 3 and 4. Transplanted patient 1 and volunteer patient 2 show larger differences: up to 25% of the volume.

NEFROVOL generates standard electronic medical record documents (single measurement or trend), and is compatible with 3D printing by generating STL files.

NEFROVOL addresses the problem of 3D reconstruction of organs from US scanner images, adding the estimation of volume for follow up purposes. Despite the low precision, NEFROVOL can be of used to monitor kidney volume increase, which is the goal of the research. Better precision will be addressed by including intermediate parallel scans.
SP167.5 - Can Removal of Middle Molecular Uremic Retention Solutes be Estimated by UV-absorbance Measurements in Spent Dialysate?

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The objectives of this study were: (1) to compare removal of the middle molecular (MM) and small uremic retention solutes; (2) to investigate if MM removal can be assessed by UV-absorbance at the wavelength of 297 nm during various dialysis treatment modalities. Seven uremic patients, four females and three males, mean age 58.1±8.7 years, were included into the study during 28 chronic hemodialysis sessions. A parameter, reduction ratio (RR) in percentage, was calculated for a small uremic retention solute urea, for a MM retention solute beta2-microglobulin (B2M), and for UV-absorbance at the wavelength of 297 nm during different dialysis modalities: conventional hemodialysis (HD), high flux hemodialysis (HF-HD), and postdilutional online hemodiafiltration (HDF) with different parameter settings. Achieved results were compared regarding mean values and SD, and by systematic and standard errors (BIAS±SE). It was found that RR is similar for small and MM uremic retention solutes in case of dialysis modality with the highest convective transport, HDF (78.9±8.1% for urea and 78.1±6.8% for B2M, N=7). Moreover, RR of small uremic retention solutes can be estimated with sufficient accuracy by UV-absorbance at 297 nm in the spent dialysate for all modalities (BIAS±SE: 1.7±4.0%, N=28), and for MM uremic retention solutes only for HDF (BIAS±SE: 1.1±7.1%, N=7). The results should be confirmed by appropriate kinetic modeling in the next studies.

Keywords— Middle molecules, uremic toxins, beta2-microglobulin, uremic retention solutes, urea, dialysis, UV-absorbance.

SP167.6 - Discrimination of prostate tissue with a combination of Raman spectroscopy and tactile resonance technology

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Prostate cancer (PCa) is the most common cancer in men in Europe with 416 700 new cases reported in 2012 and in the USA with an estimate of 233 000 new cases for 2014. The most prevalent curative treatment for PCa is radical prostatectomy (RP). In Europe, RP made up 59% of the curative treatments in 2000 and in the USA about 70 000 men were offered RP in 2003. The standard procedure after RP is to examine the resected prostate histologically. One important examination is the evaluation of tumour cells in the surgical and the anatomical margins (PSM) since there is an increased risk of PCa recurrence if tumour cells are found at the surgical margin. A new dual-modality probe has been developed for prostate cancer detection by us. The probe combines two methods, a tactile resonance sensor that measures the tissue stiffness modality, and Raman spectroscopy, that measures the molecular content. Together the two methods are the basis for the dual-modality probe and a hypothesized method intended for detecting PSM during radical prostatectomy. The idea is that the surgical margin, i.e. the surface, of the prostate is to be scanned to locate stiffer areas using the stiffness modality of the combined instrument. Harder nodules are an indication of tumour presence but also of stiff benign structures, such as prostate stones. The Raman spectroscopy modality would then be applied at these locations to discern the boundaries between cancerous and non-cancerous stiff tissue. The aim of this study was to evaluate the ability of the combined probe to discriminate different tissue types in fresh human prostate slices ex vivo.

The results from four human prostates show that the tactile resonance modality was able to discriminate significantly between two different tissue types: soft epithelial tissue and stiff stroma (p < 0.05). The Raman spectra exhibited a strong fluorescent background at the current experimental settings. However, stroma could be discriminated from epithelia by integrating the value of the spectral background. Combining both parameters resulted in 100% sensitivity and 91% specificity.

We conclude that the results indicates that the two modalities together increase the sensitivity and specificity and are promising for further development of an instrument and method for discriminating prostate tissues and thus also cancer that is the final goal.

SP167.7 - Appropriate Medical Devices for Low Resource Settings: Electronically Controlled Gravity-Feed Intravenous Infusion Set

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ABSTRACT

Background

Despite an improvement in the reduction of the Infant Mortality Rate (IMR), 45/1000 as of 2012 down from 54/1000 in 2009, Uganda continues to lag far behind target for achieving the Millennium Development Goals. Children continue to die from preventable diseases such as pneumonia and diarrhoea which contribute to nearly 40% of the IMR. The majority of neonates and infants with pneumonia, diarrhoea and malaria often present in advanced disease stages; hence requiring intravenous fluid and/or drug delivery. Unfortunately, existing infusion sets are not tailored to the needs and resources of Uganda. Medical equipment surveys in Low and Middle Income Countries (LMICs) show that equipment needed for neonatal and infant care is imported and in short supply largely due to high cost. It is also invariably poorly maintained, and is often rendered non-functional or potentially hazardous by users. Furthermore, electrically operated devices are usually unable to withstand prevailing intermittent power supply.

Method

The Electronically Controlled Gravity-Feed Intravenous (ECGI) Infusion Set has been designed to overcome the deficiencies of existing intravenous therapy systems by providing an easy to use, cost effective plug-on intravenous administration monitoring and control system. Additional features will include occlusion detection, high and low drip rate alarm settings and visual readout of the drip rate all provided for on a microcontroller platform. The power supply will be characterized by a hybrid battery charging bed (solar and electrical mains). Implementation will be executed using Proteus software, preliminary prototyping with bread boards and finally Printed Circuit Board (PCB) development.

Results

Design and simulation of the sensing/monitoring hardware circuit has been completed in Proteus simulation software with desirable waveforms displayed on the oscilloscope in the illustration below.
This circuit has been implemented on a bread board and output results are within 5% error when compared with the simulation results. Interference due to noise and ambient light are apparent in the breadboard circuit. We anticipate a smaller error margin once implemented on a PCB. The control module has also been simulated in Proteus and is yet to be implemented on a bread board and subsequently PCB.

Conclusions

Pending designs include simulation of the user interface display hardware circuit in Proteus and incorporation of LCD function coding and testing. We will also identify a charge management Integrated Circuit (IC) for the rechargeable batteries to build the power supply system.
Encourage research on simple, essential lifesaving health technologies.

Technical specifications were identified and submitted for further global expert review. In the future, in order to increase access to lifesaving health technologies for the world’s most vulnerable people, WHO, regulatory bodies and NGOs should encourage greater attention on essential health technologies needed in low resource settings.

References


SP168.3 - Portable microwave based stroke and trauma diagnostics
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Worldwide, about 17 million people suffer a stroke each year. The human cost is horrific. Out of the sufferers 5 million die and another 5 million are permanently disabled. Among stroke survivors, 20% have serious remaining dysfunctions. A much larger proportion has less conspicuous, dysfunctions, which still seriously affect quality of life for the patient and relatives. The European yearly cost (2010) has been estimated to 64.1 billion € for the around 800 000 stroke patients.

Here we present different brain diagnostic devices based on microwave technology and the associated proof of principle measurements that show that the systems can differentiate hemorrhagic from ischemic stroke in acute stroke patients, as well differentiate hemorrhagic patients from healthy volunteers. The system was based on microwave scattering measurements with an antenna system worn on the head. Measurement data were analyzed with a machine-learning algorithm that is based on training using data from patients with a known condition. CT images were used as reference. The detection methodology was evaluated with the leave-one-out validation method combined with a Monte Carlo based bootstrap step.

The clinical motivation for this project is that ischemic stroke patients may receive acute thrombolytic treatment at hospitals, dramatically reducing or abolishing symptoms. A microwave system is suitable for pre-hospital use, and therefore has the potential to allow significantly earlier diagnosis andtreatment than today.

The relative simplicity and potentially small size of a microwave-based diagnostic system underlines a specific aim of the project which to start the path towards implementation, in the sub-Saharan Africa, where there are very limited resources in terms of medical personnel, hospitals and medical devices, that can be used by ambulance personnel, at the scene of incident, for instance at the patients home, or at the local hospital.

Our microwave-based systems have the advantage of being completely safe and without side effects since the power levels used are only a fraction of what is transmitted by a mobile phone. This also allow the systems to operate in continues mode as a monitoring device. The systems also have the potential of becoming quite cost effective as the component costs are driven down by the considerably larger telecom industry.

SP168.4 - Bending the cost curve: Towards a $1000 diagnostic X-ray imager for scalable and sustainable healthcare
Author(s): Karim S Karim, Sina Ghanbarzadeh
Electrical And Computer Engineering, University of Waterloo, Waterloo/CANADA

Cost, quality and accessibility are major barriers to disease detection globally. For an easily communicable disease like tuberculosis, diagnostic or screening tests based on sputum, blood and urine analysis have slow response, are difficult to administer in remote locations, and have relatively high transportation and storage costs. Medical-grade state-of-the-art digital x-ray imaging systems are versatile in disease detection, faster, incorporate teleradology for remote diagnosis, but are prohibitively expensive making them affordable only by major hospitals or labs that are located mostly in urban centers with high patient volumes. Here, a value priced, high quality, digital x-ray imaging system could address many global health issues by enabling fast, accessible and inexpensive early detection of curable diseases including tuberculosis especially in rural, remote or under-populated areas.

In this research, we propose a path to achieving an inexpensive, high quality, digital X-ray system by focusing on the X-ray imager, a component that can reach 50% of the manufacturing cost of an imaging system. High manufacturing costs today are largely a function of small production volumes and various specialized fabrication processes. Our approach leverages two technologies developed in-house that leverage existing manufacturing infrastructure because they are fully compatible with older generation amorphous and poly-silicon TFT display manufacturing lines: the first is a low dark current, high quantum efficiency optical radiation sensor that rivals state-of-the-art amorphous silicon pin photodiodes and the other an amplified pixel circuit having a straightforward offset and gain correction scheme that yields higher signal-to-noise ratio than state-of-the-art passive pixels. When our sensor and pixel circuit technologies are integrated, the result is a high performance, low manufacturing cost diagnostic X-ray imager that can help achieve sustainable healthcare globally.

SP168.5 - Creating a Continental Network of Healthcare Innovation Centers: Collaborating across National Boundaries to design Devices and Best Practices
Author(s): Fred W. Hosea
Clinical Technology, Kaiser Permanente, Oakland/UNITED STATES OF AMERICA

Managing the lifecycle challenges of healthcare systems exceeds the current capacities of any country in the world, and the difficulties are only growing. Central problems are: -Unprecedented technical complexity -Demand for universal services and new service lines -Interdependence of systems -Global economic slowdown, without likelihood of recovering previous growth rates -Velocity of change -Obsolete, inadequate infrastructures -Fragmentary market mechanisms and perverse incentives -Political and economic interests that preserve a dysfunctional status quo -Obsolete professional and organizational structures -Disjointed incrementalism -Demographic pressures that exceed current and future capacity -Predicted impacts of climate change: migration of populations, infectious diseases; and economic refugees to unprepared locations A new age of integrated innovation is essential to achieve the possibilities of Health for All.
-New forms of collaboration and interdisciplinary knowledge are necessary. Innovation must be re-defined to include innovations that effectively integrate established technologies, instead of creating a relentless treadmill of expensive high-tech point solutions that often promise more than they deliver. National innovation centers will serve as hemispheric resources in their areas of investigation and best practices (e.g., telemedicine, tropical diseases, disaster management), and will serve as consultation centers to all other countries in the network, providing expertise oriented along the entire lifecycle of successful innovation.

We envision innovation that leverages collective resources more effectively to achieve a higher adoption rate of appropriate and interoperable technologies with less wastage of resources, less planned obsolescence, more universal coverage, lower cost, and a more rational staging of medical infrastructures as economies and service models mature.

COLLABORATIVE DESIGN FORUMS to engage key stakeholders at the trans-national level of strategy and planning

NON-PROFIT INTER-SECTORAL ALLIANCES to solve core technology challenges (e.g., The Continua Alliance)

STRATIFIED INNOVATION GOALS to re-target manufacturing, facilities and workforces more equitably to low and medium resource markets, with more local production.

STRATEGIC CONSULTATIONS with regional alliances across Ministries of Health to develop and align mid- to long-term infrastructure plans and capital budgets, within regional and multi-national planning and purchasing frameworks

COORDINATED ACADEMIC PARTNERSHIPS COORDINATED to cultivate sustained, multi-disciplinary research and professional development programs aimed at integrated healthcare planning

REGIONAL/CONTINENTAL NETWORKS OF INNOVATION CENTERS to distribute the enormous workload of innovation design, assessment, testing and planning

“DESIGN FOR CASCADE” – design of higher-cost systems for staged re-use in low-resource locations

Adoption of a COMMON INTEROPERABILITY MATURITY roadmap that enables co-evolution of medical devices with IT systems and clinical treatment practices.

SP168.6 - Towards a WHO List of Priority Medical Devices for Cancer Care, targeting low and middle income countries

Author(s): M. Mikhail Lette, A. Velazquez Berumen, G. Jimenez Moyao, A. Migliore, D. Rodriguez Rodriguez; HIS/EMP/PAU/Medical Devices, World Health Organization Headquarters, Geneva/SWITZERLAND

Cancer mortality disproportionately affects low and middle income countries’ populations; 70% of global deaths attributable to cancer occur in low and middle income countries. In view of an alarming trend of increased incidence and prevalence of NCDs (non-communicable diseases) and their disproportionate adverse effects upon low and middle income populations, the WHO Medical Devices team has embarked upon a promising new project to develop a Priority Medical Devices List for Cancer Care, to target low and middle income countries, in the goal of better empowering countries to develop or improve cancer healthcare capacities. During this incipient few-year endeavor, the entire spectrum of devices needed for the continuum of cancer care - screening, diagnostics, and treatment (both curative and palliative) - will be analyzed and compiled for six types of cancer: cervical, breast, prostate, lung, colorectal, and leukemia. Collaboration is being invited. Project progress is presented.

First, an extensive review of evidence-based clinical guidelines was performed to select ones which comprise the continuum of diagnostics and care and are aligned with current clinical knowledge benchmarks (with guideline database updated at regular intervals). Guidelines were chosen from several world regions and current implementation and relevance of them in low and middle income settings will continue to be assessed. Based upon guidelines, matrices of clinical interventions were developed and stratified for each type of cancer. This provided a basis to generate an extensive database of medical devices per intervention via the following algorithm: Condition\Stage of Care\Intervention\Steps of the Procedure\Device Category\Device Code\Name(s) of the Medical Device\Description\Level of Care.

Nomenclature of interventions was compared against and harmonized with the ICHI (International Classification of Health Interventions). Likewise interventions were segregated by level of care and the associated health care facility:

- Community level health post
- Health center (outpatient care)
- District or general hospital
- National or specialized referral hospital

This project also seeks to provide a concise clinical background and staging overview for each disease in question, to research epidemiologic data on global burden of disease, to define countries to involve in this project, and eventually to conduct in-country workshops and case studies.

Further work will include inter-agency cooperation (with other UN organizations) and with professional organizations (e.g. NGOs, collaborating centres, professional societies, academic institutions). Experts and expert groups will be sought to form relevant committees willing to contribute to this project in their respective areas of expertise, to verify the interventions and priority medical devices, and eventually to validate and support implementation of the lists.

This project has been undertaken courtesy of a grant from OFID (the OPEC Fund for International Development, Uniting against Poverty).

The ultimate goal is to have available information on technologies that are required to diagnose and treat cancer patients in low and middle income countries.
Empowering patients through information technologies

**SP169.1 - Empowering patients through information technologies**

**Author(s): Eleni Kaldoudi**
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Patient empowerment is about enabling the patients to be involved in managing disease and adopting and sustaining health promoting behaviors. Patient empowerment, although a popular concept, is rather ill defined. This lecture aims to elucidate the different meanings and perceptions, together with misconceptions, that surround this construct, and to discuss how patient empowerment relates to current medical methodologies, such as evidence based medicine, and other societal and organizational factors. Furthermore, the lecture will provide an overview of how information and communication technologies are employed to empower patients, with emphasis in chronic patients with comorbidities.

The discussion will first address the “who”. This includes an overview of common health problems that call for empowered patients, the types of patients that normally engage in empowering interventions and the specifics of the stakeholders who design and support such interventions.

Then we will look at the “how”. The discussion here will focus on an overview of the diverse approaches and services that have been deployed to empower patients. This will also include the span of various technologies used and, where applicable, their measured induced outcome for the patient and the health care process.

Although the “who” and “how” of patient empowerment can rather easily be discerned from a literature research, the “what” is rather more elusive. The concept of patient empowerment has emerged as a new paradigm that can help improve medical outcomes while lowering costs of treatment by facilitating self-directed behavior change. Patient empowerment has gained even more popularity since the 1990’s, due to the emergent of eHealth and its focus on putting the patient in the centre of the interest. Current literature provides systematic reviews of the area, and shows that well defined areas (or dimensions) have eventually emerged in the field: education, engagement, control. Despite such findings, current research lacks of a structured approach towards patient empowerment. In an attempt to shed more light onto the process of empowering patients, this lecture will discuss a newly proposed holistic model of patient empowerment as a cognitive process, where we acknowledge three levels of increasing complexity and importance: awareness, participation, control.

The lecture will conclude with a proof of concept example of using this approach to develop and evaluate empowerment services for the comorbid cardiorenal patient or the patient at risk of this condition. Open issues and challenges will be presented for discussion with the audience.

**SP169.2 - Distributed learning: developing a predictive model for dyspnea in lung cancer patients based on data from multiple hospitals**

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**Purpose/Objective**

Predictive models play a major role in enabling personalized medicine. Predictive models require patient data to be trained successfully. One of the major hurdles in enabling personalized medicine is obtaining sufficient patient data to feed into predictive models. Combining data originating from multiple hospitals is difficult because of ethical, legal and administrative issues. In order to avoid these issues a distributed learning approach can be used. In this approach, the model training application is sent to the hospitals. The model learns from the data in each individual hospital without the data leaving the hospital. After training, the models are sent back to a central location where they are combined into one fully trained model.

In this work, we show that it is possible to use the distributed learning approach to train a Bayesian network model on patient data originating from multiple hospitals. The model predicts dyspnea, which is a common side effect after radiotherapy treatment of lung cancer.

**Material/methods**

Clinical data from 170 lung cancer patients, treated with curative intent with chemoradiation (CRT) or radiotherapy (RT) alone were collected and stored in 3 different medical institutes (123 patients at Maastro, 14 at Jessa and 33 at Liege). A Bayesian network model was developed to predict dyspnea (≥ Grade 2 according to the CTCv3.0). The model used gender, WHO performance status, age and overall treatment time to make predictions. Training of the model was based on data originating from two out of the three centers. The data of the remaining center was used for validation. The model was trained and validated 3 times each time using data from two different centers as the training set. The three trained models were combined by taking the average of the learned conditional probability tables. The model’s performance was expressed as the Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC). The maximum value of the AUC is 1; indicating a perfect prediction model. A value of 0.5 indicates that patients are correctly classified in 50% of the cases, e.g., as good as chance.

**Results**

Thirty-four patients (27%), 6 patients (42%) and 13 patients (39%) developed dyspnea in the Maastro, Jessa and Liege datasets respectively. The AUC of the model that was trained on data from Maastro and Jessa and validated on data from Liege was 0.66 (95%CI, 0.63–0.78). The AUC of the model that was trained on data from Maastro and Liege and validated on data from Jessa was 0.63 (95%CI, 0.49–0.72) The AUC of the model that was trained on data from Jessa and Liege and validated on data from Maastro was 0.56 (95%CI, 0.48–0.59).

**Conclusion**

Using a distributed learning approach, we have successfully trained and validated a Bayesian network model for dyspnea prediction in lung cancer patients on data from multiple hospitals. Future work will involve using a larger number of hospitals and higher numbers of patient data to train better predictive models using the distributed learning approach.
SP169.3 - User Centered Design to incorporate predictive models for Type 2 Diabetes screening and management into professional decision support tools: preliminary results. 
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Life Supporting Technologies, Universidad Politécnica de Madrid, Madrid/SPAIN

Type 2 Diabetes screening and risk stratification tools could benefit from the incorporation of predictive systems based on computer modelling. The adoption of User Centered Design techniques is fundamental in order to integrate these systems in an effective and successful way. The work presented in this paper describe the methodologies used in the context of a multidisciplinary research project and provides an overview of the preliminary results.

SP169.4 - Quantifying Bipolar Disorder for Technology-Assisted Self-Management
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Bipolar Disorder (BD) is a serious mental health condition that is characterized by recurring affective episodes, interspersed with periods of remission. Current treatment for BD focuses on pharmacological and therapeutic techniques to control the condition. In addition to this, a significant number of people with BD adopt self-management techniques in order to help maintain a stable life pattern and control their condition. There are two significant drawbacks to current self-management in that current systems tend to be paper based and reliant on user self-insight, which is frequently lost in the run up to an affective episode. These two shortcomings can be addressed with a technology-enabled solution. Through the use of specific sensors and an electronic mood diary, the important indicators of relapse in BD can be monitored and users alerted to potential indicators of relapse in a timely manner so that they can take appropriate action.

This paper presents work that has been carried out in the development of the Auto-Motive system on the quantification of indicator metrics in BD for use in a technology-enabled self-management system. We present the methodology and results from a series of focus groups that have been carried out with users and professionals to identify the important indicators in BD and the way in which the can be quantified for use in a decision support system.

Results from the focus groups are in line with the literature and professional insight and point to sleep (hours of sleep and sleep quality), physical activity, time at home and at work and medication compliance as being particularly important indicators to quantify and use in the Auto-Motive system.

SP169.5 - Hippocratic Protocol Design to Improve Security and Privacy in Healthcare Applications for NFC Smartphone
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Today the evolution of electronics technologies had created a lot of intelligent personnel devices, like calculators, GPS, and Smartphone for example. These terminal have lowers prices than terminals used before and are fully programmable that’s why are beginning to use in all sectors for implement mobile services.

Healthcare sector is not outside of this development and some experiences have been done, using not only its connectivity but also an identification technology named NFC. This result in a series of new problems, which are being studied. One of the main problems for the use of these technologies is the maintenance of privacy and security in management of patient information when using Smartphone as a mobile terminal to read data. In previous years, there have been lot of work in these areas for the health sector, for privacy and authentication..

NFC is an evolution of Radio Frequency Identification technology (RFID), specifically contactless smart cards, and interconnection technologies. Operates in the frequency band of 13.56 MHz, with very low power levels, which means that devices must be close (less than 10 cms.) to exchange data.

Hippocratic Databases fit the Hippocratic Oath, which makes doctors upon graduation. Its use has been gaining popularity due to privacy requirements appeared in new legislation on health of some countries, e.g. United States and arises as a need for implementing privacy in today’s social networks.

Transferring the Hippocratic Database concept to design a specialized protocol for the health sector, would result requirements like Verification of the purposes of data Exchange, Authentication, Data Integrity, Encryption and modes of operation for transmitting, receiving and control, which allow the user to implement accessibility and verify the above.

A family of standards ISO 11073 Personnel Health Device Communication, define a communication scheme between personal health devices and an external computer. ISO standard 11073_20601 describes a common communications infrastructure, independent of the underlying transport infrastructure data due to logical connection procedure based on Agent Manager relation, and can be used to implement this protocol.

A scheme of the proposed Health Hippocratic Protocol (HHP) is shown. It is composed for two states and five procedures. The use of this protocol improves the design of health applications that use Smartphone and the use of Hippocratic Databases in healthcare sector. Given its structure, the protocol can withstand attacks of man in the middle, impersonation and unauthorized data seamlessly, as the authentication process with the Checking permissions task guarantee security. The objective is to present a protocol that includes Hippocratic principles in its structure to improve security and privacy on personnel devices that use these technologies in the healthcare sector.

The design of a Hippocratic Health Protocol, based on a standard, for use in Smartphone with NFC will improve security and privacy in personnel healthcare applications, but more work is necessary because the design of the database that permits the implementation of Hippocratic considerations is not a simple work.

SP169.6 - Extracting Intention from Web Queries– Application in eHealth Personalization
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Personalizing healthcare applications requires capturing patient specific information, including medical history, health status, and mental aspects such as behaviors, intentions, and attitudes. This paper presents a privacy-friendly system to deduce patient intentions that can be used to personalized eHealth applications. In the proposed approach patient intention is deduced from web query logs via query categorization techniques. The architecture assumes
SP170.1 - Wireless equipment localization for medical environments  

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Searching for medical equipment in hospitals produces high costs. However, it is necessary to check each medical device periodically. Wireless systems in a medical environment must comply with the legal limits for electromagnetic interference (EMI). This work presents a tagging system for real-time localization of tagged equipment respecting that some medical devices are very sensitive for EMI. Therefore, every room is equipped with a base station and a star-shaped 2.4 GHz wireless network topology, which conforms with the latest legislative requirements for the EC and US market. Considering that, the device tags consist of a compact IEEE 802.15.4 ZigBit transceiver module with an adapted and extended stack. Furthermore, the device tags are equipped with sensors for detecting manipulation and motion. The base stations are connected to the server via wired TCP/IP network with Power over Ethernet (PoE), which reduces the radio traffic and considerably simplifies communication. Virtual floor plans in the dashboard software visualize the actual positions of the medical devices. The user is able to locate either a single device by its name or a list of all devices in a ward. Using two AAA batteries the device tags have an operation time of 24 months, wherein they can be in motion for 7.75 percent. The web-based dashboard software grants the medical staff an easy access via computer or mobile device. In addition, the dashboard is able to access the SAP database of the hospital for detailed information about the medical device.

SP170.2 - Exploring Approaches to Optimise the Estimation of Preterm Birth Using Machine Learning Techniques  

**Author(s):** Monique Frize¹, Daphne Ong¹, Jeff Gilchrist¹, Hasmik Martirosyan¹, Erika Bariciak²  

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In past work, our research group obtained a number of high quality databases of newborns and mothers in order to develop models to predict premature birth before 23 weeks gestation, using only data collected from pregnant mothers. Unfortunately, the most accurate test currently used is the fetal fibronectin, which is invasive, expensive, and is done some weeks later in the pregnancy. Our initial development succeeded in matching the accuracy of the fetal fibronectin test using data from the PRAMS (Pregnancy Risk Assessment Monitoring System) database with an accuracy of 66% sensitivity (true positive cases) and 85% specificity (true negative cases). [Catley et al, 2006]

Recent work has concentrated on exploring a number of machine learning techniques such as decision trees (DTs) and artificial neural...
networks (ANNs) and the addition of new databases to optimise the performance of the models we develop to predict preterm birth (PTB). One approach is to use decision trees with the 5-by-2 cross validation method to help select the most important features to use with our ANN tool. The methodology consists of separating cases involving preterm versus full term babies, and then randomly creating ten different train and test sets to perform the prediction with decision trees. Our previous work focused on selecting the variables that had the best compromise between sensitivity and specificity when used to generate the single DT model and incorporating them as features to build an ANN model for PTB. [Frize and Yu, 2010] We are now assessing the average variable usage across all ten DT models and by eliminating the variables that have limited usage, we hope to improve the classification of preterm cases when using these variables to build the final ANN model. This new ANN was developed using the FANN (Fast Artificial Neural Network) Library as a base, on which we built many enhancements that we were using in previous work. [Frize et al. 2013] Moreover, the use of a new database collected on all newborns in Ontario (BORN= Better Outcome Registry and Network) will enable our team to determine which variables in both the PRAMS and BORN databases can optimise the classification of PTB. Preliminary results are encouraging.


SP170.3 - Smartwatch App as the Chest Compression Depth Feedback Device
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For the high quality CPR (Cardio-Pulmonary Resuscitation), the feedback devices to show chest compression depth are used to ensure the compression depth to be over 51 mm, which is one of key factors of the 2010 American Heart Association (AHA) guidelines for adults. We propose the smartwatch based app as the chest compression depth feedback device and evaluated its accuracy. The accelerometer which is inside the smartwatch makes the signal during chest compression and the real time signal processing techniques are used to estimate the compression depth. Through the manikin study, the estimation error was 3.2 mm in average which can be acceptable for its usage. With the smartwatch app as the feedback device, the rescuer can perform the chest compression without the inconvenience of gripping the device and the visual interference with hands.

This paper presents an approach to capture of the human movement and posture with a Kinect Sensor, in order to assist physicians in the Parkinson’s Diagnosis. The Kinect Sensor allow to measure displacements in the motionless posture that can be interpreted as increments of tremors intensity. This paper presents an approach to capture of the human movement and posture with a Kinect Sensor, in order to assist physicians in the Parkinson’s Diagnosis. The Kinect Sensor allow to measure displacements in the motionless posture that can be interpreted as increments of tremors intensity.

SP170.5 - A System to Support Regional Screening Programs to Identify School-age Children at Risk of Neurodevelopmental Disorders.
Author(s): Elisa Santos Febles1, Vivian Reigosa-Crespo2, Klaudia Garcia-Liashenko1, Adan Echemendia-Montero3, Gabriel Pujols-Farinas3, Enrique Plasencia-Montero3, Aymée Alvarez-Rivero2, Eduardo Eimil-Suarez3
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This paper describes a system to support regional screening programs to identify school-age children (6 to 12 years old) that are at risk of a neurodevelopmental disorders. The screening method is based on research carried out at the Cuban Neuroscience Center. The system is a combination of an Android application for a Tablet and a Web application. The Android app enables easy and quick exploration of learning and behavior disorders, hearing impairment, parental care and certain clinical health parameters. All the information is provided by teacher reports or direct measuring on the child. The Web application manages the screening program and organizes it by geographical regions, allowing adaptations to the local educational system. The user’s access is role-based and depends on the job function and the regions assigned to the user. The Web application was developed using the PHP framework Symfony2 and stores data using a relational MySQL database. The data exchange between both applications is implemented via download and upload XML file, thereby allowing the Android app to work offline in order to use it in sites with limited communication infrastructures. The system can gather, store, access and analyze data to aid in decision-making. The system will clarify the need of referral for early intervention services and/or other evaluations. It will also enable longitudinal follow-up neurodevelopmental studies in large samples of children.

SP170.6 - Support platform to decision making in research and technological development in public health: a brazilian scenario approach.
Author(s): Carlos E. Rocha, Yuri P. Marca
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The area of biosciences has promoted significant changes in national competence linked to innovation in health care by creating scientific favorable for the construction of public policies on ST & I, has also been presented as a strategic dimension of prominence in the training of human resources within areas of future patients, as well as the installation and consolidation of organizations linked to the process of Research, Development and Innovation.

Thus, the activities biotechnological processes require more accurate and consistent decision-making and consider the variables inherent in the organizational environment itself Institutions of Science and Technology. This position paper analyses the current state of affairs concerning the Brazilian health industry in strategic sectors.

SP170.4 - Diagnosis of the corporal movement in Parkinson’s Disease using Kinect Sensors
Author(s): Raquel Torres1, Monica Huerta2, Roger Clotet1, Ricardo Gonzalez1, Jose Porrone Pumol1, Mayra Erazo1, Giovanni Saguay2
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This paper presents an approach to capture of the human movement and posture with a Kinect Sensor, in order to assist physicians in the Parkinson’s Diagnosis. The Kinect Sensor allow to measure displacements in the motionless posture that can be interpreted as increments of tremors intensity.
A brief overview of the most critical infectious diseases and the associated technologies available for their diagnosis is given, pointing out research and development opportunities for the national industry for the health sector. Therefore Decision making in the process of implementation of projects of Research and Development in Health is an important activity in Brazil, since the amount of proposed projects is incompatible with the financial resources. An estimate to ensure the success of the proposal is something that would facilitate the manager’s work.

For this, it was developed an application in the programming language C++ that serves as support for the manager in decision making, where it makes the evaluation of the proposed project based on some modeling variables. Moreover, the use of this software can make it more robust and over time more effective for determining the estimated success of a proposal.

Finally, current challenges and perspectives concerning national policies for the Brazilian health sector are discussed.

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**SP171 - Clinical Engineering / Physics, Patient Safety & Imaging**

**PRESIDENTS CALL**

**SP171.1 - Properties Evaluation of Gd2O3-DEG as New Contrast Agent Nanomagnetic Particles Comparing to Gd-DTPA in MRI**

_Author(s):_ Banafsheh Nikfar¹, Nader Riahi-Alam¹, Soheila Haghgoo², Ensiyeh Gorji², Hosein Ghezati¹, Behrooz Rafiei³, Sara - Heydarnazadi³, Mohammad Khosroshahi⁴

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Magnetic resonance imaging (MRI) is widely used for imaging purposes. However, the sensitivity and intrinsic contrast of the MRI is low. In order to improve the quality of images Gd-DTPA (commercial Magnevist) is normally. Because of some limitations of low molecular weight of gadolinium chelates, nanoparticles gadolinium based contrast agents are proposed. In this study, we synthesized Gd-DTPA and compared its effects with Gd2O3-DEG nanoparticles. The samples were prepared at concentrations of 0.3, 0.6, 0.9 and 1.2 mM respectively by adding 1.5 ml deionized water. The corresponding Gd2O3-DEG nanoparticles diameter was measured about 80 nm. An in vitro study was performed using a 1.5 T scanner with standard spin echo protocol. Clearly, the signal amplitudes in both cases were increased with the Gd concentration at constant relaxation time. Also, a linear relation between signal intensity and longitudinal relaxation rate (R₁) was observed with a correlation coefficient close to 1. The values of 4.30 and 14.27 (s⁻¹·mM⁻¹) were achieved for Gd-DTPA and Gd2O3-DEG nanoparticles special relaxivity, respectively.

**SP171.2 - Imaging the Schlemm’s Canal using an ultrahigh resolution spectral-domain optical coherence tomography working at 1.3 micrometer center wavelength**

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Center Of Biomedical Engineering, Addis Ababa Institute of Technology, Addis Ababa/ETHIOPIA

We present an ultrahigh resolution spectral-domain optical coherence tomography imaging system that uses a broadband superluminescent diode light source emitting at a center wavelength of 1.3 micrometer. The light source consists of two spectrally shifted superluminescent diodes that are coupled together into a single mode fiber. The effective emission power spectrum has a full width at half maximum of 200 nm and the source output power reaches up to 10 mW. The imaging system has an axial resolution of 3.9 micrometer in air (<3.0 micrometer in biological tissue), and a lateral resolution of 6.5 micrometer. The sensitivity and the maximum line rate are 95 dB and 46 kHz, respectively. Images of an infrared viewing card and a cornea from human eye suffering from glaucoma showing Schlemm’s canal are presented to illustrate the performance of the system.
SP171.3 - Technology Trajectory Hybrid Tomography by Positron Emissions
Author(s): Victor Malvaez
Management Of Technology, CIECAS IPN, Mexico/MEXICO

This work studies, by means of the technological surveillance, the origin and evolution of the hybrid tomography by positron emission, commonly known as PET-CT. This tomographic technique is currently used in the medical diagnosis of patients with tumors or neoplasias, and its efficient use in Mexico could reduce costs and increase the opportunities for more people to have access to advanced medical technologies. To this end it is necessary to make them known, together with the fields of actual and potential applications. The main providers of this technology and their core competences are detected by means of patent analysis, as well as their technological profiles, advances and future developments. Patent analysis is carried out by consulting data bases as USPTO, EPO, JPO and WIPO. The technological surveillance was accomplished with the help of the International Classification of Patents (ICP) protocol, which allows the identification of the technological fields that are related to PET-CT. Future trends in the technology and possible evolution of equipment and radioactive marker prices are also found.

SP171.4 - Myocardial perfusion imaging by low-dose CT
Author(s): Sabee Mollai, Benjamin Ziemer, Logan Hubbard, Jerry Lipinsky, Bahman Sadeghi, Hanna Javan, Elliott Groves
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Coronary heart disease remains widely prevalent and is the leading cause of mortality and morbidity in the world. It is well established that the extent of coronary artery disease and left ventricular dysfunction are predictive of future cardiac events. Several clinical trials have demonstrated that mortality and morbidity can be reduced when medical and surgical interventions are applied to selected subsets of patients stratified according to coronary anatomy and left ventricular function. Coronary CT angiography is a well-established, non-invasive imaging modality for the detection and exclusion of atherosclerosis. However, coronary CT angiography cannot accurately determine whether an intermediate severity stenosis is flow limiting that requires additional functional testing, which increases the radiation dose and cost to the patient. Furthermore, international guidelines recommend the functional assessment of stenosis severity prior to revascularization. A CT perfusion technique would provide valuable functional information, in addition to the anatomical data obtained from CT angiography. As a result, many dynamic CT perfusion techniques have been developed to provide functional assessment of coronary artery disease; however, widespread clinical implementation of such techniques has been hampered by the fact that these techniques deliver a high radiation dose. Hence, there is a need for a low-dose CT perfusion technique for noninvasive functional assessment of coronary artery disease. It is possible to measure myocardial perfusion using a low-dose first-pass analysis (FPA) technique. This technique relies on conservation of mass by making measurements in an arterial tree perfusion bed before contrast exits through the venous system. Implementation of this technique using CT requires fast, whole-heart scanning combined with ECG-gating. Therefore, the FPA technique was implemented with a prospective ECG-gated protocol using a 320-slice CT scanner. This technique can measure myocardial perfusion using a minimum of two volume scans, which can substantially reduce radiation dose as compared with existing dynamic perfusion techniques. The study was carried out in anesthetized, closed-chest swine using angioplasty balloon catheters to produce partial occlusion. After segmentation of the myocardium and extraction of the coronary arterial trees, perfusion measurements were made using the FPA technique. The perfusion measurements were validated using colored microspheres as the reference gold standard. The perfusion measurements using FPA (PFPA) and colored microspheres (PMic) were related by PFPA = 0.97 PMic + 0.12 mL/min/g (r²=0.92). The results show that CT perfusion measurements have excellent correlation with microsphere perfusion measurements. In conclusion, the results indicate that accurate CT perfusion can be made with a substantial reduction in radiation dose as compared with existing dynamic CT perfusion techniques. Therefore, CT can potentially be used for both anatomical and physiological assessment of coronary artery disease.

SP171.5 - Renal Dynamic Phantom for Use in SPECT
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Renal Dynamic Phantom for Use in SPECT

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Quality control of nuclear medicine is performed through the use of phantoms during the processes necessary for consumption of quality control tests. Ideally, a specific phantom is employed for each type of procedure. Dynamic renal scintigraphy using DTPA (diethylenetriamine pentaacetic acid) is labeled with technetium-99m. This renal radiopharmaceutical tracer allows evaluation of the dynamics of renal blood flow and its symmetry, the topography and morphology of the kidneys, and the passage of the radiopharmaceutical through the urinary tract to the bladder until arrival. The objective of this study was to develop and evaluate the performance of a renal dynamic phantom, for use in SPECT. An adult human kidney was used for making the mold, ensuring phantom geometry. It was used alginate for the manufacture of the shaped form of the kidneys. Following preparation, the acrylic kidney was connected to the top of each kidney with one injection pump connected to a reservoir. To perform the flow, the phantom is controlled with injection pumps. The electrical system controls how long each pump is in operation. Changes of the operating time of the pump at different flow rates imply elimination of the radioisotope, allowing it obtain various forms of disposal. The renal dynamic phantom was constructed of acrylic and included injection pumps to simulate renal dynamics in scintigraphy with 99mTc-DTPA. This phantom was scanned with a dynamic protocol and compared with clinical data. Using this phantom it is possible to acquire similar renal images as in clinical scintigraphy, including the response of the imaging system to the form of a renogram with normal renal scintigraphic appearance. Moreover, it is expected to perform intercomparisons between different renograms scintillation cameras and nuclear medicine clinics. Therefore, the dynamic renal phantoms can be very effective for use in the quality control of renal scintigraphy and image processing systems.

Keywords— Dynamic phantom, nuclear medicine, quality control.

Renal Dynamic Phantom for Use in SPECT
**SP171.6 - Physics Plan Checking Practices**

**Author(s):** Gordon Chari¹, Lee Chin², Harald Keller³, Keith Nakonechny⁴, Cathy Neath⁵, Greg Salomons⁶

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The physics treatment plan / chart check has been shown to be a critical factor in ensuring safe high-quality radiation therapy. However, there is very little publicly available documentation on plan checking. Anecdotal evidence suggests that the practice of plan checking is highly variable even among physicians within the same centre. In order to ensure a high and uniform quality in treatment plans it is imperative that the process be standardized and documented.

In order to determine the current practice in regards to physics treatment plan checking, the Medical Physics Community of Practice Working Group in Ontario conducted a survey of the medical physics departments at all cancer centres in Ontario. The survey was intended to cover all aspects of the physics checking, including which elements of a patient’s plan are being checked by the physicist, what level of documentation is being performed with the checking, and where in the planning to treatment process the physics plan checking is being performed. The survey was designed to have the physicists at each centre (typically 5-6) complete the survey together as a group and provide a single response from their centre. Answers to the questions were designed to reflect the variability in practice within a centre.

We will present the results from this survey such as the responses shown in Figure 1 below. Initial survey results suggest that often the plans are accepted as is even though they could be improved upon. Comments accompanying the question indicated that the time between a physicist receiving the plan for review and the patient’s scheduled appointment, was a big factor in deciding whether to accept a sub-optimal plan or not.

The process of completing the survey also provided direct benefits to the participating centres. Initial feedback suggests that the dialogue which was generated was beneficial to the participating physicists and will hopefully increase the consistency and quality of the plan checking process in those centres. Hopefully, the dialogue generated by publishing the results of the survey will have an equally beneficial effect. It is anticipated that the results of this survey will lead to new guidelines for physics involvement in patient plan QA.

**Figure 1.** Responses to the question: “What is done with a sub-optimal plan that meets the prescribed goals?” The responses indicate the proportion of physicists who will take a certain action for a sub-optimal plan. Multiple selections were allowed.

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**SP171.7 - Commissioning of a Flattening Filter Free Beam Using an Anisotropic Analytical Algorithm (AAA)**

**Author(s):** Satya Ranjan Saha

Medical, Tradevision Limited, Dhaka/Bangladesh

**Aim:** To compare the dosimetric parameters of the flattened and flattening filter free (FFF) beam and to validate the beam data using anisotropic analytical algorithm (AAA).

**Materials and Methods:** All the dosimetric data’s (i.e. depth dose profiles, profile curves, output factors, penumbra etc.) required for the beam modeling of AAA were acquired using the Blue Phantom RFA for 6MV, 6FFF, 10MV & 10FFF. Progressive resolution Optimizer and Dose Volume Optimizer algorithm for VMAT and IMRT were also configured in the beam model. Beam modeling of the AAA were compared with the measured datasets.

**Results:** Due to the higher and lower energy component in 6FFF and 10FFF the surface doses are 10 to 15% higher compared to flattened 6MV and 10MV beams. FFF beam has a lower mean energy compared to the flattened beam and the beam quality index were 6MV 0.867, 6FFF 0.629, 10MV 0.74 and 10FFF 0.695 respectively. Gamma evaluation with 2% dose and 2mm distance criteria for the Open Beam, IMRT and VMAT plans were also performed and found a good agreement between the modeled and measured data.

**Conclusion:** We have successfully modeled the AAA algorithm for the flattened and FFF beams and achieved a good agreement with the calculated and measured value.

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Machine: Truebeam by Varian Medical Systems AG

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**SP171.8 - Effects of 24 hour Wakefulness on Tilt Based Targeting Tasks**

**Author(s):** Jeffrey Bolkhovsky¹, Ki Chon², Michael Qin³

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This study investigated the effects of short term sleep deprivation while using a tilt-based control device. Accuracy and various performance parameters of subjects using tilt based devices to perform target acquisition tasks were monitored over a period of 24 hours to assess the susceptibility of performance to acute sleep deprivation. Performance was analyzed by means of the principles of Fitts’ law using movement time, throughput, and time intercept as measurements. All task sessions were analyzed using movement time and difficulty correlation to determine that the tasks completed by all participants did in fact adhere to Fitts’ law with an average R² of 0.99 and a standard deviation of 0.01. Accuracy was examined by looking at movement error, movement variability, and number of target reentries. These accuracy statistics were derived by comparing the subject paths for acquiring targets to the ideal paths within the task. Ten volunteers completed sets of two sets of learning tasks and then completed a set of tasks every two hours up to a time at which the subject had been awake for a consecutive 24 hours. Each
SP172 - Mammography and Tomosynthesis

TRACK 01: IMAGING

SP172.1 - Evaluation of automatic exposure control in digital mammography

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Digital mammography has been largely employed in several screening programs for detection of breast cancer. In this technique, the exposure technique is usually chosen by the automatic exposure control (AEC) in order to optimize the relation between the absorbed dose and the image quality.

In this work, we compare the contrast-to-noise ratio (CNR) and the average glandular dose (Dg) obtained for different x-ray spectra in order to evaluate the exposure techniques provided by the AEC. The study was performed in a Senographe DS equipment (GE Medical Systems) using CIRS breast phantom with different thicknesses and compositions: 4 cm – 50% glandular (model 010B), 5 cm – 30% glandular (model 010A) and 6 cm – 20% glandular (model 010C). All AEC modes available were studied: standard, contrast and dose. Additionally, using the manual exposure mode, all the different anode/filter combinations selectable on the systems (Mo/Mo, Mo/Rh and Rh/Rh) were evaluated for all tube voltages settings available. The results of CNR and Dg were combined in a Figure of Merit (FOM=CNR²/Dg) in order to study the optimal x-ray spectra for each thickness.

The results obtained using the AEC mode showed that the exposure techniques selected for the 4 cm thick phantom is the combination Mo/Rh at 27 kV, while the Rh/Rh combination at 29 kV was selected for both 5 and 6 cm phantoms. All AEC modes selects the same techniques, while the mAs values chosen by the AEC-dose mode are up to 37% and 102% greater than for the AEC-standard and AEC-contrast, respectively. The variation in relative noise (σ/p) with pixel values (p) was adjusted to an allometric function (σ/p=kp⁻n) and an n value equal to 0.27 was obtained, which indicates the presence of a non-neglect structural noise. Results of the FOM indicated that the optimal spectrum for the 4 cm phantom is the Mo/Rh combination at tube voltage between 28-30 kV. For the thicker phantoms, the Rh/Rh at tube voltage between 26-28 kV showed the best performance in terms of dose saving or image quality improvement. The results obtained indicate that x-ray spectra with energies lower than those selected by the AEC mode should be used in this system, which differs of the most energetic x-ray spectra obtained in previous works. This result can be related to the high contribution of the structural noise in the detection system evaluated. Finally, our results show that the optimization studies are system dependent, instead universal, and the exposure techniques selected by the AEC should be revisited. Besides, the determination of the optimal exposure parameters also should take into account the major components for noise in image. Thus, further studies regarding optimization of mammographic techniques could evaluate other image quality parameters (i.e., image contrast and DQE) and/or include the determination of the optimal mAs.

This work was sponsored by the Office of Naval Research.
Background: Mammographic compression is used for optimizing image quality and reducing radiation dose. Excessive compression can cause pain and discomfort to women. Current force-based compression guidelines have largely been optimized for western women and do not take breast size into account. Thus, Asian women are subjected to protocols that might not be suitable for them. Previous studies using a 10 kPa pressure-standardized protocol significantly reduced pain without compromising apparent image quality and radiation dose.

Purpose: To investigate mammographic compression practice at our center, by analyzing the variability of compression parameters between and within women in terms of both force and pressure.

Materials and Methods: We processed 18,436 digital mammograms (CC and MLO views) from 4,609 women aged 40-80 years using VolparaAnalytics and VolparaDensity to assess compression force (CF), compression pressure (CP), compressed breast thickness (CBT), breast volume (BV), volumetric breast density (VBD) and mean glandular dose (MGD) as a function of contact area (CA). Standard deviation and Wilcoxon test were used to assess variability and statistical significance between and within women, as indicated by the large standard deviations and Wilcoxon test used to assess variability and statistical significance between and within women, respectively.

Results: CFs were significantly different for CC (10.8 ± 2.9 daN) and MLO (13.2 ± 2.9 daN) views (p<0.001). Similarly, CPs were also significantly different for CC (21.5 ± 11.5 kPa) and MLO (13.3 ± 4.9 kPa) views (p<0.001). CBTs were significantly different between CC and MLO views (5.1 ± 1.0 cm and 5.7 ± 1.3 cm, respectively; p<0.001). Lastly, CA was significantly different between CC (0.6 ± 0.4 dm²) and MLO (1.1 ± 0.4 dm²) views (p<0.001). Compression parameters including CF, CP, CBT and CA for CC and MLO views were highly variable between and within women, as indicated by the large standard deviations and Wilcoxon test. Figure 1(a)-(f) shows the relationships of CF, CP, CBT, BV, VBD and MGD versus CA. Based on our median CA (0.8 dm²) and the proposed 10 kPa pressure-standardized protocol, the corresponding CF should be about 8.0 daN (Figure 1a(i)). In comparison, our women population was subjected to about 50% higher (12.0 daN) force.

Conclusion: We observed compression parameters were highly variable between and within women. Based on the suggested CP standardized at 10 kPa, we estimated the CF should be approximately 50% lower than our current practice. We will investigate the impact of the pressure-standardized protocol on image quality and radiation dose in Asian women (who generally have smaller breasts) that is of great interest.

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Conclusion: We observed compression parameters were highly variable between and within women. Based on the suggested CP standardized at 10 kPa, we estimated the CF should be approximately 50% lower than our current practice. We will investigate the impact of the pressure-standardized protocol on image quality and radiation dose in Asian women (who generally have smaller breasts) that is of great interest.
from the DICOM meta-data.

Results

The mean patient age was 55±13 years (range 30-85), the mean compressed breast thickness was 55±13 mm for DBT and 58±13 mm for FFDM. The AGD values increase with increasing compressed breast thickness (Figure 1). The mean AGD for a single view DBT and FFDM exposure were 1.49 ± 0.36 mGy and 1.62 ± 0.55 mGy, respectively, which is a small but statistically significant difference (Wilcoxon matched-pair signed-rank test, p< 0.001). Subanalysis where patients are categorized according to breast thickness, revealed that only for breast thickness categories >50 mm the AGD of DBT was significantly lower than the AGD for FFDM, indicating that the dose reduction is most pronounced in thicker breasts.

Conclusion

On average, the radiation dose of a single view DBT exposure is comparable to a single view FFDM. For patients with thicker breast, the radiation dose of DBT is found to be slightly lower than FFDM.

Figure 1 AGD values as a function of breast thickness for single view acquisitions for a) FFDM and b) DBT.

1European Guidelines for Quality Assurance in Breast Cancer Screening and Diagnosis. 4th ed. 2006

SP173 - Ultrasound and OCT: Methods

SP173.1 - A comparison study on shear wave velocity estimation of thin layered media using shear wave imaging

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Shear wave imaging allows noninvasive and quantitative evaluation of mechanical properties of human tissues. Generally, shear wave velocity (CS) can be estimated using lateral time-of-flight method (LTOFM) if a medium is unbounded. Thereafter, Young’s modulus (E) is calculated directly from the estimated CS, i.e. E=3pCS where p denotes density. However, shear waves propagating through a thin layered medium are influenced by strong dispersion effects. Recently, Lamb wave based method (LWBM) has been proposed to overcome this limitation. In this study, the two methods were compared to validate the effectiveness of LWBM by performing a finite element (FE) analysis and a phantom experiment for thin layered media.

Figure 1 shows the results of the FE analysis using PZFlex® for a thin layered model (thickness=1mm). The perpendicularly applied pressure generated shear waves propagating in the transverse direction. After obtaining axial velocity data from the FE analysis, CS was estimated using the two methods. CS_MEAN in (b) was not equal to CT in (a) and showed a non-uniform distribution, although the model was assumed to be homogeneous. On the contrary, LWBM precisely estimated CS in (C) by fitting the FE result with the theoretical curve of leaky Lamb waves.

SP172.4 - Absorbed dose in PMMA and Equivalent Breast Phantom in a Digital Breast Tomosynthesis system: Monte Carlo Assessment

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Digital breast tomosynthesis (DBT) is a screening and diagnostic modality that acquires images of the breast at multiple angles during a short scan. The Selenia Dimensions (Hologic, Bedford, Mass) DBT system can perform both full-field digital mammography and DBT. The system acquires 15 projections over a 15° angular range (from -7.5° to +7.5°). The estimation of breast dose is an important part of mammographic quality control for x-ray mammography. Nevertheless, there are presently no standard protocols for dosimetry of breast imaging in 3D. The purpose of this work was to assess the absorbed dose by projection angle in slabs of polymethyl methacrylate (PMMA) and breast equivalent thickness using the Monte Carlo code MCNPX and typical x-ray energy range (25, 28, 31, 34, 37 and 40 kVp) recommended for breast tomosynthesis. Absorbed dose is a nearly linear function of glandularity, independently of x-ray spectra and decrease with increased PMMA thickness. Taking into account 45 mm thick PMMA and 53 mm thick equivalent breast, the difference in absorbed dose by projection angle has been up to 1.33%, 3.83% e 10.98% for x-ray energies of 25, 28 and 40 kVp, respectively. Normalized glandular dose (DgN) values may be used directly to measure the glandular dose in DBT quality control procedures.

Figure 2 illustrates the results of a thin layered phantom (thickness=1.9mm). To obtain axial velocity, a 2D autocorrelator was employed to ultrasound in-phase quadrature data acquired with Aixplorer® and a 7.5MHz linear probe. There was a considerable discrepancy between CS_MEAN in (b) and the previously measured CS (=5.6 m/s) of a bulk sample of 1.5% agar phantom. As for LWBM,
no significant difference in C5 was shown between the layered phantom and the bulk phantom.

In conclusion, we showed that LWBM can be applied to accurately estimate shear wave velocity for thin layered media, while LTOFM is suitable only for unbounded media.

**SP173.2 - Temperature Dependence of Nonlinear Acoustic Harmonics in Water: Measurement and Simulation**

**Author(s):** Borna Maraghechi, Michael C. Kolios, Jahan Tavakkoli Physics, Ryerson University, Toronto/Canada

Thermal therapeutic applications of ultrasound consist of hyperthermia and thermal ablation which are both clinically approved. In ultrasound hyperthermia, the tissue temperature increases up to 45°C through exposing it to a therapeutic ultrasound beam in order to destroy cancer cells or to sensitize them to radiotherapy or chemotherapy. A temperature monitoring technique is required to control and guide the heating during the thermal therapy.

In this study, the temperature dependence of the harmonics generated by nonlinear ultrasound beam propagation in water at a transmitting fundamental frequency of 13 MHz has been investigated both experimentally and through simulations.

The experiments were performed using a wide-band high-frequency single-element circular focused ultrasound transducer (f-number 2.1). Acoustic harmonics were generated by transmitting 15-cycle pulses at 13 MHz with focal positive peak pressures of approximately 1.3 MPa in water. The acoustic pressure signals were measured by a calibrated needle hydrophone placed at the focal point of the transducer. Water temperature was uniformly increased from 26°C to 46°C in increments of 5°C. The pressure amplitudes of the fundamental frequency (p1), and its harmonics (second (p2), third (p3), fourth (p4), fifth (p5) and sixth (p6)) generated by nonlinear ultrasound propagation were obtained by calculating the frequency spectrum of the measured acoustic pressure signals.

Nonlinear ultrasound beam simulations were performed using a time-domain numerical solution of a modified Khoklov-Zabolotskaya-Kuznetsov (KZK) nonlinear wave equation in which the temperature dependence of the medium parameters were included. Nonlinear propagation of a 15-cycle pulse at 13 MHz in water with the source pressure amplitude of 0.1 MPa from the same transducer geometry used in the experiment was simulated. This source pressure amplitude was used in simulation in order to get the same degree of nonlinear waveform distortion as to what obtained in experiment at the focus when the water was at the baseline temperature of 26°C. The changes in the p1, p2, p3, p4, p5 and p6 values at the focus were analysed as the water temperature increased from 26°C to 46°C.

The experimental results show that due to the temperature elevation the p1, p2, p3, p4, p5 and p6 values increased by 2.5±2%, 14%±7%, 18%±5%, 30%±12%, 34%±7% and 63%±15%, respectively compared to their initial value at 26°C. The results obtained from the KZK nonlinear simulations show that the p1, p2, p3, p4, p5 and p6 values changed by 0%, 1.6%, 3.3%, 5%, 7%, 9% as the temperature was raised from 26°C to 46°C. The simulation and experimental results show similar trend in the temperature dependence of the harmonics generated in water. However, the magnitude of the changes is lower for the simulation results and the source of the difference is currently under investigation.

The results indicate that the nonlinear harmonics generated in water from a 13-MHz transmit pulse are temperature dependent and their temperature sensitivity increases with the harmonic number. Therefore, the nonlinear harmonics generated from high-frequency ultrasound beams could potentially be used for ultrasound-based thermometry.

**SP173.3 - 3D trans-rectal ultrasound for high-dose-rate prostate brachytherapy: a comparison of sagittally-reconstructed 3D image volumes with sagittally-assisted axial image sets**

**Author(s):** William T. Hrinivich1, Douglas Hoover2, Kathleen Surry2, David D’Souza2, Aaron Fenster3, Eugene Wong4

1Department of Medical Biophysics, Western University, London/Canada, 2Department of Oncology, Western University, London/Canada, 3Imaging Research Laboratories, Robarts Research Institute, London/ON/Canada, 4London Regional Cancer Program, London Health Science Center, London/Canada

**Background:** High-dose-rate brachytherapy (HDR-BT) is a prostate cancer treatment option where hollow applicators are inserted into the gland through the perineum. Dose is delivered by indexing a high-activity source to dwell positions within the applicators based on the relative positions of applicators, the prostate, and nearby organs. Conventional HDR-BT imaging involves indexing a trans-rectal ultrasound (TRUS) probe in the superior/inferior (S/I) direction, typically in 5-mm intervals, using the axial crystal to produce an image set for planning. These axial images have limited spatial resolution in the applicator insertion direction (S/I), so the sagittal crystal is used to identify applicator tips, which are transferred to the axial image set through a manual registration of the axial images and live sagittal view, adding a potential source of uncertainty. Correct localization of applicators is critical for accurate dosimetry. A sagittally reconstructed 3D-TRUS image volume with high S/I spatial resolution could eliminate the need to identify applicator tips on separate images, potentially mitigating errors in applicator tip position.

**Purpose:** To compare applicators localized on 3D-TRUS to those localized on sagittally assisted axial image sets, and to assess the dosimetric impact of these differences.

**Methods:** Our lab previously developed a mechatronic device for image-guided trans-perineal needle insertions enabling sagittally reconstructed 3D-TRUS. The device has recently been used for both axial image and 3D-TRUS acquisition. A patient underwent HDR-BT using a sagittally assisted axial image set. A 3D-TRUS image volume was acquired prior to the axial images, enabling rigid image
alignment using anatomical landmarks. Applicators were then localized on 3D-TRUS, and dwell positions were compared with those determined intra-operatively. Planned dwell times were transferred to the 3D-TRUS-localized dwell positions and changes in relevant dosimetric parameters were assessed.

**Results:** Means±SD differences in Right/Left, Anterior/Posterior, and Superior/Inferior applicator tip positions were 0.2±1.1 mm, 0.3±0.4 mm and 0.3±1.8 mm respectively. The 3D-TRUS dwell positions resulted in reductions in prostate V100% from 97.1% to 95.5%, urethra D10% from 116.8% to 112.0%, and rectum D0.5cc from 64.4% to 63.5%.

**Conclusions:** Applicator localization with 3D-TRUS has the advantage of eliminating a source of uncertainty relative to sagittally assisted axial image sets. Differences in dwell positions were largest in the applicator insertion (S/I) direction. For this patient, spatial differences had little effect on dosimetric parameters. We will report on-going analysis of a larger patient cohort comparing 3D-TRUS with sagittally assisted axial image sets for HDR-BT.

**SP173.4 - Understanding lung ultrasound artifacts using a phantom lung model**

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**Background:** Fluid resuscitation as part of the early goal-directed therapy in sepsis is recommended. A conservative fluid strategy is associated with reduced risk of pulmonary oedema, highlighting the importance of limiting fluid therapy in patients at risk of pulmonary oedema. Ultrasound has been used to assess this. Diseased lungs have better ultrasound penetration and resolution, producing ultrasound artefacts known as B-lines. There is an association between these B-lines and lung water volume. However, there is limited study in classifying and quantifying B-line artefacts as a function of lung water volume.

**Objective:** To recreate A-line and B-line ultrasound artifacts using a phantom lung model, and determine factors influencing changes in these artifacts, and the possibility of quantifying these changes.

**Method:** A phantom lung model was created from melted gel wax, which was solidified in a phantom holder over 12 hours, and placed on a layer of cling film wrapped over an air-filled plastic container. 10µL and 200µL pipette tips, and 0.5mL tube were embedded in the phantom model. Using a linear probe, the A-line and B-line artifacts were obtained from scanning the phantom model. Factors assessed were the different phantom thickness, different phantom surfaces, ultrasound frequency, location of meshed gel wax and weight of meshed gel wax. Data collected and analysed were based on the number of A-lines, distance between each A-line, and the average length of B-lines.

**Results:** Scanning empty pipette tips and tube created A-lines. B-lines were created by scanning pipette tips and tube filled with liquid (i.e. water, Gelofusin, and plasma) and semisolid (i.e. meshed gel wax) materials. The A-lines - The thickness of phantom model is directly proportional to the distance between A-lines, but inversely proportional to the number of A-lines. The ultrasound frequency is inversely proportional to the intensity of A-lines. There was no difference in the A-lines between the flat and semicurved surface phantom, or the different pipette tips and tube sizes. The B-lines - The B-lines in pipette tips filled with water showed broader distance between each B-lines compared to pipette tips filled with meshed gel wax. The ultrasound frequency was inversely proportional to the intensity and average length of B-line. The average length of B-lines appears to increase with increasing meshed gel wax weight, although not in a progressive manner. The distance between each B-lines appears to be shorter in water-filled and plasma-filled compared to Gelofusin-filled tubes. There was no difference in the B-line between the different pipette tips and tube sizes. There was no relationship between the average length of B-lines and the location of meshed gel wax within the pipette tips (i.e. distance between ultrasound probe and meshed gel wax).

**Conclusion:** We managed to recreate A-line and B-line artifacts using this model. Increasing volume of substance was associated with ultrasound artifacts changes, confirming a potential role for ultrasound use in quantifying volume. Although there were factors with good association to ultrasound artifacts demonstrated, there were several limitations identified. Further improvement to the phantom model design is required for more accurate study.

**SP173.5 - Accuracy of Tissue Elasticity Measurement using Shear Wave Ultrasound Elastography: A Comparative Phantom Study**

**Author(s):** Chu En Ting¹, Chai Hong Yeong², Kwan Hoong Ng³, Basri Johan Jeet Abdullah¹, Huong En Ting¹

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**Introduction:**

There is a strong correlation between tissue elasticity (Young’s modulus) and pathological state. The information of tissue elasticity superimposed to any anatomical image provides great diagnostic value, hence improving treatment outcome. Shear wave elastography (SWE) is a relatively new imaging technique using ultrafast ultrasound to measure tissue elasticity. Though studies have reported the reliability, specificity and reproducibility of SWE in elasticity quantification, the accuracy of elasticity measurements compared
to a gold standard has not been reported.

**Aims and Objectives:**

The objectives of this study were to verify the accuracy of tissue elasticity measured using SWE compared to the gold standard (electromechanical microtester) and to investigate several factors (size, depth and overlapping inclusions) that might affect the accuracy of SWE measurement.

**Methods and Materials:**

A tissue-mimicking phantom with acoustic and shear elasticity properties similar to the human breast was developed using animal hide gelatine. Elasticity values of inclusions embedded in the phantom were manipulated by varying the amount of its gelatine content. Each inclusion was made in pair, one for in vivo measurement using a commercial SWE scanner (Aixplorer, SuperSonic Imagine, France) and the other for destructive in vitro measurement with the microtester (Model 5848, Instron Co, USA). The measurements using both methods were compared statistically using the paired-sample t-test with 95% confidence interval. To investigate the possible factors affecting SWE measurements, the phantom was also designed to encompass inclusions with varying diameters and elasticity values, embedded at different depths in the phantom. The diameters of the inclusions were varied using pairs of hemispherical moulds with sizes ranging from 17 to 30 mm. SWE measurements were obtained for each inclusion.

**Results and Discussion:**

Despite a strong linear correlation, a statistically significant difference (p<0.05) was found between the elasticity values measured using SWE and the gold standard, whereby the SWE overestimated the elasticity by a mean of 22.79±15.00 kPa. This overestimation might be due to artefacts caused by wave interferences between the elasticity boundaries. Shear wave reflection at boundaries could cause either constructive or destructive interference, depending both on boundary conditions and the incoming wave, consequently causing underestimation or overestimation of the actual elasticity values. Due to shear wave reflection, an increase in contrast between elasticity boundaries was also shown to reduce reproducibility of consistent measurements. A spatio-temporal directional filter has been suggested as a means to reduce the artefacts in the reconstructed shear modulus map. Size and depth of inclusions did not affect SWE measurements; however the depth of shear wave detection was limited to 8 cm from the surface.

**Conclusion:**

Elastography plays a significant role in clinical diagnosis by providing useful structural and pathological information on soft tissues. This study shows that the elasticity values derived from commercial SWE system were consistently higher than the gold standard, which is likely due to wave interference at the elasticity boundary. In order for SWE to be incorporated into clinical diagnostic practice, it is vital to identify a solution to overcome these artefacts.

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### SP174 - Motion Management: Part 2

#### TRACK 04: RADIATION ONCOLOGY

**SP174.1 - Assessment of lung dose in patients undergoing deep inspiration breath hold for left sided breast cancer**

**Author(s):** Peta Lonski1, David Jolly1, Shankar Siva2, David Ball2, Boon Chua3, Damien Philips4, Maria Portillo4, Steven David5, Amanda Phillips5, Tomas Kron1

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**Aim:** Deep inspiration breath hold (DIBH) is being used to reduce cardiac dose in patients undergoing radiotherapy for left sided breast cancer. Due to chest wall expansion there is concern that the amount of lung in the high dose region could increase. We aimed to evaluate this in a cohort of patients from a prospective trial who had both a free breathing (FB) and DIBH CT scan for planning comparison purposes.

**Methods:** Ten consecutive left sided breast cancer patients were enrolled in this study. Each patient underwent a FB and a DIBH CT scan in treatment position on an elevated breast board using a Philips Brilliance wide bore 16 slice CT scanner. Plans were created using 6 MV x-rays to treat the whole breast volume as marked clinically. A field in field tangential technique was used. Plans were created in Varian Eclipse version 11 using the Anisotropic Analytical Algorithm (AAA version 11.0.31). The volumes of lung receiving 5, 20 and 30 Gy (V5, V20 and V30 respectively) were assessed on the FB and DIBH scans. Lung DVH data was analysed in terms of both absolute and relative lung volumes.

**Results:** There was an average increase in absolute volume of lung receiving 5, 20 and 30 Gy in DIBH compared to FB. However, assessment of the same DVH parameters in terms of relative volume of lung showed an average decrease in DIBH. The difference in V5, V20 and V30 between DIBH and FB (positive values indicate a higher dose in DIBH) are shown in the table in terms of both absolute and relative lung volumes.

<table>
<thead>
<tr>
<th>DIBH - FB: absolute lung volume (cc)</th>
<th>DIBH - FB: relative lung volume (%)</th>
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</thead>
<tbody>
<tr>
<td>mean</td>
<td>standard deviation</td>
</tr>
<tr>
<td>V5</td>
<td>+203</td>
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<tr>
<td>V20</td>
<td>+91</td>
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<tr>
<td>V30</td>
<td>+87</td>
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</table>

**Conclusion:** DIBH resulted in an increase in the absolute volume of lung present within the target region but paradoxically reduced the evaluated DVH parameters in terms of dose to relative lung volume. Lung DVH data therefore requires careful evaluation when assessing the dosimetric consequences to lung in patients undergoing DIBH. Comparative evaluation of the clinical consequences of absolute versus relative irradiated lung volume in DIBH is warranted.
SP174.3 - Application of RADPOS System for Dose and Position Quality Assurance of 4D CyberKnife Treatments

Author(s): Raanan Marantz1, Eric Vandervoort2, Joanna Cygler3

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Introduction

The CyberKnife robotic radiosurgery system uses Synchrony respiratory motion compensation. This complex dose delivery system needs independent performance verification to assure safe patient treatments.

In this work, we use the RADPOS 4D dosimetry system to verify CyberKnife’s motion tracking and delivered dose. RADPOS motion measurements are compared with internal metal fiducials and external LED optical markers log files. Dose measurements are compared with GAFCHROMIC film and treatment planning system (TPS) calculations.

Methods

RADPOS and EBT3 GAFCHROMIC films were calibrated using an ion chamber in Solid Water (5 cm depth, 80 cm source-detector distance, 60 mm cone). A CT based treatment plan was created for a Solid Water breast phantom containing fiducials and the RADPOS detector. Dose calculations were performed using the MultiPlan TPS, Monte Carlo (MC) and ray tracing (RT) algorithms on static phantom only. Before treatment, film was inserted inside the breast phantom adjacent to the RADPOS detector. The breast phantom and LED markers were positioned on the chest platform of a Quasar Respiratory Motion Phantom. Position logging began for RADPOS and Synchrony, Quasar motion started, and irradiation commenced.

A coordinate alignment algorithm was implemented, allowing all position tracking modalities to be compared within the fiducial coordinate system.

Results

Position

After LED and RADPOS position data are aligned to the fiducial coordinate system (average difference < 0.01 mm in any direction), the standard deviation of the differences between LED and RADPOS position measurements was 0.33, 0.39, and 0.56 mm along the left/right, superior/inferior, and anterior/posterior directions, respectively.
SP174.4 - Derivation of the probabilistic treatment margin for two targets with correlated motion

Author(s): Simon Van Kranen, Jan-Jakob Sonke, Marcel Van Herk
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Introduction
Margin recipes are widely used to derive PTV margins from random and systematic errors. Here we address a common situation with unknown solution: a margin that jointly covers two targets with correlated motion. E.g., primary tumor and lymph node targets in lung cancer are known to move somewhat correlated.

Material and methods
We assume two targets moving in 3D with a normal distribution with random / systematic error vectors $\alpha$ and $\Sigma$. For simplicity we assume the following type of correlation: each vector component of target 1 correlates with the corresponding component of target 2 with the same and known correlation, $r$. Finally, we assume that the margin for systematic errors can be expressed as $\alpha \Sigma$, where $\alpha$ is function of $r$. Because the margin for random errors is derived from the local target motion relative to the dose distribution, correlation has no influence, and the margin remains unchanged, e.g., $0.7\sigma$ simplified. The margin for systematic errors needs to achieve an acceptable probability that both targets are covered together. For a single target, 90% probability is reached with $\alpha = 2.5$. For two targets with uncorrelated motion, $\alpha$ needs to be 2.8 to achieve 90% joint probability for both targets ($0.95^2$). To finally derive the appropriate margin given correlation $r$, we need to establish the correlation $R$ of the dichotomous (i.e. 0 or 1) variables $V_1<\alpha \Sigma 1$ and $V_2<\alpha \Sigma 2$, where $V$ is the error vector length of a target. The probability, $P$, that $V_1<\alpha \Sigma 1$ and $V_2<\alpha \Sigma 2$ is given by $P = p^2 + p(1-p)R$ (equation 1), where $p$ is the probability of this condition for each target independently. In this study continuous correlation $r$ and dichotomous correlation $R$ are linked using a simulation for a practical range of $\alpha$.

Results
We first obtain $R$ from $r$, then $p$ from $R$, and finally $\alpha$ from $p$. Our simulations show that for this type of correlation, $R$ fits $r^4$ well for $2.5 < \alpha < 3.2$. The appropriate $p$ given correlation $R$ is a solution of eq. 1 for $P=0.9$. Finally, $\alpha$ is found as the inverse of the cumulative chi-square distribution with three degrees of freedom at $p$ (e.g., 2.5 for $p=0.9$). The combined equations are approximately linear with $z = 1-R$, or $z = 1-r^4$. The simplified margin recipe is given by $M = 0.7\sigma + (2.5 + 0.3z)\Sigma$, which assures with 90% probability that 2 targets are within the 95% isodose line.

Conclusions
Based on an empirical relation between a continuous and a dichotomous correlation, a practical margin recipe for two targets with correlated motion was derived. This margin formula is generic, except that $z$ depends on the type of correlation. Because the dichotomous
correlation $R$ is much smaller than the underlying continuous correlation, $r < 0.5$ can be treated as uncorrelated. The introduced formalism opens up the way to derive analytical margin recipes for an arbitrary number of targets with correlated motion.

**SP174.5 - How Truthful Is the 4D Dose Calculation?**

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**Purpose:** “4D dose” can be constructed using patient respiratory-correlated 4D CT image. However, patient respiratory-induce target/organ motion is mostly heterogeneous between breathing periods. Therefore, it is questionable if the 4D dose represents the “true dose” obtained from the entire breathing motion during the CT scanning. In this study, 4D CT scanning was simulated and used in the 4D dose calculation. The dose discrepancy between the “4D dose” and the “true dose” was evaluated and correlated to the heterogeneity of respiratory-induced motion pattern.

**Method & Material:** Computer simulation was performed using simulated and measured free breathing curves to generate a 4D target and an adjacent normal organ motion CT images. Two 4D dose distributions in the target and organ were constructed. The first one, named the 4D dose (D1), was calculated by tracking the point displacements in the target or organ manifested on the 4D CT images and including the physical density changes in the phase CTs, meanwhile the second one, named the true dose (D2), constructed based on the point displacements and density changes along the whole breathing motion curve. Treatment dose was generated using 6 co-planer beams aimed to the target center without using target margin. Dose discrepancy between D1 and D2 was calculated using different breathing curves with either non-uniform excursion or heterogeneous breathing period. The correlation between breathing pattern variation and dose discrepancy in the target and organ adjacent to target was determined and evaluated.

**Result:** The dose discrepancy in both the target and adjacent organ is highly correlated to the variation of breathing-induced target motion excursion and period. The maximum dose discrepancy in the target was on average 5% (±2.7% of one SD) to 8% (±3.3%) with the standard deviation of the motion excursion variation from 1 mm to 4 mm, meanwhile 6% (±3.7%) to 12% (±8%) with the standard deviation of the motion period variation from 0.3 sec to 0.7 sec. For the adjacent normal organ, the dose discrepancy was larger, especially for the motion period variation. When both variations appeared, the dose discrepancy could be >12% (±8.3%) for the target, and >16% (±11.5%) for the adjacent organ, meanwhile 10.6% (±9.8%) of the target volume and 21.8% (±15.8%) of the organ volume had dose discrepancy bigger than 5%.

**Conclusion:** The 4D dose constructed using 4D CT image can have large discrepancy when patient respiratory-induced target/organ motion has a heterogeneous pattern. However, this dose discrepancy can be estimated for treatment planning evaluation using the measured breathing curve during the 4D CT scanning.

**SP175 - Treatment Planning - Biology & Fractionation**

**SP175.1 - Adaptive radiotherapy for bladder cancer using deformable image registration of empty and full bladder**

**Author(s): Prabhjot Junesja, Hannah Caine, Peter Hunt, Jeremy T. Booth, David Thwaites, James O’Toole, Anen Vestergaard, Jesper Kallehave, Andrew Kneebone, Thomas Eade**

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A common objective of various adaptive radiotherapy (ART) strategies for bladder cancer is to reduce irradiation of normal tissue, thereby reduce the risk of radiation induced toxicity, and maintain or improve the target coverage. Bladder radiotherapy, typically involves generous margins (up to 20 mm) for bladder planning target volume (PTV).

The goal of this retrospective study is to define, evaluate and optimize new patient-specific anisotropic PTVs (a-PTVs) using deformable image registration (DIR) between empty and full bladder computed tomography (CT) scans. This will provide an ART that incorporates the extreme deformations of the bladder, and is applicable from the first day of treatment.

Deformation vector fields (DVFs), measured from the deformable image registration between empty and full bladder CTs, were scaled and constrained to construct the a-PTVs. For each patient, four a-PTVs were constructed such that a-PTV1 was the largest and a-PTV4 was the smallest. All the a-PTVs were defined such that they covered at least the bladder volume plus 5 mm margin. These a-PTVs were retrospectively evaluated and compared to the current clinical standard (conv-PTV), with 10 mm uniform margins, using 5 bladder cancer patients and a total of 100 fractions.

It was found that the smaller a-PTV, a-PTV4 and a-PTV3, were appropriate in 87% of the fractions, while a-PTV2 and a-PTV1 were required in 12% of the fractions respectively. The use of the a-PTVs reduced the PTV volume by 32% (28-36%) as compared to conv-PTV.

In conclusion, the results of this pilot study indicate that the use of a-PTVs could result in substantial decrease in the course averaged planning target volume. This reduction in the PTV is likely to decrease the radiation related toxicity and benefit bladder cancer patients. Currently, more patients are being investigated to strengthen these findings, and also dosimetric analysis is underway.

**SP175.2 - Dosimetric and clinical benefits of conformal radiotherapy combined plus volumetric modulated arc therapy in the treatment of non-small cell lung cancer**

**Author(s): Xiance Jin, Congying Xie**

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Background Radiation pneumonitis (RP) is one of the most common dose-limiting toxicities in conformal radiotherapy (CRT) and has a considerable impact on patient’s morbidity and mortality for lung cancer patients. Intensity-modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT) have been applied in the
treatment of lung cancer in an intent to spare the normal lung tissue and escalate dose to target. However, the use of IMRT and VMAT have been limited due to low dose dosimetric considerations. The purpose of this manuscript is to investigate the dosimetric and clinical benefits of a technique by combining conformal radiotherapy (CRT) plus VMAT in the treatment of non-small cell lung cancer (NSCLC). Materials and methods There were 200 NSCLC patients analyzed retrospectively and treated by CRT, CRT plus VMAT, and full course of VMAT, respectively. Matches were chosen based on stage, PTV size, tumor location, age, and gender. CRT scheme was planned with two parallel opposed, antero-posterior and posterioro-anterior (APPA) beams for 36 Gy, then followed by off-cord conformational beams for 24 Gy at 2 Gy per fraction. CRT plus VMAT was planned with initial CRT APPA beams for 36 Gy, then followed by a single-arc VMAT plan for 24 Gy. The full course VMAT plan was 60 Gy over 30 fractions with a single arc. Dosimetric differences, RP rates and their correlation were investigated. Results The number of patients analyzed in CRT, CRT plus VMAT and full course of VMAT were 42, 28, and 53, respectively. The V93 and V95 (percent volume covered by isodose line) of PTV were improved from 95.7±2.2% and 94.5±2.4% in CRT to 97.9±4.6%, 98.3±3.2% and 96.3±5.8%, 97.1±4.1% in CRT plus VMAT and full course of VMAT, respectively. CRT plus VMAT improved the PTV coverage compared with CRT in a cost of higher spinal cord maximum dose (p=0.02), larger lung volume receiving 5 Gy (V5, p=0.02) and mean lung dose (MLD) (p=0.04), and decreased the low dose lung volumes compared with VMAT. The RP rates were 26%, 39% and 49% for CRT, CRT plus VMAT and VMAT, respectively. V5 was significantly associated with RP and had a threshold of 60% and 65% for CRT plus VMAT and VMAT, respectively, to limit the RP rate <30%. The median three-year overall survival were 17.5, 23.2, 24.5 months for CRT, CRT plus VMAT and VMAT, respectively, without significant difference (p=0.29).

Conclusions: CRT plus VMAT is a promising with increased target coverage compared with CRT and reduced low-dose lung volume and RP compared with full course of VMAT in the treatment of NSCLC. V5 was significantly associated with RP and with a predicted threshold of 60% and 65% for CRT plus VMAT and VMAT, respectively, to limit the RP rate <30%. The interplay effect of chemotherapy with CRT plus VMAT on RP needs further study. Clinical trials with large population are needed to further verify the benefits of CRT plus VMAT in the treatment of NSCLC.

SP175.4 - Compressed Sensing-Based LDR Brachytherapy Inverse Treatment Planning with Biological Models
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New compressed sensing-based planning algorithms allow for fast computations of optimal planning results in low-dose-rate (LDR) brachytherapy. This enables to integrate complex models in the planning process. In this paper, we develop a new strategy for including a biological model on tumor control probability (TCP) and normal tissue complication probability (NTCP) into the objective function for plan optimization. These models were tested on clinical prostate cancer cases for their effects on the planning results relative to standard physical dose constraints for planning as reference. Interestingly, with weighting treatment risks, we observe plans using biological models assign more dose to the urethra since it is less radiation sensitive than the rectum whereby the latter is spared in order to reduce side effects. At the same time, the overall TCP is comparable. We conclude that the standard plan quality evaluation based on physical dose alone does not easily allow correctly assessing treatment risks. Hence, biological models for LDR brachytherapy treatment planning are a promising approach for an optimal management of treatment outcomes of brachytherapy.

SP175.5 - Investigation of Dosimetric and Biological Differences between Flattened and Unflattened Beams from the TrueBeam System
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Purpose/Objective(s): To investigate the dosimetric and biological differences between flattened and unflattened beam plans using different anatomic cancer sites.

Materials/Methods: Flattened and unflattened beams of the TrueBeam system were commissioned on the Eclipse treatment planning system (TPS). Beam energies were chosen to be 6 MV and 10 MV. Fourteen clinical cancer cases were used to simulate the clinical treatment. Static intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) were used to deliver the dose. Based on the dose-volume histogram (DVH), biological effective dose (BED), equivalent uniform dose (EUD), tumor control probability (TCP) and normal tissue complication probability (NTCP) were calculated to evaluate the biological effectiveness of the treatment plan. In-house developed Matlab code was used to statistically analyze the results. Direct comparisons were made to study the dosimetric and biological differences between the flattened and the unflattened beams for both energies.

Results: Nearly the same target coverage was obtained by the unflattened beam compared with the flattened beam for all cancer cases. For organ-at-risk (OAR) with high radiation sensitivity but received low dose (e.g. lens of the eye), the unflattened beam had up to 38% mean dose reduction and 34% maximum dose reduction compared with the flattened beam, leading to 85% reduction in the NTCP value. For OARs which were closer to the treatment field and had larger dose (e.g. brainstem), the unflattened beam had up to 14% reduction in the mean dose, 10% reduction in the maximum dose and 55% reduction in the NTCP value.

Conclusion: The clinical data indicated that the unflattened beam
could provide similar target coverage as the flattened beam in all 4 types of cancer. Improved dose sparing effect was obtained by the unflattened beam, leading to lower NTCP value in general. Significant dose sparing effect of the unflattened beam was observed for the head and neck cancers with large field size (about 16x20 cm²). The maximum dose rate of the unflattened beam may not always be achievable for large treatment field size (e.g. 20x20 cm²) due to the speed limitation of the multileaf collimator (MLC).

**SP176 - Characterization of Detector Systems for Therapy Dosimetry: Part 4**

**Track 05: Dosimetry and Radiation Protection**

**SP176.1 - Evaluation of surface dose distributions using ferrous benzoic xylenol orange translucent PVA cryogel radiochromic dosimeters**

**Authors:** Molham Eyadeh, Marcin Wierzbicki, Kevin Diamond

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**Purpose**

The purpose of this study is to evaluate the ability of a radiosensitive bolus material to monitor the surface dose distribution. Poly-(vinyl alcohol) cryogels (PVA-C) are flexible and can be fit snugly against skin over large, curved regions, where it may be challenging to achieve the same coverage with film or TLDs. We propose a method to use ferrous benzoic xylenol orange (FBX) in translucent PVA-C in place of bolus to perform in vivo dosimetry in regions where surface dose is important.

**Materials and Methods**

In this study, a series of open fields with gantry angles ranging from 0° to 90° were delivered to a radiochromic bolus and film stack on the surface of a polystyrene phantom. These measurements established the relationship between surface dose (estimated using Gafchromic EBT-2 film) and the dose measured in a 5 mm thick piece of radiochromic bolus. This calibration was then applied to clinical head and neck IMRT treatment plans that were delivered to a RANDO phantom. Radiochromic bolus was added electronically to the CT scan of the RANDO phantom to approximate the conditions of the actual patient treatments. The radiochromic bolus was imaged pre- and post-irradiation using a charge coupled device (CCD) camera, illuminated using a uniform, red LED array. All radiation treatment plans were developed using Pinnacle 9.2.

**Results**

The ratio between surface dose and the dose measured in the radiochromic bolus increased with increasing gantry angle, ranging from 0.745 ± 0.005 at 0° to 0.890 ± 0.017 at 67.5°. The average ratio of 0.799 ± 0.009 was used as the calibration factor. The calibration factor was applied to the radiochromic bolus dose measurements of the IMRT treatments delivered to the RANDO phantom. A gamma comparison between the radiochromic bolus and film was performed, using 3%/3mm criteria and a 10% threshold. The pass rate ranged from 95.1% to 97.7%.

**Conclusion**

A comparison of film and FBX-PVA translucent cryogel suggests that the radiochromic bolus provides an accurate estimate of surface dose using a simple correction factor. It may be possible to improve agreement using a more complex, angle dependent correction scheme, but this may over-complicate the dose estimation process.
SP176.2 - Suitability of Diodes for Point Dose Measurements in IMRT/VMAT Beams

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Recent advances in diode dosimetry analysis techniques, and resulting improvements in the accuracy of diode measurements of small field dose, have led to renewed interest in the use of diodes to measure point doses in modulated radiation fields. This study investigated one potential source of inaccuracy for diode measurements in modulated beams; the effect of diode housing asymmetry on measurement results.

Point dose measurements in modulated beams are used to augment dose plane measurements, for both system commissioning and treatment verification, and small-volume dosimeters have the potential to minimise volume averaging across dose gradients. For this reason, diodes are an attractive option for the measurement of intensity modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT) point doses. However, use a non-water-equivalent (silicon) active volume with a variable field size dependence, which is often embedded in epoxy resin and surrounded by high-density shielding and electrical contacts. The longitudinal asymmetry of cylindrical diode construction is expected to lead to inaccurate or unpredictable results when the diode positioned parallel to the beam (usually horizontally) in a solid phantom, for IMRT/VMAT point dose measurements.

In this study, the possible effects of diode housing asymmetry on the measurement of steep dose gradients were evaluated by measuring beam profiles, for a 5x5 cm2 static field, with three cylindrical diodes and two commonly used ionisation chambers, with each dosimeter positioned in a 3D scanning water tank with its stem perpendicular to the beam axis (horizontal) and parallel to the direction of scanning. The resulting profiles were used to compare the penumbrae measured with the diode stem pointing into (equivalent to a “stem-first”) setup and out of the field (equivalent to a “stem-last”) setup in order to evaluate the effects of dosimeter alignment and thereby identify the effects of dosimeter asymmetry.

Small but noticeable differences between the penumbrae measured in the stem-first and stem-last directions, for all five dosimeters used in this study. The different orientations resulted in differences of up to 0.2 mm in the measured 20-80% penumbra width and differences of up to 0.4 mm in the off-axis position of the 90% isodose. These differences, which are smaller than previously reported for older model dosimeters, were apparent in the profile results for both diodes and small-volume ionisation chambers.

As an extension to this study, the practical use of all five dosimeters was exemplified by measuring point doses in IMRT test beams. These measurements showed good agreement (within 2%) between the diodes and the small volume ionisation chamber, with all of these dosimeters being able to identify a region 3% under-dosage which was not identified by a larger volume (6 mm diameter) ionisation chamber.

This study does not attempt to resolve the issue of diode over-response to the small beam segments delivered during modulated treatments, however the results of this work should help to remove some of the barriers to the use of diodes for modulated radiotherapy dosimetry in the future.

SP176.3 - Development of a boron distribution monitor using prompt gamma-rays for boron neutron capture therapy

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At Kyoto University Research Reactor Institute, over 500 clinical studies of Boron Neutron Capture Therapy (BNCT) have been performed as of January 2015 using research reactor. On the other hand, clinical trials using accelerator-based epithermal neutron source were started on December 2012. The information of neutron and boron concentration is needed to perform BNCT. Boron concentration is measured by prompt gamma-ray analysis or an Inductively Coupled Plasma (ICP). Blood sample containing with boron is taken before the irradiation. During the irradiation, boron concentration is keeping by using the method of continuous injection of boron compound. However, the real-time information of not only neutron flux but boron concentration is needed to perform the precise dose estimation. We already developed the real-time neutron flux monitor using tiny scintillator combination with the quartz fiber. It is necessary to develop a monitor of boron distribution during the irradiation. In this presentation, we report the developed real-time boron distribution monitor using the information of prompt gamma-rays.

During the BNCT irradiation, prompt gamma-rays with the energy of 478 keV are emitted by the reaction between thermal neutron and boron-10. Boron concentration can be estimated using the measured counts of prompt gamma-rays and thermal neutron flux. We developed the system for measuring prompt gamma-rays using 8x8 Gd3Al2O12:Ce:GAGG scintillator array combination with multi-anode photomultiplier. Ce:GAGG scintillator was manufactured by FURUKAWA Corporation LTD. This scintillator has the characteristics such as high light output, shorter decay time, better energy resolution compared with BGO scintillator that is usually used for the imaging of gamma-rays. Each scintillator with the size of 5mm x 5mm x 10mm3 is isolated with the light reflector. Scintillator array is coupled with multi-anode photomultiplier of H8500C. Each readout signal of photomultiplier is shaped and amplified by multi-channel amplifier and converted to digital signal to obtain energy spectrum of prompt gamma-rays. The gamma-ray collimator is set in front of detection head. This system is surrounded by lead and LiF to shield back ground gamma-rays and thermal neutrons, respectively. Performance test using 137Cs gamma-ray source was performed. It was confirmed that gamma-rays of 662 keV was measured at each readout channel with the energy resolution of less than 12%. The gamma-ray image from 137Cs source was measured by using the region of interest around 662 keV of energy spectrum for each scintillator. It was shown that this system was able to detect the image of prompt gamma-ray emitted from the reaction between thermal neutron and boron-10. In the future, this system will be applied to BNCT irradiation field to detect boron distribution.

SP176.4 - Study of potential effects of a strong magnetic field on radiation dosimeters (TLD, OSLD, EBT3 film, PRESAGE)

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Introduction: Accurate dosimetry in the presence of a strong magnetic field (B) is essential to the use of a magnetic resonance image-guided linear accelerator (MRI-linac) system. In particular, it is important to characterize the response of dosimeters in a B field to determine which types of dosimeters may be used for beam quality assurance and in-vivo dosimetry in a MRI-linac system. In
ABSTRACTS  |  IUPESM 2015 WORLD CONGRESS ON MEDICAL PHYSICS & BIOMEDICAL ENGINEERING

SP177 - Radiation Shielding - Design and Outcomes

TRACK 05: DOSIMETRY AND RADIATION PROTECTION

SP177.1 - Simple expression of x-ray doses below 1 MeV grazing incident on shields of concrete and iron backed by lead

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For an x-ray beam, metal pipes are sometimes used to transport the beam, in which the scattering x-rays are grazing incident on the inner surface of the pipe. Moreover, for targets in medical accelerator facilities, a thick shield is necessary near the target; however, far from the source, a thinner shield is sufficient. For such a tapered shield, the x-rays can be incident on the thin part at a small angle. With increasing incident angle, the contribution of almost vertically scattered x-rays will be dominant owing to the shortest travelling path in the shield, as shown in Fig. 1. In this study, the doses for broad x-rays grazing incident on slabs of concrete and iron backed by lead were calculated using Monte Carlo codes. The results showed that the dose transmission in concrete can be expressed as $D = D_0 e^{-\mu' t}$ at $\cos \theta = 0.01$ and $0.1$ between $0.2$ and $1$ MeV as shown in Fig. 2; $D_0$ is the assumed source strength at the scattering point, and $t$ is the shield thickness. The parameter $\mu'$ was found to be almost equal to the attenuation coefficient for the nearly vertically scattered x-rays. The values of $D_0$ were dependent on $\theta$. For iron backed by lead between $0.08$ and $1$ MeV when $\theta$ was $88^\circ$, the attenuation slope gradually changed and converged to the rate corresponding to the energies of the nearly vertically scattered x-rays in lead. The same experiment was also performed for a stainless steel pipe wrapped with lead slabs of $0$–$2$ mm thickness and white narrow x-rays with a peak energy of $0.09$ MeV incident at $85^\circ$. The results reproduced the doses predicted by the Monte Carlo calculations.

Method: All four types of dosimeters were separated into two categories which were either exposed or not exposed (control) to a strong B field. In each category a group of dosimeters was irradiated with a dose of $0$, $2$, $4$, or $6$ Gy. In the first part of the experiment, dosimeters were exposed to a B field inside a small animal MR scanner in a B field slightly greater than $2.5$ T for at least $1$ hour pre-irradiation and at least $1$ hour post-irradiation. Results were compared with irradiated control groups without exposure to a B field. In the second part of the study, dosimeters were irradiated inside an MR-linac prototype where the B field was $1.5$ T, and the control groups were irradiated with a conventional Linac without a B field.

Results: For dosimeters exposed to a B field before and after irradiation, small difference (<2%) was observed in comparison to the control groups for all four types of dosimeters. For dosimeters with simultaneous exposure to a B field and radiation, OSLDs had the best agreement with the control groups (~1%). For TLs and films, the agreement was about 5%, which was within experiment uncertainty (~6%). However, larger disagreement in PRESAGE dosimeters was observed (10-12%).

Conclusion: Exposure to a strong B field before and after irradiation does not appear to change the dosimetric properties of TLs, OSLDs, EBT3 films or PRESAGE dosimeters. With simultaneous exposure to both the B field and radiation, TLs, OSLDs, and films seem not significantly affected by the B field within the experimental uncertainty (6%). The cause of disagreement in PRESAGE dosimeter data has not been fully determined. Further study is ongoing to test reproducibility and reduce experiment uncertainty.

Fig. 1 Grazing incident x-rays on the shield
SP177.2 - Evaluation of conversion coefficients from Air Kerma to Ambient Dose Equivalent for secondary barriers in diagnostic radiological facilities

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Introduction: The ambient dose equivalent operational quantity is used in many countries for planning purposes of the physical barriers in a radiographic installation. Therefore, it is important to use a conversion coefficient, which turns this dosimetric quantity into a recommended operational quantity [1]. Brazilian regulation establishes that a conversion coefficient (1.14 Sv/Gy) must be used in area monitoring.

Methods: An experimental method was developed for measurement of secondary spectra using a spectroscopic system with CdTe detector [2] and an 1800 cm³ ionization chamber. The thoracic region of an anthropomorphic phantom, RANDO Man, was used as a scatter region. The voltages used began 40 kV up to 150 kV in displacements of 10 kV, the scattering angles were 30°, 60°, 90°, 120° and 150° with respect to the axis of the primary beam. The mean conversion coefficients are calculated using the equation [3]:

\[
\bar{C}_k = \frac{\int_0^{E_{max}} C_k(E) \cdot \Phi(E) \cdot \left(\frac{\mu_{en}(E)}{\rho}\right)_{ar} \cdot \exp(-\mu(E) \cdot x) \cdot dE}{\int_0^{E_{max}} \Phi(E) \cdot \left(\frac{\mu_{en}(E)}{\rho}\right)_{ar} \cdot \exp(-\mu(E) \cdot x) \cdot dE}
\]

Results and Discussion: The Figure 1 shows the mean conversion coefficient as a function of the mean energy of the spectra for secondary beams scattered in angles of 30°, 60°, 90°, 120° and 150° degrees. The blue line corresponds to the constant value of 1.14 Sv/Gy.

Conclusions: In a typical example of radionuclide survey, the estimated ambient dose equivalent using the conversion coefficient calculated from the evaluated spectra, is 40% higher compared to the value obtained using the coefficient recommended in Brazil.

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Figure 1 - Mean conversion coefficient as a function of the mean energy of the spectra for secondary beams scattered in angles of 30°, 60°, 90°, 120° and 150° degrees. The blue line corresponds to the constant value of 1.14 Sv/Gy

References:

SP177.3 - Shielding photon beams to account for adjacent, underground building of a radiation therapy facility

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Introduction
Adjacent buildings may impose not obvious conditions to shield the floor of radiotherapy treatment rooms. Even when a full occupation is considered in lateral places, potential underground, adjacent sites can be of concern due to oblique transmission through the floor.

Method
We consider a barrier wall (primary or secondary), buried underground to a certain depth H, without a concrete slab floor (figure 1). With the same use and occupation factors of the points P1 and any P2, the line p will be sufficiently protected when the broad beam transmission factor corresponding to the path length between the source and P2 is less or equal to that of T, which in turn accounts for any possible position of the source. The variation of the distance from the source to the points on p is neglected, a fact that makes
the model analytically tractable and conservative.

In these cases, the approach can also be extended to account for groundshine radiation in a nearby floor.

**Figure 1:** Shielding barrier of material w and thickness T. The lines a, b, c, d, e and f represent different ray trajectories. tw and te represents the wall and earth thickness traversed by the line c.

Let define the scaling factor from the first tenth value layers: \( f_w,e = \frac{TVLw}{TVLe} \).

If \( f_w,e < 1/2 \) (standard density wall) then the transmission factor corresponding to the line c passing through vertex V1 is greater than those of other parallel lines. The same holds for the line e if \( f_w,e < 1/2 \) (high density wall). Interestingly, a compact expression was obtained:

\[
H_{\max} / T = \sin^3 \theta_{\max} / (1 - \cos^3 \theta_{\max}) \text{ for } f_w,e < 1/2 \text{ and }

H_{\max} / T = \sin^3 \theta_{\max} / \cos^3 \theta_{\max} \text{ for } f_w,e = 1/2,
\]

where \( \cos^3 \theta_{\max} = f_w,e \) and \( H_{\max} \) is the maximum wall depth necessary to shield the line \( p \) for any ray trajectory and the given beam energy.

**Results**

For earth and ordinary concrete (1.5 and 2.35 g/cm\(^3\)) we have \( f_w,e = 0.638 \), \( \theta_{\max} = 30^\circ \) and \( H_{\max}/T = 0.364 \) for any beam energy and type of barrier. In case of high density walls, deeper wall penetration is needed.

**Conclusions**

The critical angles \( \theta_{\max} \) are compatible with typical source positions. The effect of distance has little effect on the accuracy, i.e. it is of the order of \( \cos^3 \theta_{\max} \).

Unless there is a basement under the floor, a full concrete slab is not necessary to shield nearby underground areas. Similar, compact expressions were obtained when bending the wall inwards a certain horizontal length to shield the floor in laminated, primary barriers.

**SP177/4 - Vectorization of the time-dependent Boltzmann transport equation for photon beams: applications in radiation shielding**

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**Purpose**

We introduce a method to evaluate the steady state solution of the angular photon flux after numerical evolution with the time-dependent Boltzmann transport equation (TE). The Penelope Monte Carlo (MC) method was used to test the convergence and accuracy for different time, energy, direction and spatial mesh sizes. Benchmarking was performed by calculation of radiation transmission in primary barriers of radiotherapy treatment rooms for different wall materials, beam energies and angles of incidence. Laminated barriers where simulated to assess the effect that different positions of a lead layer within a concrete slab has on the overall transmission factor and beam energy spectra.

**Formalism**

We applied our model on a semi-infinite slab, yet preserving the main phase space data details. The TE was converted into a system of ordinary differential equations by integration over a number of spatial mesh intervals, keeping only the temporal derivative. A weighted diamond difference scheme was used to ensure positive solutions. Flux vectorization in angle and energy was carried out using discrete ordnates and the multi-group approach, respectively. The system was expressed as \( \delta \Phi(t) / c \delta t = A \Phi(t) + b \), where \( \Phi \) is the vectorized flux, \( c \) is the speed of the particles, \( A \) is a time independent, square matrix that contains physical and numerical parameters like cross sections and spatial mesh sizes. The vector \( b \) accounts for the boundary conditions.

We found that under proper numerical conditions the matrix \( A \) is strictly diagonally dominant by columns. As such, it is non singular and the steady state can be calculated from \( \Phi(t=\infty) = -A^{-1}b \). Also, all the elements of \( b \) are non negative and the matrix \( -A \) is a non singular, M matrix. As such, all the elements of its inverse are non negative. Thus, the former product always yields positive values.

Jacobi and Gauss Seidel methods can be used by discretization of the time variable in intervals \( \Delta t \). For a spatial mesh size \( \Delta x \) the former properties of \( A \) and numerical convergence are attained if \( \Delta x^2 < (\Delta t)^2 \), where \( \sum T \) is the maximum total, macroscopic cross section for the given mesh size and energy spectrum under consideration.

**Results and conclusions**

Numerical simulations agreed well with MC simulations and published data of transmission factors for different barriers and incident beam angles were accurately predicted. Interestingly, it was found that the position of a lead layer within a concrete slab significantly affects the overall transmission factor of the laminated barrier when irradiated with Co\(^{60}\) beams. We note that beam softening in the concrete part improves the lead absorption capability when placed in the distal part of the shield. This could be relevant when lead is used to increase the shielding of a Co\(^{60}\) high dose rate brachytherapy room.

Spatial integration and matricial theoretical treatment of the transport equation allowed for the numerical conditions for convergence,
positivity and speed of the approach, without the need of explicit
collection of the matrix A.

Despite the algorithm was tested for a 1D geometry, the concept
could be extended to 2D and 3D situations.

### SP177.5 - The use of FLUKA Monte Code in the re-design of
radiotherapy mazes with the use of lead cladding of a few mm
thickness

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**Abstract**

A novel proposal of covering part or the whole of the maze concrete
walls with a few mm of lead will be presented. The findings have
direct implications for new designs of mazes for radiotherapy rooms
and can help with upgrades, especially when space is limited [1].
Covering part or all of the maze walls with lead was studied in situa-
tions where extending the maze length or changing its shape
would be not possible because of space restriction.

**FLUKA**

Monte Carlo simulations were used to examine the reduction of the
dose from scattered photons at the maze entrance of radiotherapy
room facilities. A pilot study at Singleton Hospital in Swansea, UK,
has pioneered the use of lead sheets of various thicknesses to
absorb scattered low energy photons in the maze of radiotherapy
room. The Figure shows the new shape of the maze incorporat-
ing this feature. The FLUKA computations have shown that there
was a noticeable reduction in the dose when lead sheet of a 2 mm
thickness was added to certain walls and floor in the maze (Table).
One explanation for this finding is that the reduction was due to the
strong effect of the photoelectric interaction of the lead, in effect
trapping the back scattered photons. The results showed that adding
1 to 4 mm lead to walls and floor of the maze reduced the dose
at the maze entrance by up to 90%. However, certain walls contrib-
uted more
than others for the dose reduction. The floor was found to contrib-
ute about 8% in the dose reduction when it was covered with 2 mm
lead. Other scenarios were simulated where the reduction was most
cost effective. By comparing the dose reduction from the FLUKA
calculations with measurements it is concluded that FLUKA Monte
Carlo Code was found a very useful tool for maze design, support-
ing
modifications that offer better access for patient and machine main-
tenance without sacrificing radiation protection.

[1] Al-Affan I A M, Hugtenburg R,
B, Al-Kharouf S and Ghaith, A, 2015, Dose reduction of scattered
photons from concrete
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**Table.**

Calculations of dose at the maze entrance using FLUKA code for
scattering photons from concrete walls with 2mm lead (4 maze
walls and floor).
A fundamental challenge in understanding mechanisms behind functional and pathologic states of the brain is to describe the functional and effective connectivity within the brain. This knowledge is a key step towards developing neuromodulatory strategies to control cortical circuits in the treatment or prevention of neurological disorders. In humans large scale functional networks obtained from electroencephalography, intracranial EEG, or functional magnetic resonance imaging cannot describe cortical processing at the microcircuit level, the result being that to date this aspect of human neocortex remains largely unexplored. A high throughput approach is required to elucidate connectivity principles between different neuron phenotypes in the human brain and link cellular activities to physiologic signatures such as cortical rhythms and how these rhythms modulate cognition and behavior.

We have recently described that human cortical tissue, which is maintained in vitro, can be induced to generate coordinated population activity (oscillations) similar to those observed in vivo. Both narrow and broad band power increases were observed with narrowband activity being dominated by theta oscillations and which modulated high gamma (broadband) activity. Theta oscillations were coherent between cortical laminae with deep layer theta leading superficial layer activity. By further exploring the cellular basis of these findings, we have described laminar specific cellular specializations: deep layer putative pyramidal neurons have features that promote theta generation in deep layers (h-current, higher input resistance).

To extend these results, and investigate large scale cellular activities in the human cortex, we have performed in vitro multi-electrode array recording. Data were obtained from 500 μm thick temporal neocortical slices (tangential to pia) using a submerged 64-channel multi electrode array (MEA) system USB-MEA60 (Multi Channel 151 Systems, Germany) on a TIN array with inter electrode spacing of 200 μm. The data was acquired at 25 KHz and then split into local field potential (LFP; 1-300 Hz) and multiunit activity (MUA; 300-3000 Hz) using band pass filters. Individual spikes were detected in the MUA time series using a negative threshold defined to be 4 times the average background noise level. Slices were ultimately processed histologically to localize the electrodes and confirm the units’ depth in the cortical laminae. Unit activity was characterized during a 10 minutes baseline period, during bath application of 50 nM kainate (10–15 min), and then addition of 50 μM of carbachol - condition during which we have observed theta oscillations.

This protocol induced theta oscillations and gamma activity observed as increases in spectral power in LFP signals. Preliminary analyses on MUA signals revealed that we can sort units into narrow-spiking and broad spiking units, and these units display distinct patterns in their inter-spike intervals, which appears to be layer specific. Overall our results suggest that there are laminar specific specializations at the cellular level that may underlie the coherent theta oscillations observed between superficial and deep laminae.

SP178.2 - Astrocytes enhance neuronal long term potentiation in a biophysical model of epilepsy
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While originally astrocytes have been thought to only act as support to neurons, recent studies have implicated them in multiple active roles. In particular they have been shown to be able to moderate and alter neuronal firing patterns both in normal and epileptic conditions. Astrocytes can perform this using several mechanisms, including potassium clearance from the extracellular space as well as through the formation of tripartite synapse with both pre- and post-synaptic terminals. It has been shown that astrocytes exhibit impaired potassium clearance in epileptic models, which leads to hyperexcitability conditions in the network. Additionally, astrocytes react to glutamate release into the synaptic cleft triggering a signalling pathway that culminates in the increase of intracellular calcium concentration in postsynaptic neurons. In addition to being involved in the hyperexcitability of epileptic networks, intracellular calcium increase is also key in long term potentiation (LTP) of neuronal connections which is mediated both through NMDA-receptor channels and via the formation of new AMPA channels. Coincidentally, ripple high frequency oscillations (HFO; ~100 Hz) which have been experimentally shown to invoke LTP under normal conditions, have also been suggested as one of the potential biomarkers for epilepsy in patients. Despite these findings and general interest in the deeper insight into the biophysiological mechanisms behind epileptic seizures, computational modelling efforts have been focused more on complex neural networks without the significant inclusion of astrocytes.

Methods
In this study we introduce a computational model of CA3 region of hippocampus, consisting of a network of an astrocyte and a pyramidal cell with a feedback inhibitory interneuron. We use it to investigate the effects of astrocytic ion homeostasis modulation and calcium dynamics on long term potentiation as one of the factors in the onset and cessation of seizure like events. In addition to phenomenological feature assessment, frequency analysis is used to determine frequency dynamics during long term potentiation and depression.

Results
Preliminary results of the model show that astrocytes respond to seizure-like conditions with (a) increased calcium release, (b) reduced rates of potassium clearance mechanisms, and (c) enhancement of long term potentiation of pyramidal cell-interneuron connection following 100 Hz stimulation of the pyramidal cell.

SP178.3 - Influence of the ‘sympathetic slump’ on biomechanics of the sympathetic trunk
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Introduction
Several sources show a correlation between altered peripheral nerve biomechanics and disturbed nerve function. Some clinical studies suggest that mechanical strain on the sympathetic trunk (ST), a small autonomous nerve bundle in front of the spine, could play a role in chronic disorders like sympathetically maintained pain. A clinical test, the ‘sympathetic slump’, consisting of full spinal
flexion combined with contralateral lateral flexion and rotation in a long sitting position, was proposed to maximally lengthen the ST and thus evoke symptoms. However, biomechanical data is lacking. Investigation of the ST is challenging both through dissection and medical imaging due to its position, size and numerous side branches. Therefore, the aim of this study is to develop a technique to visualize and quantify ST motion in the sympathetic slump position.

**Methods**

The ST's of a cadaver specimen were dissected from an anterolateral angle, until there was sufficient visualization for bilateral insertion of 30 metal markers without detaching the ST from its environment. CT scans were performed in supine position, neutral long sitting position, and sympathetic slump position to the left and right. A second supine CT scan was used to assess possible marker migration. Markers and vertebrae were segmented and 3D-rendered. Displacement of markers from the neutral to each experimental position were calculated and adjusted for vertebral movement using custom Matlab code. Furthermore, inter marker distances between adjacent markers (along a mathematical spline curve drawn between the markers to approximate the course of the ST) were calculated for each position to measure ST changes in length. Only marker movements larger than the combined errors of segmentation, registration and marker migration were taken into account (4.22mm for long sitting position, 4.51mm for slump positions and 2.18mm for inter marker distances).

**Results**

Overall, marker movement and inter marker movement were consistent. Only the lower lumbar markers showed significant cranial movement in both sympathetic slump positions (fig1.A), and significant movement was noted around two osteophytes during contralateral sympathetic slump (fig1.B). The traditional slump showed no significant movement of the ST.

**Conclusion**

Despite the limitations in motion quantification (strain could not be calculated since only markers and not the entire nerve structure was visualized), the results of this study suggest that the sympathetic slump inflicts most ST movement in the lower lumbar region and around structural pathological changes like osteophytes. Larger datasets could confirm these findings and further increase insight into ST biomechanics.

**SP178.4 - Superparamagnetic Nanoparticles for Epilepsy Detection**

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Epilepsy is the most common neurological disorder that is known with uncontrolled seizure. Around 30% of patients with epilepsy resist to all forms of medical treatments and therefore, the removal of epileptic tissue is the only solution to get these patients free from chronic seizures. The precise detection of an epileptic zone is the key to its treatment. In this paper, we propose a method of epilepsy detection using brain magnetic field. The application of superparamagnetic nanoparticles (SPMNs) as nanoprobes for the detection of the epileptic area inside the brain is investigated in this new research approach. The aggregation of nanoparticles in the weak magnetic field of epileptic brain is modeled using potential energy minimization technique. The results prove the aggregation of nanoparticles influenced by weak magnetic field in the range of pT.

**SP178.5 - Automatic detection of epileptic seizures in scalp EEG**

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The study and clinical diagnosis of epilepsy is performed by a specialist with years of experience through simple visual inspection of the EEG record with the aim of identifying areas where seizures that characterize this condition occur. However, given the variability of the morphology of epileptic seizures and their similarity to other events as various artifacts, alpha spindles and paroxysmal activity detection work is hindered greatly. In addition, long-term records, due to the volume of information, the time used specialist study is considerable. For this reason the automatic detection of epileptic seizures has become a vital tool for the specialist.

This research proposed design and development of an algorithm for automatic detection of epileptic seizures by using simple statistics measurements, the Teager Energy Operator and power spectral analysis techniques for features extraction from a data set of reference seizure events. The database used for this project belongs to Cuba Neuroscience Center (CNEURO) it contains non-invasive EEG recordings of 20 patients of both sexes, aged between 4 and 37 years, of which 15 had may generalized seizures and 5 partial seizures, further data were recorded in the various states of wakefulness and sleep. EEG signals were acquired using the equipment MEDICID 5 at a sampling frequency of 200 Hz and an A / D converter of 16 bits. For the record signal an array of 19 electrodes with international Positioning System 10-20 and referential mount was used. The implementation of the algorithm was performed in the MATLAB tool, and then scored as a result of quantitative evaluation of the sensitivity of 94.5% and a selectivity of 87.6%.

The results of the quantitative evaluation of the algorithm show that could be used as a tool to support the specialized medical staff.
Seizure Detection Algorithm

SP178.6 - Beta/Theta Neurofeedback Training Effects in Physical Balance of Healthy People

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This study aimed to investigate beta/theta ratio (BTR) neurofeedback training (NFT) effects in physical balance of healthy individuals. Thirty-one healthy volunteers were randomly assigned to NFT group (n=15) and non-NFT control group (n=16). The NFT group completed 25 sessions in consecutive five days with five sessions per day. Before and after NFT, physical balance was measured by Wii Balance Board (WBB). The non-NFT control group only performed the physical balance test on the first day and the fifth day without any training. The results showed no significant improvement in physical balance in the NFT group compared to the non-NFT control group. The reason of the failure will be further studied in our future work.

SP178.7 - Potential Benefits in Comparing the Neural Control Networks Studies Between the Oculomotor and Cardiac Pacing Systems

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Clinical evidence has reported cases of acquired ocular motor apraxia after aortic surgery [1]. This paper draws attentions to potential insights gained by comparing neural control network studies between the oculomotor and cardiac pacing systems.

Both authors independently did original research on the oculomotor system, but no experience in the cardiac pacing system. In view of the rapidly increasing health problems of cardiac arrhythmia particularly among aging populations, we report our findings in the oculomotor system and suggest implications for the cardiac pacing system. It is not unusual for the biological systems to share common mechanisms for their operations.

In 1974, Cheng, Outerbridge performed inter-saccadic interval analysis of nystagmus eye movements of vestibular and optokinetic [2] origins. Optokinetic nystagmus from healthy human subjects were recorded at different intensity levels elicited by different speeds of the optokinetic stimulus. The time intervals between the onset of consecutive saccadic components, which appear random, were analyzed statistically. Resulting interval histograms showed multimodal form in which the higher order modes were approximately integral multiples of the basic mode. Now, the inter heart beat intervals (RR intervals) during cardiac arrhythmia appears also to be random, and if the histograms of the RR intervals also exhibit multi-modal behavior, it would imply that during heart-beat pauses in some “sick sinus syndrome”, there is high probability that ensuing pauses between hear beats could suddenly take on twice or three times as long, thus greatly raising the risks of syncopal episodes.

Recently, Ghahari, Enderle used advanced computational modeling to demonstrate an integrative systems approach to address the challenges involved in the implementation of the saccade dynamics from the local neural circuit computations in the midbrain [3]. A biophysically-realistic neural network model was developed to examine the saccade dynamics. To explore the synaptic network function and characteristics in post-saccade oscillations, computational neural modeling of the glissades was investigated as a deficiency in the oculomotor control mechanism. In conclusion, comparison of the glissades with normal saccades confirmed that glissades were observed because of anomalies in saccade neuronal programming. They theorized that such deficits are due to unplanned post-inhibitory rebound burst firing in the antagonist motoneurons, as a coordi-
nation error in returning to tonic firing rates.

The brainstem has neural sites in the medulla oblongata responsible for controlling heart rates. Potential research are: First, explore more evidence to answer a vital question: “could glissades in eye movement be compared with the sick sinus syndrome of cardiac arrhythmia?” Second, search details on neuroconnectivity structure and underlying neural control processes important for driving the cardiac sinus pacemaker. The answers are hoped to have far-reaching proportions in benefiting patients dealing with arrhythmia disturbances.

References

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SP179 - Brain, Head/Neck, Spine: Part 2

SP179.1 - Acceptance Test of the first Hospital Cyclotron for Production of PET tracers in Iran

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Introduction: The first fixed-energy hospital isochronous cyclotron (GE PETtrace 700) installed in Masih Daneshvari hospital can accelerate the negative hydrogen ions (H-) up to 9.6 MeV energy. This cyclotron equipped with six targets for production of the most common radioisotopes used for PET/CT scanners. It is well known that the acceptance tests should be done by physicist when a cyclotron installed in order to measure the performance claimed by manufacturer. This study reports the results of acceptance tests in our GE PETtrace 700 after installation for all targets.

Material and methods. Production of 18F- is done using the fluorene-18 silver body target with 1.7 ml volume by bombardment of enriched 18O-water in 120 minutes irradiation time and using 50 μA target current and high-pressurized helium. Whereas by bombardment of 16O-water with 35 μA target current, the 13N-NH3 is produced after 25 minutes. The 13N-NH3 target consists of a silver container with 0.8 ml volume which over pressure methane is used to the target for direct production of 13N-NH3. Production of 11C-11CO2 is performed by the gaseous target with aluminum target body and volume of 23 ml. The 11C-11CO2 is produced by the bombardment of Nitrogen-14 using 30 μA target current in 30 minutes. After bombardment the activities were transferred to the dispenser unit and measured by dose calibrator separately (ATOMLAB 500).

Results: The yield performance of 2858.32, 138.15 and 1047.5 mCi has been observed for 18F, 13N,13NH3 and 11C,11CO2 after 120, 25 and 30 minutes irradiation time with target current 50, 35 and 30 μA respectively. It is clear that product yield that measured in factory were 2500, 75 and 900 mCi, respectively using the mentioned standard situation.

Conclusion: during our acceptance test, the measured yield for all tracers was higher than the value reported by manufacturer

SP179.2 - HiFEM - An Integrated Approach for Human Centered Risk Management for Medical Devices

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The implementation of appropriate processes for risk management and usability engineering are mandatory for the approval and application of medical devices (s. ISO 14971:2006 & IEC 62366:2007). As the complexity and speed of development of medical devices is increasing together with the incidents of human error in medicine [1-3], more sophisticated tools for interlinking usability engineering and risk management, i.e. human error risk analysis and human risk control respectively seem to be mandatory. The HiFEM methodology and the corresponding software tool mAIXuse developed in our lab, supports medical device manufacturers and developers by a
model based human risk analysis approach. Based on a two-folded approach, HiFEM provides a task-type-sensitive modelling structure with integrated temporal relations based on [4] combined with a subsequent analysis of critical resources allocation and related potential errors adopted from and related error taxonomies. The approach can be used in an early developmental stage as well as for product validation. In a comparative study the HiFEM method outperformed a classical process-FMEA related the detection of critical errors of a surgical planning and navigation systems. These positive results have been confirmed in further applications. Moreover, we implemented a new method for systematic human risk control (mAIXcontrol) as part of the HiFEM methodology. Accessing information from the method’s knowledge base enables the operator to detect the most suitable countermeasures for a respective risk. 41 approved generic countermeasure principles have been indexed as a resulting combination of root causes and failures in a matrix. The methodology has been tested in comparison to a conventional approach as well. Evaluation of the matrix and the reassessment of the risk priority numbers by a blind expert demonstrate a substantial benefit of the new mAIXcontrol method vs. classical methods. Concerning the number of appropriate counter measures for risk control, the mAIXcontrol method shows predominance compared to classical brainstorming approach, although the required time for application of the method is slightly higher than for brainstorming. Evaluation showed, that the use of the method requires a certain learning curve. The test subjects needed a learning time of more or less 15 minutes before a working routine had been adopted. This presumes a learning effect that increases time efficiency for experienced users.

References

SP179.3 - Ultrasonic Microscanning for Digital Dental Impression

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Introduction
Silicone based impression-taking of prepared teeth is well-established but potentially less reliable, error-prone and inefficient for computer aided design and manufacturing (CAD/CAM) of dental prosthetics. Introral optical scanners have been introduced to increase efficiency of CAM but no breakthrough occurred so far. An accurate impression of the tooth preparation is highly important for the final fit of the prosthesis. Therefore, retraction cords or electro-surgery are commonly used to invasively uncover subgingival margins prior to the impression. These methods may lead to inflammation or permanent damage of the gum. In addition, bleeding from inflamed gingiva, saliva, air bubbles or other particles can decrease the accuracy outcome of both the conventional and optical impression. Digitizing a gingiva-covered margin is an infeasible task due to the fact that optical waves can hardly penetrate gingival tissue.

Concept
High frequency ultrasound (HFUS) has been recently introduced as an alternative to optical scanning [1]. HFUS is less sensitive against oral fluids and in principal able to penetrate gingiva non-invasively. Although HFUS-systems have been introduced in other medical fields, none of them suits the challenging requirements and high accuracy demands for dental impressioning. Hence, our goals are to develop a new ultrasonic technology, which is able to scan supra- and subgingival dental hard- as well as soft-tissue structures and to integrate it into the CAD/CAM-process for dental restorations. Whereas in case of optical digitization the dentist usually has to wait until bleeding and swelling subsides, an HFUS-based impression can be performed within the same session.

Results
We conceived a miniaturized device based on HFUS-technology and a coupling adapter for impedance matching during intraoral application [1]. Therefore, we have integrated a HFUS transducer (>50 MHz) into an intraoral scanner in order to achieve the necessary spatial resolution for impressioning. A multi-axis kinematic has been developed and successfully tested for accurate positioning of the HFUS-probe. In-vitro surveys using comparable transducers have already proved the applicability of the concept [2]. In a recent study Marotti et al. show a potentially good fitting accuracy of metallic copings for single tooth crowns planned with HFUS-Scans [3].

Discussion and Conclusion
Ultrasound-based impressions have been able to compete with optical systems concerning the accuracy and the final fit. Subsequent to the completion of the technical development the evaluation of the presented system in clinical surveys remains.

References

SP179.4 - A study on prefrontal blood flow in patients with moderate dementia and severe dementia using near-infrared red/infrared

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Recently, near-infrared spectroscopy (NIRS) is one of the most im-
We examined 30 patients with severe dementia (age 83.7±6.6, 7 male, 23 female, MMSE:1-14) and 20 moderate dementia (age 82.7±7.1, 5 male, 15 female, MMSE:15-23), 16 health elderly controls (age 80.5±4.6, 2 males, 14 females, MMSE:24-30). Activation with the subtasks starts at 0, 15 and 45 second in the category fluency task, 45 and 75 second subtasks again.

The average number of category fluency task is shown in Fig.1. Severe dementia patients achieved an average score of 2.7±2.3 in the category fluency task. On the other hand, moderate dementia achieved score of 4.4±2.3, health elderly controls score were 8.2±2.2. Figure 2 shows increase volume of prefrontal blood in Fp1. Our results have shown that health elderly controls show an increase in the blood volume during the category fluency task while those with severe dementia patients did not show any relevant increase of blood volume while performing the same task.

The results obtained suggest that category fluency tasks and near-infrared spectroscopy may be useful to determination for severity of dementia.

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**SP180 - Information Technologies in Healthcare Delivery and Management: Part 4**

**SP180.1 - Increasing efficiency of data transfer in WBANs**

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Due to aging of the society and subsequent increase of incidence of chronic diseases, use of wireless technologies in patients monitoring had large growth in latest years. After initial relatively simple point to point telemetry applications, today there is a large number of wireless devices for patients’ physiological data monitoring, mobility tracking and exercising evaluation etc. These new applications are due to development of low power and inexpensive wireless communication technologies and they are mainly realized as a wireless body area network (WBAN). In health care today there is a need for more complex patient monitoring with trend predictions which cause increasing quantities of data for their transfer from the patient, but also increase current consumption drawn from the battery. It is crucial to obtain high efficiency of all segments in WBAN communication, so that the device can maintain reduced battery size and keep continuance. For user acceptance, it is crucial to make the wireless sensor nodes of the WBAN sensor node inconspicuous, enabling that they do not interfere with measurements. In this paper we present a solution for direct database access from microcontrollers in WBANs, which is power and code efficient. It provides standard powerful way of using microcontroller based WBANs with classic SQL database. This reduce development time and lower power consumption.

**SP180.2 - Decision support system for no common emergency in a big city with intelligent routing algorithm and attention quality parameters evaluation.**

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The latest news on no common emergencies or disasters occurred in the world show us the necessity to develop tools in order to support a rapid and efficient response. The arrive time and the first attention to the patient in the emergency place is the golden time of the response. The objective of this paper is to support decisions in a disaster for a big city on decrease arrival time and improve attention quality in the place of the emergency. It is important to notice that the model is for a no common emergency like earthquake, flood, tsunami or terrorism and specific when we don’t know what is happening on the route of the emergency and the scope of the tragedy so for the first reaction. The first instants of the response have been modelated to have two important details, the routing of the emergency vehicle and the primary attention in the place of the emergency. A specific routing algorithm for states of not common emergency was developed. The algorithm has been implemented in language C, having being defined two interactive knowledge bases for the information network and an intelligent search with a specific heuristic for no common emergency. Besides, a discreet event simulation model is used to support decisions of the rescue teams.
on the place of the emergency. This model is a good tool to be implemented inside the rescue vehicles in order to support rescues, it could be used without capitation time if the rescues manage interactive computers tools. Finally we can conclude that rescues could use this tool for the first reaction to the emergency and this gold time could be supported.


**SP180.3 - Development of a Multi-Center Clinical Trial Data Archiving and Analysis Platform**

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Quality results from multi-center clinical trials require consistent and robust trial protocols capable of quantifying or eliminating differences across participating institutions. The vision of the Quantitative Imaging for Personalized Cancer Medicine (QIPCM) program is to provide end to end testing and analysis support for clinical trials to achieve improved consistency and reliability in clinical trial data.

**Methods:** The QIPCM clinical trial data archiving and analysis platform consists of a customizable image anonymizer and secure transport pipeline (RSNAs Clinical Trial Processor, CTP), a dedicated remote analysis platform, and a dedicated server for the archival and storage of medical images.

The anonymized images received from the remote sites are held in a secure drop box where there are subjected to a quality assurance check. This check ensures both that no patient health information remains and that the image set is complete before it is then subsequently forwarded to the clinical trial PACS at which point trial based permission controls are enforced. The images can then be analyzed either by QIPCMs dedicated team of imaging experts or remotely by the trial investigators.

In addition to the platform infrastructure, a set of customized image analysis tools has been developed which are available for use on the remote analysis workstations. These tools range from quantitative functional imaging tools for 4D kinetic modeling of dynamic contrast enhanced-CT and MRI and hypoxic fraction analysis in PET; to simple 1D RECIST. Alternatively remote users can choose to utilize their own custom applications on the virtual environment while still making use of the central data storage and powerful remote analysis servers.

**Results:** The QIPCM team has established infrastructure and support services to sustain an ever growing number of multi-centre clinical trials. The platform currently serves 15 internal and 6 multi-center clinical trials spanning 9 hospitals and imaging centers in Canada and the United States, with more trials to be added over the upcoming months. The image store currently holds in excess 1.8 million individual tomographic slices comprising more than 510 individual imaging studies from over 145 patients. The QIPCM team has also provided PET QA services for 3 different multi-center trials at 10 different sites across North America.

**Conclusions:** The current QIPCM platform is a fully functional commercial system with robust backup, storage and processing capacity. Within the next two months a further 50 TB of storage and 2 more high powered computational servers will further enhance performance.

**SP180.4 - Global Health Catalyst: A systematic Space-time compression platform for catalyzing global health collaborations in Radiation Oncology**

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The benefits of global health collaborations in cancer Care, Research and Education (CaRE), are already well established, and there is growing consensus that our ability to address the growing global burden of cancer will increasingly depend on concerted international collaborations. Such collaborations could benefit from a major recent upsurge of interest in radiation oncology global health highlighted in recent Red Journal articles. However, apparent to this upsurge, a common issue evident at global health summits, seminars, or symposia is that SPACE-TIME is a major barrier to many who really want to participate/collaborate in global health CaRE. Given the increasing disproportionate global burden of disease in Low and Middle Income countries (reported in the recent World Health Organization report), there is growing urgency for strategies that can reduce this space-time barrier, make it easier for people to collaborate. Systematic Space-time compression represents one such strategy. Here space-time compression refers to the use of advanced Information and Communication Technologies (ICTs) that condense or elide spatial and temporal distances. In this work a catalogue of ICTs for space-time compression to enhance global health collaborations in Radiation Oncology (RadOnc) including Medical Physics is presented. A new platform, Global Health Catalyst, being developed at Harvard Medical School to integrate these ICTs for concerted high impact global health CaRE collaborations is presented. Preliminary projections show that this systematic approach could convert the huge upsurge in global health interest into coordinated high impact global health collaborations in RadOnc CaRE, and enhance the effectiveness of other global health initiatives. Figure 1 highlights some of these ICTs for Radiation Oncology Global health integrated in the Global Health Catalyst platform.

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PS01 - TRACK 01: IMAGING

PS01.002 - Correction of Metal Artefacts Induced from Pace-maker and ICD Leads in CT-Based Attenuation Correction of Cardiac SPECT data
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Objective: In CT-based attenuation correction (CTAC) of myocardial perfusion SPECT data, the metallic artefacts due to pacemaker and ICD leads attached to the myocardial wall can induce overestimation or underestimation of activity in some segments of the myocardium. In the present study, we have identified the cause of this discontinuity artefact. A 1-cm air gap is introduced between the two halves of a 30-cm diameter Solid Water phantom to accentuate the artefact, which is manifested as fading stripes in the scan direction (figure 1a,b). The artefact remains when the phantom is rotated to place the gap at an arbitrary angle relative to the horizontal. As the gap thickness is increased, a semi-circular dark streak appears around the isocenter. In the sinograms (figure 1c,d), the artefact does not follow a sinusoidal path; instead, it is a fading remnant of the gap at a fixed detector location. This indicates that the artefact is caused by detector lag due to the incomplete readout of the flat-panel imager, which leads to ghost signals after high intensity irradiation. The lag blurs the edges by a few pixels, which leads to the discontinuity at the isocenter (figure 2). Analysis of the sinogram profiles (figure 1c,d) shows that the lag decay can be described by a double exponential, which agrees with the literature. The variation of the lag with the mA yields different decay time constants. Previous studies have characterized and/or corrected for the radial increase and the azimuthal decrease of the lag, but have not identified the presence of a discontinuity at the isocenter as a manifestation of detector lag.

Figure 2: A vertical profile from the difference of the sinograms, CW minus CCW. The abscissa is the index of the projections. The ordinate is the pixel value in thousands. The discontinuity is around the projections that pass through the air gap.

PS01.001 - A discontinuity artefact at the isocenter of on-board CBCT images
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In our recent investigation [Ali et al PMB 60 1461 (2015)], rotational artefacts in the Elekta XVI cone beam computed tomography system were identified and corrected for. However, a residual discontinuity artefact remained at the isocenter. It was dependent on the scan direction but only slightly on its speed. In the present study, we have identified the cause of this discontinuity artefact. A 1-cm air gap is introduced between the two halves of a 30-cm diameter Solid Water phantom to accentuate the artefact, which is manifested as fading stripes in the scan direction (figure 1a,b). The artefact remains when the phantom is rotated to place the gap at an arbitrary angle relative to the horizontal. As the gap thickness is increased, a semi-circular dark streak appears around the isocenter. In the sinograms (figure 1c,d), the artefact does not follow a sinusoidal path; instead, it is a fading remnant of the gap at a fixed detector location. This indicates that the artefact is caused by detector lag due to the incomplete readout of the flat-panel imager, which leads to ghost signals after high intensity irradiation. The lag blurs the edges by a few pixels, which leads to the discontinuity at the isocenter (figure 2). Analysis of the sinogram profiles (figure 1c,d) shows that the lag decay can be described by a double exponential, which agrees with the literature. The variation of the lag with the mA yields different decay time constants. Previous studies have characterized and/or corrected for the radial increase and the azimuthal decrease of the lag, but have not identified the presence of a discontinuity at the isocenter as a manifestation of detector lag.

Figure 1: (a,b) Discontinuity artefact at the isocenter for clockwise (CW) and counterclockwise (CCW) scans. (c,d) Lag effect, demonstrated as a fading remnant of the gap at a fixed detector location. Time is flowing downwards in the CW sinogram and upwards in the CCW sinogram.
It should be noted that due to low spatial resolution of SPECT images and considering the CT-based attenuation correction process which smoothes the CT images, the impact of metallic leads in SPECT images that corrected for attenuation using artificial CT images is not clinically significant.

![Figure 1](image1.png)  
**Figure 1.** Typical CT image in a patient with a ICD lead: (a) artifactual CT image, (b) corrected CT image with MAR, (c) difference image between a and b, (d) μ-map of artificial CT image, (e) μ-map of corrected CT image with MAR, (f) difference image between d and e.

The Figure 1.b shows the microcalcifications detected using wavelet and Segmentation by threshold. For detecting microcalcifications in an image mammographic.

**Author(s):** Rubens V. Souza Sales¹, Lourdes M. Brasil², Fatima Elpidio¹, Janice Lamas¹

¹Gama, University of Brasilia (UnB), Gama-DF/BRAZIL, ²Fga, UnB, Brasilia/BRAZIL

According to the World Cancer Research Fund, breast cancer is currently the second most common cancer in women worldwide. Many breast cancers are characterized by the presence of calcifications which are calcium accumulation in breast regions, which can be benign or malignant. Among the calcifications stand out microcalcifications, which are generally smaller than five millimeters, these are more suspicious of malignancy making early diagnosis essential.

Due to the size, microcalcifications are more difficult to detect directly in an image of mammography, requiring image processing techniques, to assist the health professionals in the diagnosis. The techniques used for comparison in the detection of microcalcifications are: one based on Transformed Wavelet and another in segmentation by threshold.

Prior to the comparison, it is necessary to perform the detection of microcalcifications using each technique separately from the same image. In Figure 1.a has the original image of mammogram used in both techniques for microcalcifications detection. After the implementation of the two techniques, we can compare the results of both based on the number and position of the detected microcalcifications. The platform and language for development of algorithms is the Software Matlab, while that mammography images used are provided by Radiology Clinic Janice Lamas of Brasilia, Brazil.

In the wavelet technique, the image is decomposed into three directions (horizontal, vertical and diagonal), and the sum of these produces the resulting decomposition, it performed using two levels of decomposition and the Haar mother wavelet. After the decomposition occurs thresholding and binarization. In segmentation, an initial thresholding is used to define the points of interest, the dilatation of these points is then performed, and then the image are thresholded and binarized to indicate the detected microcalcifications. For your hit rating and detection performance, is needed help of specialist.

The Figure 1.b shows the microcalcifications detected using wavelet

**PS01.003 - Anthropomorphic Phantom of the Pancreas for Scintillation Camera Tests**

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It is well known that several medical procedures involving the use of ionizing radiation has made the radiation physics indispensable in modern medicine. The nuclear medicine, for example, is a medical specialty that uses the known radiopharmaceuticals. The radiopharmaceuticals, also known as radioactive tracers, have radionuclides associated with drugs in their composition and are administered to the patient for diagnosis and treatment of various diseases. For diagnostic purposes, particularly, it is important that the images reveal, more accurately possible, the relevant details of any present anomaly. Therefore, to ensure the quality of the equipment used in nuclear medicine services, it is important that quality control tests be performed frequently. In this context, organizations such as the International Atomic Energy Agency (IAEA) recommend periodic testing of quality control of scintillation cameras. However, it is unacceptable that such tests be performed directly on patients, since the use of ionizing radiation can damage your health. In this regard, the use of physical and anthropomorphic phantoms becomes indispensable for quality control tests be performed more safely and efficiently. Therefore, the objective of this work was the development of the phantom of the pancreas for quality control optimization in scintillation cameras, and hence obtaining images more reliable for diagnosis in addition to controlling the dose of the radiation is used in efficiently to the quality and definition in image processing. The studies performed showed that the anthropomorphic phantom of the pancreas can be used to optimize image acquisition devices, in particular for spatial resolution tests. Besides the nuclear medicine test equipment, it is important to mention that the simulations with phantom of the pancreas can contribute to the continuing education of professionals in nuclear medicine, improving its ability in the identification of cold nodules and/or hot nodules.

**PS01.004 - Comparing two image processing techniques, Wavelet and Segmentation by threshold, for detecting microcalcifications in an image mammographic.**
technique, while Figure 1.c shows the detected microcalcifications using a technique segmentation by threshold. Note that by Wavelets could be detected more calcifications compared with segmentation (2.1 times more). This shows the advantage of using wavelet due to the fact that we can work on multiresolution for different frequencies. The Segmentation there is more information losses in steps thresholding and dilation. The main challenges of this work was to detect efficiently and reliably microcalcifications, set values for thresholds which often are not in the medical literature.

**PS01.005 - Measuring red blood cell velocity in capillary using video and image processing**

**Author(s):** Siwa Suwanmanee¹, Pedro Cabrales², Surapong Chatprun¹

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Microvascular blood flow velocity is important in physiological health monitoring and it is essential in oxygen supply, nutrient transportation and waste removal. Blood flow is relevant to the occurrence of many diseases such as Raynaud’s phenomenon, diabetes, hypertension, sepsis and cardiac diseases. Red blood cells (RBCs) velocity can represent microvascular blood flow. In capillaries, it is an important parameter in clinical hemorheology and microcirculation. For both in vitro and in vivo studies, RBCs velocity can be determined by using video image processing. Therefore, this study aimed to determine RBCs velocity from the videos recorded. The capillary blood flow videos were recorded from an animal dorsal skin window chamber model. The computer algorithm was developed to estimate the RBCs velocity. The proposed algorithm applied a digital image processing method to provide quantitative assessment of video signal to determine RBCs velocity. There were four steps to perform image processing of video images: i) image improvement, ii) image binarization, iii) image segmentation and iv) RBCs centroid estimation. In order to estimate the velocity of RBCs, it can be calculated by using the moving distance of centroid of RBCs between frames. Each frame was stored and used to calculate the RBCs velocity by dividing the frame rate of the video. Moreover, to make this algorithm more useful and efficient, the graphic user interface (GUI) was developed and tested. The final outcome of this study provided the in-house software for the velocity of RBCs in a capillary.

**PS01.006 - Development of a Quantitative PET QA Procedure for Multi-Center Clinical Trials**

**Author(s):** Brandon Driscoll¹, Ivan Yeung², Doug Vines³, Harald Keller³

¹Techna Institute, University Health Network, Toronto/ON/CANADA, ²Dept Of Radiation Oncology, University of Toronto, Toronto/ON/CANADA, ³Radiation Physics, Princess Margaret Cancer Center, Toronto/CANADA

Purpose: To develop an inter-institutional PET QA procedure especially tailored to the increasing requirement for quantitative (as opposed to qualitative) image analysis. Such a QA procedure should allow for harmonization of image acquisition and reconstruction such that images can be pooled across institutions.

**Methods:** The PET QA procedure utilizes the NEMA IEC Body Phantom which contains a set of 6 spheres and a torso shaped background reservoir. The phantom is filled at two background levels (2:1 and 4:1) and imaged three times at each level. Well counter readings from the signal and background compartments are collected for absolute quantification. The sites were each asked to select the protocol they would utilize for a full body PET scan with a time per bed position of 5 minutes.

At this stage, 7 different scanners have been tested across 4 institutions. For each scanner a number of quantitative measures were analyzed such as dose calibrator to well counter cross-calibration, absolute agreement with well counter, recovery ratios, and background noise levels.

**Results:** The protocols utilized by individual sites varied considerably in terms of reconstruction and image acquisition parameters. Two PET scanners had Time-of-Flight acquisition capability contributing to the variability.
PS01.007 - Unwrapping highly wrapped phase using Nonlinear Multi-Echo phase unwrapping

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1Radio-oncology Department, Hirslanden, Lausanne/SWITZERLAND, 2Department Of Nuclear Medicine And Molecular Imaging, Geneva University Hospital, Geneva/SWITZERLAND

**Introduction:** The unwrapping problem has been a major topic of research for more than a decade. A variety of algorithms have been proposed to overcome this problem, although a correct solution is by no means guaranteed, and many of the proposed approaches are time-consuming. In this work, we propose a simple and fast method, which combines conventional temporal unwrapping with the nonlinear phase model to unwrap multi-echo data (nonlinear multi-echo (NME) unwrapping). The approach was tested on simulated and in vivo brain data acquired from 10 subjects at 3 Tesla. The accuracy of the proposed method was evaluated against 2D and 3D spatial unwrapping methods and also against conventional temporal unwrapping.

**Materials and Methods:** The proposed method to unwrap highly wrapped phase NME requires a minimum of 2 echoes. The first echo is acquired with an echo time TE smaller than the maximum velocity encoding. Therefore, the echo difference between the two acquisitions TE can be selected on the basis of knowledge of the typical range of the field map B0 values encountered at the field strength in question to avoid unintentional phase wrapping. The second echo is acquired at long echo time TE (>20ms) to get a high wrapped phase. In the presence of large susceptibility artifacts, the linear assumption of the phase evolution is broken. To overcome this problem, we propose a model to account for this nonlinearity using a 1D random walk theory when the images are acquired at long TE. Finally, we combine the nonlinear approach to describe the temporal phase evolution and the conventional temporal phase unwrapping to correct for high phase aliasing. To assess the accuracy of our approach in presence of high phase wraps at long echo time; we used simulated wrapped phase with different wraps complexity and different noise levels. In vivo MRI scans were performed on a 3T Magnetom Trio (Siemens Healthcare, Erlangen, Germany). Data were acquired with a 3D bi-polar multi gradient echo sequence. NME was compared with 2D conventional Matlab unwrapping, 2D and 3D spatial unwrapping.

**Results and Discussion:** Both simulated and in vivo results showed that NME provides a good phase unwrapping with high accuracy (>90%) in the presence of high phase topography complexity and noise level, which reflects the real image quality at long echo time TE. Therefore, 2D, 3D spatial unwrapping and conventional temporal unwrapping present some limitations especially when phase wraps complexity and noise level are high. NME requires 2 echoes acquired at different TE; the method removes with success phase wraps occur near brain edges and paranasal sinus where the field gradient inhomogeneity is large. NME accounts for the nonlinear phase model which reduces significantly regions over-unwrapped with the conventional temporal unwrapping.

**Conclusion:** In this work, we proposed a simple and fast method to unwrap highly wrapped phase; the method combines conventional temporal unwrapping and nonlinear phase model to overcome phase aliasing even in the presence of high field gradient artifacts.
PS01.008 - Investigation of optimal display size for viewing MRI images using a digital contrast-detail phantom
Author(s): Hideki Fujita, Nao Kuwahata, Hiroyuki Hattori, Hiroshi Kinoshita, Haruyuki Fukuda
Radiation Oncology, Osaka Saiseikai Nakatsu Hospital, Osaka/JAPAN

In this study, we clarified the relationship between the display size of MRI images and observer performance using a digital contrast-detail (d-CD) phantom. The d-CD phantom was developed using Microsoft Visual Basic 2010 Express (Figure 1). It had a 512 x 512 matrix in size and a total of 100 holes, whose diameter increased stepwise from 4 to 40 pixels with a 4-pixel interval in the vertical direction; the contrast varied stepwise in the horizontal direction. The digital driving level (DDL) of the background, the width of the DDL, and the contrast were adjustable. These parameters were determined on the basis of the actual T1-weighted magnetic resonance (MR) images of the brain. In this study, the DDL, width, and contrast were set to 85, 20, and 1, respectively. The observer performance study was performed for three different display sizes (30 cm x 30 cm as the enlarged size, 13 cm x 13 cm as the original size, and 7 cm x 7 cm as the reduced size) using a 2-megapixel color liquid crystal display monitor and the results were analyzed using the Friedman and Wilcoxon statistical tests. The observer performance for the original display (P < 0.01) and the reduced display sizes (P < 0.01) was superior to that for the enlarged size, whereas there was no significant difference between the original display and reduced display sizes (P = 0.7) (Figure 2). Evaluation with the digital phantom simulating MR imaging also revealed that the original and reduced display sizes were superior to the enlarged display size in observer performance. The d-CD phantom enables a short-term evaluation of observer performance and is useful in analyzing the relationship between display size and observer performance.

Contrast-detail curves for the visual evaluation.

PS01.009 - Investigation of presampled MTF using a slit device with slightly wider aperture
Author(s): Yasuyuki Kawaji, Tatsuhiro Gotanda, Tetsunori Shimono, Shinichi J. Nakayama, Miki Hisamoto, Sae Matsumoto, Ayato Misago, Rumi Gotanda
1Department Of Radiological Science, Faculty Of Health Sciences, Junshin Gakuen University, Fukuoka/JAPAN, 2Department Of Radiological Science, Faculty Of Health Sciences, Junshin Gakuen University, Fukuoka/JAPAN, 3Department Of Radiological Sciences, Ibaraki Prefectural University of Health Sciences, Inashiki-gun, Ibaraki/JAPAN

The resolution properties of an imaging system are commonly described by its modulation transfer function. The slit and edge methods are the two most commonly used and accepted techniques for measuring the MTF. The use of a slit requires very precise fabrication and alignment of the device in the radiation beam, a high radiation exposure to allow sufficient transmission through the narrow slit (aperture 10 μm). We took notice of the slit aperture and a new slit device with slightly wider aperture (40 μm) was made for the improvement of the conventional slit device. The aim of this work was to show the properties such as the X-ray tube loading, the alignment and the MTF using the new slit device with slightly wider aperture. Imaging plates in the CR system were employed in this measurement.

The use of the 40 μm aperture slit device can decrease one-fourth of the X-ray tube loading compared to the conventional device (Table 1). The use of the 40 μm aperture slit device can improve the alignment for the slit device rotation and the incidence X-ray offset. The MTF using the 40 μm aperture slit device is higher than that using the conventional device (Fig. 1). The maximum difference was 0.025 (at 1.3 cycles/mm). The exposure condition of the 40 mm aperture slit device is near to clinical conditions and the MTF indicates the resolution property under clinical conditions.

Our results showed that the use of 40 μm aperture slit device allows easy acquisition of a slit image on the detector without precise alignment and ensures an appropriate MTF for the CR system under near-clinical exposure conditions.

The appearance of the developed d-CD phantom.
### PS01.010 - 3D Tumor delineation in Positron Emission Tomography reconstructed images restored by the use of Lucy Richardson blind deconvolution method

**Author(s):** Alpaslan Koc, Albert Guvenis  
**Institute Of Biomedical Engineering, Bogazici University, Istanbul/TURKEY**

**Background**  
Positron Emission Tomography (PET) can give the metabolically active tumor volumes necessary for radiotherapy planning and the therapeutic management of cancer patients. However, the automated edge finding algorithms and the partial volume effect due to the limited resolution of the camera can be a challenge.  

**Purpose**  
To evaluate the gain obtained in tumor volume estimation by making use of the image restoration Lucy-Richardson blind deconvolution method for 3D active contour based delineation strategies.  

**Method and Materials**  
Three 3D active contour methods have been used for delineation: Active contour with 50% threshold, active contour with edge attraction, and active contour with clustering. We have used a set of simulated 3D [18F]FDG PET oncology images including spheres of diameters 37, 28, 22, 17, 13 and 10 mm in a NEMA cylindrical phantom which were reconstructed using a 3D filtered backprojection algorithm. Data were obtained from the NCI database. The images were deconvolved by using the Lucy-Richardson blind deconvolution method. The deconvolution parameters were adjusted for best accuracy. The number of iterations was set to 7.  

**Results**  
First results showed that none of the three 3D active contour methods showed a consistently better accuracy for all spheres. The errors increased with smaller spheres. Significant improvements were obtained for all three delineation algorithms for the first four largest spheres between by deblurring the images. The improvements ranged between 98% and 25%.  

**Conclusion**  
The accuracy of 3D Active Contour delineation of tumors for estimating metabolically active tumor volumes is higher when images are deblurred with the Lucy-Richardson blind deconvolution. Work is underway for improving the accuracy of delineation of the smaller spheres.

### PS01.011 - Different options for stimulation intensity in mapping cortical motor area in navigated transcranial magnetic stimulation

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Department Of Clinical Neurophysiology, Kuopio University Hospital, Kuopio/FINLAND

**Background**  
Navigated transcranial magnetic stimulation (nTMS) is a modern technique used for mapping cortical motor areas in presurgical planning and stereotactic radiosurgery. One of its drawbacks is that it is sensitive to the selection of an appropriate stimulation intensity (SI) used in the procedure. Too low SI does not produce responses with good confidence and too high SI cannot perform focal stimulation. The SIs are determined based on resting motor threshold (rMT) prior to mapping. Commonly suprathreshold SI of 110% or 120% of rMT is used. Intuitively, a method able to determine an SI for the mapping procedure should be based on the lowest possible SI that maximizes the occurrence rate of motor responses. This can be accomplished via the use of the upper motor threshold (UT) determined with Mills-Nithi method \[1\] as it assumes 100% occurrence rate instead of the 50% assumed by the rMT \[2\].

**Methods**  
9 right-handed volunteers (6 males, age 24–61 years) were studied. The primary motor cortex on the left hemisphere was mapped for the extent of cortical area producing motor evoked potentials (MEPs) in three resting hand muscles using controlled suprathreshold stimulation intensity of 110% and 120% of rMT as well as using UT. Stimulus locations and corresponding responses were used to evaluate the size of the excitable cortical motor area \[3\].

**Results**  
UT was higher than 110% rMT \((p=0.026)\) and lower than 120% of rMT \((p=0.011)\). The representation sizes followed a similar trend. Comparison of size variations between the subjects revealed that the range of the resulting motor representation sizes was lowest with UT, while the size with UT and 110% rMT were significantly smaller compared to 120% rMT (Figure). The representation size determined with UT demonstrated best inter-subject repeatability based on confidence interval width with 2.0 cm$^2$, while the confidence interval width of 2.2 cm$^2$ and 2.8 cm$^2$ were observed with 110% and 120% rMT, respectively.

### Table 1 X-ray tube loading at the same maximum digital value

<table>
<thead>
<tr>
<th>Slit Size</th>
<th>Tube Loading</th>
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<tbody>
<tr>
<td>10 μm slit</td>
<td>74 kV</td>
</tr>
<tr>
<td>40 μm slit</td>
<td>(1008 mAs)</td>
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<td>(252 mAs)</td>
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### Table 2 X-ray tube loading at the same maximum digital value

<table>
<thead>
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<td>(252 mAs)</td>
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</table>
Conclusions: The highest repeatability in representation size was observed with UT as compared to the commonly used 110% and 120% rMT SIs. Then the UT appears as an appropriate choice to be used with motor mapping applications to outline functional motor areas on the cortex when using nTMS pre-surgical applications and radiosurgery planning to base the mapping SI to UT.

References:


PS01.012 - Software Breast Phantom for Phase Contrast Imaging Applications

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Breast cancer is the most common cancer in women worldwide. Although mammographic screening techniques have considerably reduced breast cancer mortality, the rate of missed lesions and false positives remain crucial. Phase Contrast Imaging is an emerging technique based on X-ray phase change arising from diffraction and refraction effects that take place at the boundaries of different refractive materials, producing images with strong edge enhancement. There are no phantoms for phase contrast breast imaging applications available today. The goal of this work is to develop a software phantom that mimics the refractive properties (indexes) of breast tissues, specialized for phase contrast applications. Such a phantom will enable simulated image quality evaluations and dose analysis in the case of phase contrast imaging. For this reason 17 different compounds were investigated in order to find the optimum materials to represent fibroglandular tissue, adipose tissue, skin, lymph, microcalcifications and breast masses for an energy range between 18keV and 40keV. A comparison of the δ values between these breast tissues and the mimicking materials has been calculated according to the equation \( \delta_{ph} = \left| \frac{\mu_{ph} - \mu_{br}}{\mu_{br}} \right| \times 100 \). Where \( \delta_{ph} \) represents the refractive index of the breast tissue and \( \delta_{br} \) the refractive index of the mimicking material. The XPARImagingSimulator, an in-house developed software platform used for novel investigations in x-ray imaging, has been used for image acquisition. Simulation modules have been adapted to analytically simulate physical interactions taking place in Phase Contrast imaging based on Fresnel-Kirchhoff diffraction theory. A breast like semi-cylindrical phantom of 18mm radius and 45mm thickness filled with polystyrene as background material has been modeled. In this background five cuboids of nylon, polyethylene, paraffin wax, polystyrene and silicone gel, two spheres of water of 1mm and 2mm radius and two clusters of Al of 0.098mm and 0.115mm respectively were inserted. Subsequently, x-ray planar images were produced with coherent radiation emerging from a point monochromatic source in both Phase Contrast and Absorption mode. The two images of the phantom were obtained at 20keV, with SID 23m and ODD 40.0mm and 5μm resolution. The two planar images were compared in terms of contrast and edge enhancement using four different line profiles. Results from the evaluation of the line profiles showed an important edge enhancement of the details embedded in the phantom. Especially for the adjacent materials polyethylene and paraffin wax that cannot be differentiated in the absorption mode, phase contrast image was able to clearly reveal their borders. Simulation images acquired show a significant edge improvement when the phase contrast effect was taken into account. For further investigation we are planning to verify the presenting results with synchrotron experimental data.

PS01.013 - Actions for Implementation Program of Image Quality of Mammography

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Globally were established many quality programs that have proven effective in early detection of the breast cancer. In Brazil was instituted, by the Department of Health, the ordinance 531/2012 that establish the basic guidelines for the implementation of the National Program for Quality in Mammography (PNQM) to ensure the quality of digital mammography exams. But in November 2013 it was updated by the ordinance nº 2898 added which the role of public and private agencies to fulfillment this ordinance, not adding any technique process. This work has the aims to implement the ordinance 531/2012 with a principal focus on training and periodic retraining of health professionals. As methodology was proposed a set of actions for hospitals and clinics regularize the conditions imposed by the law, always seeking quality mammographic images. The result was the creation of seminars and specific courses for radiologists and radiology technician, with the aim to resolve such failures always prioritizing the quality in the image digital mammography. Other tender, for comply the ordinance, is the establish a committee that will go assess the insertion of PNQM, regularly sending reports to health authorities regarding the implementation of the program and regimen and still taking providences in case of non-compliance with the quality criteria.

Figure: Estimates of motor cortical muscle representation area of three hand muscles determined for all subjects applying three stimulation intensities. The red dots represent area of each individual subject. The blue lines represent the 95% confidence intervals and black line indicates the mean. Non-parametric paired-samples comparisons are indicated.
PS01.014 - Evaluating Techniques of Transformation Intensity for Contrast Enhancement in Mammographic Images

Author(s): Angelo Granado1, Raquel J.P.D. Lima1, Michele F. Angelo2
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Mammography has a high sensitivity, but the interpretation of the images may be affected by factors such as the density breast and the limitations of mammography equipment. Thus, it is of great importance the use of image pre-processing techniques to enhance contrast and consequently the present structures in the image are interpreted correctly. This work is dedicated to the study of the performance of intensity transformation techniques for contrast enhancement of mammographic structures. Initially, five different techniques (logarithmic, exponential, gamma, sigmoid and stretching linear function) were applied in regions of interest containing microcalcifications. Subsequently, the signal/noise ratio and the contrast/noise ratio of the images were calculated to evaluate the performance of the techniques. According to the results, the sigmoid function presented the better performance.

PS01.015 - Influence of Contrast Enhancement to Breast Density Classification by Using Sigmoid Function

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1Department Of Technology, State University of Feira de Santana, Feira de Santana/BRAZIL, 2Faculty Of Electrical Engineering, Federal University of Uberlândia, Uberlândia/BRAZIL

The classification of breast density is very subjective even for the experts, the categories 2 and 3, in many cases are confused. Thus, the objective of this study is to evaluate the influence of the sigmoid function in the density classification of images with lesions by using texture attributes. It was used 28 images with lesion, 19 belong to the category 2 (P2 - partially fat) and 9 to category 3 (P3 - dense). The sigmoid function was implemented and applied to all images to contrast windowing. A set of 14 Haralick descriptors were implemented. After the attributes extraction step it used the clustering technique K-Means to classify the category images of breast density 2 and 3. Seven of the 14 Haralick descriptors (energy/uniformity, contrast, vari-ance/homogeneity, average sum, variance of the sum, entropy difference and maximum correlation coefficient) showed higher success rate when used images processed with sigmoid function. However, five attributes (correlation, entropy sum, difference variance, correlation information measured 1 and 2) presented classification results below those that results by using the original images, and two attributes (inverse difference moment and entropy) obtained the same results, for classification of both images (images with sigmoid function and original images). The attributes combination used to classify images with sigmoid function were better and the combination that had the best classification accuracy rate was the contrast and variance attributes. The use of the sigmoid function directly influenced the results of classification in the categories 2 and 3, however, when it was used by only one attribute in the classification, not all attributes showed great correct response rates, as happened to the results obtained using attributes combination.

PS01.016 - Evaluation of the difficulties of the learning process of mammographic readings

Author(s): Pedro Cunha Carneiro1, Leticia Oliveira Mamere2, Ana Cláudia Patrocinio1
1Laboratory Of Biomedical Engineering, Federal University of Uberlândia, Uberlândia/BRAZIL, 2Faculty Of Medicine, Federal University of Uberlândia, Uberlândia/BRAZIL

Breast cancer is the second most frequent type of cancer in the world, being the most common among Brazilian women. Thus, the best way to prevent from such disease is by having mammographic exams regularly. However, the mammographic report does not depend exclusively on the analysis of the physiological factors of the visualized structures and the technical characteristics of the image acquisition and storage system, but also on the interpretation of the images by the specialist. The aim of this paper is to identify and evaluate the parameters used to elaborate the mammographic reports which show a higher level of difficulty from the quantification of mistakes of the residents when reporting mammographic exams.

On this paper, 346 mammographic images were analyzed by radiology residents using a questionnaire elaborated on a previous work and it is based on BI-RADS™ to characterize the mammographic lesions found. The collected and analyzed data are: the positive and negative cases of the BI-RADS™ classification, the pattern of density and complexity of the image, the capacity of identifying nodules, calcifications of the vascular/parallel type, calcification of benign aspect and axillary and intramammary lymph nodes. In order to broaden the evaluation of the results some statistical methods we used, such as: sensitivity (Se), specificity (Sp), Kappa coefficient (K) and area under ROC curve (AUC).

Later, these reports were compared to the reports provided by the staff (specialized physicians), aiming at identifying the level of difficulty of the radiology residents in reporting mammographic exams. Out of the 321 negative reports defined by the staff, the residents matched 292 of them (91%). On the 25 positive cases defined by the staff, the residents matched 13 of them. Regarding the level of complexity of the lesions, the highest percentage of mistakes is found in cases considered of very high complexity. Table 1 presents a summary of the results obtained to each one of the parameters evaluated.

Table 1. Results obtained

<table>
<thead>
<tr>
<th>Collected data</th>
<th>Se (%)</th>
<th>Sp (%)</th>
<th>AUC</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>(+) and (-) BI-RADS™ Reports</td>
<td>68</td>
<td>95.6</td>
<td>0.852</td>
<td>0.57</td>
</tr>
<tr>
<td>Presence of nodules</td>
<td>74</td>
<td>99.3</td>
<td>0.89</td>
<td>0.79</td>
</tr>
<tr>
<td>Presence of vascular calcifications</td>
<td>84</td>
<td>99.6</td>
<td>0.931</td>
<td>0.88</td>
</tr>
<tr>
<td>Presence of calcifications of benign aspect</td>
<td>92.2</td>
<td>96.3</td>
<td>0.951</td>
<td>0.89</td>
</tr>
<tr>
<td>Presence of axillary lymph nodes</td>
<td>92</td>
<td>98</td>
<td>0.959</td>
<td>0.91</td>
</tr>
<tr>
<td>Presence of intramammary lymph nodes</td>
<td>91</td>
<td>98.7</td>
<td>0.959</td>
<td>0.88</td>
</tr>
<tr>
<td>(+) and (-) BI-RADS™ Reports</td>
<td>68</td>
<td>95.6</td>
<td>0.852</td>
<td>0.57</td>
</tr>
<tr>
<td>Presence of nodules</td>
<td>74</td>
<td>99.3</td>
<td>0.89</td>
<td>0.79</td>
</tr>
</tbody>
</table>
PS01.018 - Influence of ROI pattern on segmentation in lung lesions

Author(s): Marcelo L.N. Franco1, Lara M. Nunes2, Ana Paula P. Froner1, Ana M. Marques Da Silva2, Ana Cláudia Patrocinio1

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The early diagnosis of lung cancer is critical in determining the chances of recovery and survival of patients. Sometimes the differences between malignant and benign tissues can be imperceptible to not trained human eyes, thus, a good diagnosis depends on radiologists ability.

Because of these facts, CAD systems have been designed to get features of lesions in digital images to report the probability of malignancy nodule. An important step of developing these systems is the nodule image segmentation. If segmentation does not provide satisfactory results, the descriptors used cannot describe the real features of lung tissue.

Considering the significance of segmentation step, this project aims to compare the results obtained by two segmentation algorithms: the first one consists basically in a selection of rectangular region of interest (ROI) followed by Otsu segmentation technique and the other added an elliptical ROI after applying Otsu technique, eliminating possible structures adjacent of lesion.

The images used in this project are from 22 CT exams (5088 slices) acquired at São Lucas Hospital (PCU-RS), all containing radiological report. All exams were analyzed to determine the extent of each lesion, reducing the number of images to be processed.

Then, the ROI was selected by 2 mouse clicks on the image: each one at one vertex of main diagonal of the desired rectangular region (ROI	extsubscript{R}). Afterward, the one-threshold Otsu method was applied, segmenting the lesion. Finally, the elliptical region (ROI	extsubscript{E}) is created

Non-deterministic seed launching results

<table>
<thead>
<tr>
<th>Exams [#]</th>
<th>Slices [#]</th>
<th>Seeded [#]</th>
<th>False-Negative</th>
<th>False-Positive</th>
<th>Correctly Seeded</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>118</td>
<td>072</td>
<td>0.00%</td>
<td>39.83%</td>
<td>60.17%</td>
</tr>
<tr>
<td>2</td>
<td>376</td>
<td>158</td>
<td>0.26%</td>
<td>02.92%</td>
<td>96.82%</td>
</tr>
<tr>
<td>3</td>
<td>210</td>
<td>163</td>
<td>5.24%</td>
<td>00.00%</td>
<td>94.76%</td>
</tr>
<tr>
<td>4</td>
<td>366</td>
<td>172</td>
<td>0.55%</td>
<td>02.73%</td>
<td>96.72%</td>
</tr>
<tr>
<td>5</td>
<td>611</td>
<td>386</td>
<td>0.00%</td>
<td>38.29%</td>
<td>61.71%</td>
</tr>
<tr>
<td>6</td>
<td>385</td>
<td>385</td>
<td>0.00%</td>
<td>63.64%</td>
<td>36.36%</td>
</tr>
<tr>
<td>7</td>
<td>521</td>
<td>191</td>
<td>1.15%</td>
<td>00.00%</td>
<td>98.85%</td>
</tr>
<tr>
<td>8</td>
<td>501</td>
<td>260</td>
<td>0.20%</td>
<td>12.57%</td>
<td>87.23%</td>
</tr>
<tr>
<td>9</td>
<td>476</td>
<td>193</td>
<td>1.47%</td>
<td>00.00%</td>
<td>98.53%</td>
</tr>
<tr>
<td>10</td>
<td>094</td>
<td>067</td>
<td>7.44%</td>
<td>00.00%</td>
<td>92.56%</td>
</tr>
<tr>
<td>Total</td>
<td>3658</td>
<td>2047</td>
<td>1.63%</td>
<td>15.99%</td>
<td>82.37%</td>
</tr>
</tbody>
</table>

However, some exams presented high false-positive seeding due to the complexity of the images, such as the proximity of abdominal muscles near the end of the liver, as depicted in Fig. 1. In conclusion, the purposed use of DE has shown promising results on launching seeds inside the liver on MDCT images.
Hepatic Segmentation using CT images

Launch an Automatic Seed to Region Growing Algorithm on PS01.019 - Comparison between Elliptical and Squared ROI to Launch an Automatic Seed to Region Growing Algorithm on Hepatic Segmentation using CT images

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Early detection of liver cancer increases the survival rate by 60-70% in five years. As part of CAD development for the liver, two automatic seed selection techniques (for automatic liver segmentation using region growing technique) are compared, using the calculation of Mean Squared Error (MSE), to analyze which one has the lowest error when compared with manual segmentation.

It was used 2631 liver computer tomography slices, the first step is make the preprocess of these slices, that were submitted in the windowing CT and after it is applied a mean filter with the gamma transformation.

The first technique defines the Seed Launch on Elliptical Area (SLEA), Figure 1(a), for find the seed point, and the second technique defines the Seed Launch into Square Area (SLSA), Figure 1(b), for find the seed point.

And the seed points that were found with each one of these techniques are used to perform the liver segmentation with the region growing algorithm, and from the liver segmented is performed the entire exam volume and the MSE calculation for each technique, and these results compared with the manual segmentation.

Thus the results of this process are in the Table 1, then the average liver volume measured manually was of 1,369.99cm³, and with SLEA technique the average liver volume measured automatically was of 1,625.62cm³ and the average MSE was of 65.49±94.12cm³, and for the SLSA technique the average liver volume measured automatically was of 1,643.23cm³ and the average MSE was of 181.48±281.39cm³. The smallest MSE SLEA was of 2.04cm³ and the bigger was of 391.82cm³, and for the SLSA the smallest MSE was of 2.122cm³ and the bigger was of 1,110.82cm³. It was observed that both techniques have the average volume similar, but the SLEA technique has the smallest values and averages of the MSE.

Table 1 - Volume and MSE of exams, in cubic centimeters.

<table>
<thead>
<tr>
<th>Exam</th>
<th>Volume</th>
<th>Group 1 (SLEA)</th>
<th>Group 2 (SLSA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Volume</td>
<td>MSE</td>
</tr>
<tr>
<td>1</td>
<td>1,093.81</td>
<td>1,625.62</td>
<td>65.49±94.12</td>
</tr>
<tr>
<td>2</td>
<td>755.63</td>
<td>877.99</td>
<td>158.22</td>
</tr>
<tr>
<td>3</td>
<td>875.99</td>
<td>779.48</td>
<td>225.31</td>
</tr>
<tr>
<td>4</td>
<td>958.48</td>
<td>1,333.41</td>
<td>117.34</td>
</tr>
<tr>
<td>5</td>
<td>1,481.48</td>
<td>2,096.98</td>
<td>71.24</td>
</tr>
<tr>
<td>6</td>
<td>1,489.59</td>
<td>2,097.98</td>
<td>117.34</td>
</tr>
<tr>
<td>7</td>
<td>616.94</td>
<td>1,084.12</td>
<td>51.25</td>
</tr>
<tr>
<td>8</td>
<td>837.11</td>
<td>1,083.26</td>
<td>51.25</td>
</tr>
<tr>
<td>9</td>
<td>409.34</td>
<td>397.42</td>
<td>61.15</td>
</tr>
<tr>
<td>10</td>
<td>2,129.32</td>
<td>8,142.46</td>
<td>51.25</td>
</tr>
<tr>
<td>11</td>
<td>5,233.73</td>
<td>1,855.84</td>
<td>61.15</td>
</tr>
<tr>
<td>12</td>
<td>1,072.47</td>
<td>2,122.23</td>
<td>61.15</td>
</tr>
<tr>
<td>13</td>
<td>2,101.22</td>
<td>2,087.45</td>
<td>61.15</td>
</tr>
<tr>
<td>14</td>
<td>1,184.08</td>
<td>9,184.45</td>
<td>51.25</td>
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<tr>
<td>15</td>
<td>4,048.15</td>
<td>2,794.02</td>
<td>51.25</td>
</tr>
<tr>
<td>16</td>
<td>2,800.51</td>
<td>2,794.02</td>
<td>51.25</td>
</tr>
</tbody>
</table>

Figure 1 Example of segmentation with ROI, on the left and on the right the respective segmentation with ROI.

PS01.020 - Gd-based Nanoparticles Mediated Magnetic Field Enhancement Inside Homogenous Tissue: Simulation using Finite Element Method

Author(s): Sahar Rezaei1, Nader Riyahi-Alama1, Mohsen Ostovari2

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Tumor detection in the early stages is of utmost importance in cancer diagnosis and treatment. Magnetic resonance molecular imaging (MRMI) is a considerable medical imaging method to distinguish normal cells from cancerous cells initiating metastasis. Current MRI contrast agents are required to prevent adverse chemical activity in the body. Therefore, in conventional form of Gd-DTPA due to their relatively large size and coverage can be used only in extracellular spaces. Meanwhile, nanoparticles, because of their small size relative to the body cells, are capable of intrusion inside the cells. These materials can be used for molecular imaging; Gd based paramagnetic nanoparticles are the most widely used agents. In this paper, variation in external magnetic field as a result of using Gd-based nanoparticles in homogenous tissue was investigated with finite element method. To this end, simulations have been carried out in the presence of Gd nanoparticles and without them. This study indicated that magnitude of external magnetic field increases due to the presence of nanoparticles, and we compared the results with Vibrating Sample Magnetometer (VSM) results. In addition, Gd nanoparticles showed sigmoidal (superparamagnetic) behavior in both data set of simulation and VSM, applicable to normal cell uptake and so tumor cell tracking for cancer detection.
PS01.022 - Linear tomosynthesis with flat-panel detector for image guided radiation therapy

Author(s): Dong-Su Kim1, Tae Ho Kim2, Seong-Hee Kang1, Kyeong-Hyeon Kim1, Min-Seok Choi1, Siyong Kim2, Tae-Suk Suh1
1Biomedical Engineering And Research Institute Of Biomedical Engineering, College Of Medicine, The Catholic University of Korea, Seoul/KOREA, 2Radiation Oncology, College Of Medicine, Virginia Commonwealth University, Richmond/UNITED STATES OF AMERICA

In this study, we propose a novel imaging technique using linear tomosynthesis with flat-panel detector that can produce tomographic images at arbitrary anterior-posterior depth position for image guided radiation therapy. To verify the usefulness of the imaging performance, we performed systematic simulation studies for simple linear movement of a couch with digital phantoms in several layers along the coronal direction. Projections were acquired at specific position through the calculated proper shift amounts for particular or multi-focal level imaging. The linear tomosynthesis images were reconstructed by shift-and-add (SAA) method. Furthermore, to increase blurring effect of out-focal objects in the image, we investigated a subsidiary technique that used sections of extra detector pixels along the anatomical axis. According to our preliminary results, a designed specific coronal plane was well focused with good image sharpness and multi-focal image layers were realized with the proposed method. We have also derived the thicknesses of the focused image layer as functions of the number of pixels used in focal or out-focal section of the pixel array. Our results showed that defined plane-of-interests were well focused with image sharpness and the position of image layer center was adjusted precisely with proper shift amounts in the linear motion tomosynthesis. We expect that the proposed method will be very useful for accurate localization with less dose than other imaging modality such as cone-beam computed tomography.

PS01.024 - Optimization of acquisition parameters of the test of an overall SPECT/CT system performance.

Author(s): Piotr Tulik1, Monika Tomaszuk1, Paulina Wojcik2, Alicja Hubalewska-Dydejczyk2, Anna Sowa-Staszczak2
1Institute Of Metrology And Biomedical Engineering, Warsaw University of Technology, Faculty of Mechatronics, Warsaw/POLAND, 2Nu-clear Medicine Unit, Department Of Endocrinology, University Hospital in Krakow, Krakow/POLAND, 3Department Of Endocrinology, Jagiellonian University Medical College, Krakow/POLAND

An overall SPECT/CT system performance test provides the most comprehensive information about a long term stability of an uniformity and resolution of gamma camera installed in a clinic, but its conducting is time consuming. The recommended frequency of the test and manner of its implementation varies between different countries and nuclear medicine departments. Different acquisition parameters for this purpose are proposed by NEAM, IAEA report #6 and AAPM report #22. The question arises how to get an image with the best quality, in the least amount of time. Is it possible to decrease the time needed for an overall SPECT/CT system performance test execution and in consequence being able to perform it more often in the clinic, but not to compromise with the requirements of recommendations on the quality of the observed image? The purpose of this study was to present the process of optimizing of acquisition parameters of an overall SPECT/CT system performance test, which could be implemented in each nuclear medicine department.

All measurements were performed with the use of Symbia T16 SPECT/CT (2010, Siemens). The Jaszczyk SPECT phantom with cold spheres provided for high-resolution gamma cameras filled with 740 MBq of 99mTc was used.

The influence of the duration of a single projection (10, 15, 20, 25, 30, 45, versus 60 sec per projection), the number of projection (64, 96 versus 128 projections in a full 360-degree rotation) and the size of acquisition matrix (64x64 versus 128x128) on the quality of the resulting image were analyzed. The scans for each combination of the parameters were performed three times with two exceptions. The study with 30 sec per projection, 128 projections and 128x128 matrix were chosen to be a reference (in accordance with IAEA recommendations and additionally a standard protocol for clinical applications in the Department). All images were subjected to visual evaluation (uniformity and spatial resolution) by 2 experienced nuclear physicists. Quantitative evaluation of image contrast was performed with the use of Mann-Whitney nonparametric test. Each SPECT image was evaluated with and without attenuation correction, but always with scatter correction.

The proposed process of an evaluation of the parameters that are crucial for the image quality in nuclear medicine gave a possibility to identify the optimal acquisition parameters for considered test. Image, indistinguishable from proposed reference, but acquired in the half of time (decrease from 32 min for 16 min, respectively), was obtained with the following parameters: 30 sec per projection, 64 projections and 128x128 matrix size, with the use of attenuation correction. Reduction of the duration of a single projection, and especially the size of the matrix, or lack of AC, deteriorated image quality. An increase of the duration of a single projection over 30 sec did not bring a significant improvement of image quality, but increased the duration of the test.

The methodology of optimization of acquisition parameters for an overall SPECT/CT system performance test has been presented for Symbia T16 SPECT/CT system in terms of time of a single acquisition and quality of acquired images.

PS01.023 - Evaluation of image quality and dose for digital breast tomosynthesis (DBT) using a semi-analytical model

Author(s): Alessandra Tomal1, Martin E. Poletti2
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Digital breast tomosynthesis (DBT) is a 3-D imaging technique that has higher sensitivity and specificity, compared to mammography, for early diagnostic of breast cancer, with a similar radiation dose. The risks associated with the DBT examination is evaluated with respect to the mean glandular dose (MGD), determined from air kerma measurements and specific normalized glandular dose factors. The image quality can be evaluated by means of the contrast-to-noise ratio (CNR) and artifact spread function (ASF). In this work, we describe semi-analytical models, which were developed to study the MGD, CNR and ASF in DBT, by determining the deposited energy in single and double interactions and the intensity of transmitted radiation. The semi-analytical model was used to study the dependence of these quantities with different projection angle, different breast thicknesses and glandularities. The anode/filter combinations evaluated were: Mo/Mo, Mo/Rh and Ru/Rh, and a W anode combined with K-edge filters (Zr, Mo, Nb, Ru, Rh, Pd, Ag, Cd, In and Sn), for tube potentials between 23 and 35 kV. Results demonstrate that the normalized glandular dose decreases up to 25%, as the projection angle increases, being this decrease more pronounced for thicker and denser breasts. A decreasing in the CNR and ASF values was observed as the angular range decreases. Besides, it was observed variations up to 70% on the MGD and CNR with the x-ray spectra and breast characteristics (composition and thickness). The ASF is almost independent on the x-ray spectra. Finally, it was verified that the semianalytical models developed in this work provided results of image quality and dose parameters in DBT in a fast and simple way, with a good agreement with those or by MC simulation (discrepancies lower than 10%).
PS01.025 - Dosimetric Analysis of Patient to a Z-Gradient Coil in Head Magnetic Resonance Imaging

Author(s): Mai Lu1, Shoogo Ueno2

1Key Lab. Of Opt-electronic Technology And Intelligent Control Of Ministry Of Education, Lanzhou Jiaotong University, Lanzhou/CHINA, 2Department Of Applied Quantum Physics, Graduate School Of Engineering, Kyushu University, Fukuoka/JAPAN

In magnetic resonance imaging (MRI), magnetic field gradient coils are commonly switched at low frequency of around 1 kHz or so. Time-varied gradient magnetic fields may stimulate nerves and muscles by inducing electric fields and currents in patients, which may potentially cause health problem. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has set international guidelines for limiting the exposure. For the working frequency of 1 kHz, the ICNIRP guidelines define the reference level (RL) as 80 μT, and the basic restriction in both CNS and body tissues as 0.4 V/m. The guidelines require that the basic restrictions are not exceeded at any time. In this study, a 3D human body model i.e. the patient as shown in Fig.1 was placed in a z-gradient coil for simulating the head MRI exam. A realistic cylindrical z-gradient coil with 24 circular rings has been numerically designed. The time variation of the applied magnetic field causes induced electric fields in the body through Faraday’s induction mechanism, and can be calculated by the impedance method. The electrical properties are modeled using the 4-Cole-Cole method and can be obtained by fitting to experimental measurements. The induced electric fields in all CNS tissues have been averaged over a volume of 2mm x 2mm x 2 mm, and the 99th percentile value of the averaged field strength were compared with the ICNIRP basic restrictions. Fig. 2 shows the typical slice of the induced electric fields within the coronal plane. The spatially averaged magnetic flux density was found to be approximately 9.49 times the ICNIRP reference level, and the maximum value of the induced electric fields in CNS was found to be 5.95 times the ICNIRP basic restriction.

PS01.026 - A Novel Optical System for Contrast Enhancement in Histological Plates to Be Processed Digitally

Author(s): Rubiel Vargas-Canas1, Jorge Cortez2, Jairo A. Vasquez-Lopez3

1Physics, Universidad del Cauca, Popayan/COLOMBIA, 2Morphological Sciences, Universidad del Cauca, Popayan/COLOMBIA

For many decades, visualization of histological samples was performed using a contrast media (stain) in order to visually enhance relevant details of tissue structures that characterize a histological tissue. However, so far, there is no perfect dye or staining technique that allows visualization of all relevant details in a histological preparation because it depends on the type of dye and chemical affinity with tissue. Additionally, chromatic changes such as low contrast resolution or excess dye in the tissue are presented as a result of the misuse of the staining technique. On the other hand, nowadays, histological images can be digitally processed to obtain a variety of information, including: classifying textures, glands segmentation and identification, and nuclei and cell counting. Nevertheless, in order to perform digital processing in an efficient manner and to obtain reliable results, images must have high quality and meet certain conditions, such as uniform colouring and a good difference in contrast.

In this paper, a novel methodology to improve visualization of histological samples is presented. It uses previously calculated colour
lighting to illuminate the sample. Colour is calculated using feature lighting and a physical-mathematical model based on RGB and HSI colour spaces; this lighting differs from the white light conventionally used in optical microscopes. Because of the aim is to increase contrast in the area of interest, this development is based on the complementary colour theory, which states the following: “Each colour which allowed the painters’ primaries (red, yellow, blue) to be arranged opposite their complementary colours (e.g. red opposite green), as a way of denoting that each complementary would enhance the other’s effect through optical contrast.”, or expressed in other words, complementary colours enhance contrast to maximum each other, which is ultimately what we want to observe in a histological preparation.

The proposed technique was tested subjectively and quantitatively, first, by measuring intra- and inter-observer variations after observing morphological patterns by the histologist and pathologist, second, quantitative assessment of histomorphological image after segmenting areas of essential interest for establishing diagnosis more objectively. With the development of the proposed digital optical system, contrast, within different areas of interest in a tissue sample, both visually and through computer vision techniques, is automatically increased, so digital images can be processed more comfortably. The implementation of this technique will reduce time and cost of examinations such as tissue biopsies, facilitate diagnostic evaluation by pathologists and will reduce the waste of histological material; which will end in to benefit the most important person in the process of health care: the patient.

PS01.027 - Pixel-based dynamic contrast-enhanced CT study with low temporal resolution
Author(s): Sun Mo Kim1, Michael Milosevic2, Masoom A. Haidar3, Iven Yeung3, David Jaffray1
1Radiation Physics, Princess Margaret Cancer Centre, Toronto/ON/ CANADA, 2Radiation Medicine Program, Princess Margaret Cancer Centre, Toronto/ON/CANADA, 3Medical Imaging, Sunnybrook Health Sciences Centre, Toronto/ON/CANADA, 4Radiation Physics, Princess Margaret Cancer Centre, Toronto/CANADA

Purpose: In dynamic contrast enhanced CT (DCE-CT) study, a CT scanning with high temporal resolution is necessary to obtain accurate kinetic parameter values, but such scanning scheme substantially increases the radiation dose to the patient. A method of principal component analysis (PCA) filtering combined with the arterial input function (AIF) estimation technique is proposed to reduce patient radiation dose, while maintaining high accuracy of kinetic parameter estimates in a pixel-by-pixel analysis of DCE-CT data acquired at a low scanning frequency.

Methods: With the coarsely sampled AIF of a patient, an AIF in high temporal resolution can be generated by using the previously published technique which uses the orthonormal bases of the arterial impulse responses (AIF) extracted from a cohort of 34 patients with cervical cancer. In addition, principal component analysis (PCA) filtering was applied to the tissue curves of all the pixels in a region of interest to increase their signal to noise ratios (SNR). Because of this, it’s important to reduce radiation doses particularly in children and young patients that if they are exposed to these multiple times radiation during their lives may accumulate a significant dose of ionizing radiation, which in turn could lead to an increased risk. In TC, there is a compromise between image quality and dose of ionizing radiation. The problem is that by reducing the radiation dose in CT, the amount of noise in the images is increased. This is because the scanner detectors are fewer photons, which decreases the signal to noise ratio. As consequence, the noise can hide anatomical detail and decrease the detection of lesions with low contrasts. At very low doses, can also exacerbate undesirable effects on images, such as artifacts. To reduce the noise in images have been proposed different algorithms and mathematical methods. Among these are algorithms that directly filtered X-ray projections or reconstructed images. Process the reconstructed images instead of the projections has practical advantages: the images are available to any user, the methods are applicable to any type of scanner regardless of the manufacturer and usually do not demand high performance computing capacity. We proposes a method, which takes as a basis the bilateral filter theory with some changes to improve efficiency and add a component, the separation in frequency bands; to combine the images of high and low frequency after being filtered by the bilateral filter. In our case we use three filter functions most used in the image processing in the domain of the frequencies, the ideal, Butterworth and Gaussian filter, also add the use of an edge operator to improve contrast and highlight the edges of the anatomical structures. Our preliminary results suggest that it is possible to reduce the noise in at least one 30 to 50%. The studies with mathematical observers revealed that our method can decrease the noise of images and even guarantee a diagnostic quality suitable for the diagnosis that could result in the reduction of the dose of radiation.
PS02 - TRACK 02: BIOMATERIALS AND REGENERATIVE MEDICINE

PS02.001 - Chitosan: A Chitinous Biopolymer For The Treatment Of Crude Oil Polluted Water

Author(s): Ellien E.C. Agoha, C Atowa, Fatima Okafor, C.A. Ozodiwe
Food Sciences And Technology, Abia State University, Uturu., Uturu/NIGERIA

The level of crude oil pollution of Taabaa village stream in Ogoni, Rivers State, Nigeria and the effectiveness of snail shells waste chitosan in the treatment of crude oil polluted water were investigated. Triplicate samples of crude oil polluted water were treated with varying concentrations (0.1, 0.2 and 0.3mg/L) of chitosan. Results indicated that untreated crude oil polluted water samples had a brown colour, hydrocarbon taste and odour and a high turbidity value of 17.00 units Hazen. The water also contained high levels of lead (0.10mg/L), arsenic (0.34mg/L), and iron (0.84mg/L), and had a total plate count of 310CFU/mL, coliform count of 150CFU/mL and E. coli count of 25CFU/mL. Chitosan treated water samples was clear, colourless, tasteless and odourless with a 100% reduction in turbidity. Chitosan treatment at 0.1, 0.2 and 0.3mg/L concentrations produced 80% and 90% reductions in lead and reduced the arsenic content from 0.34mg/L to 0.04mg/L. Similarly, chitosan treatment produced 100% reduction in E. coli, while the total plate and coliform counts were reduced to WHO acceptable levels. The results showed that the Taabaa village stream was highly contaminated with crude oil and also indicated the potential use of chitosan in the treatment of crude oil polluted water.

PS02.002 - Temperature of ice formation affects integrity of alginate 3D constructs after cryopreservation

Author(s): Oleksandr Gryshkov, Lothar Lauterboeck, Nicola S. Hofmann, Birgit Giasmacher
Leibniz University Hannover, Institute for Multiphase Processes, Hannover/GERMANY

Introduction

Cryopreservation is the one available method for long-term preservation of rare cell types. Application of alginate encapsulation may improve cell viability by protecting the encapsulated cells from the ice re-crystallization and osmotic stresses upon freezing and thawing. This work explores the effect of the temperature of extra-cellular ice formation on the integrity of alginate beads.

Methods

The alginate beads with a diameter of 300 µm were generated using the high voltage encapsulation method [1]. After encapsulation and cross-linking for 15 min or 45 min, the alginate beads were re-suspended in cold culture medium (0.5 ml, 4°C). The double-concentrated cryo-medium containing 5/10/15/20% (v/v) dimethyl sulfoxide and 20% (v/v) fetal bovine serum was added (0.5 ml) and the beads were equilibrated at 4°C on ice for 15 min or 45 min. Afterwards, the sample was transferred onto a quartz dish, covered with a cover slip and placed into the Linkam cryostage (FDCS 196, Linkam, UK). The following protocol with no active control over the temperature of ice formation was used: cooling rate -1 K/min from 4°C to -20°C, equilibration at -20°C for 5 min with further thawing from -20°C to 4°C with 100 K/min.

Results

The cryomicroscopy results showed that the application of 2.5%, 5%, 7.5% and 10% DMSO with pre-freezing DMSO loading intervals (15 min, 45 min) influenced differently the integrity of alginate beads post-thawing (Figure 1). The temperature of ice formation also affected the integrity of the alginate beads after thawing. The formation and further growth of specific ice crystals at higher temperatures (-12.8°C) caused mechanical rupture of alginate beads. In addition, the temperature of spontaneous ice formation varied from -12.8°C to -19.2°C.

Figure 1. Analysis of freezing/thawing of alginate beads via cryomicroscopy for 10% (v/v) DMSO and 15 min of pre-freeze loading interval. Scale bar is 100 µm.

Conclusions and outlook

In this study it was found that the temperature of ice formation is one of the main factors affecting integrity of alginate beads after thawing. Further work will be performed to study the effect of ice formation temperature on the encapsulated cells functionalities after thawing.

Acknowledgments

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References


PS02.003 - Influence of proteins on magnesium in vitro degradation

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Introduction

Magnesium is studied as a biomaterial for nonpermanent biomedical implants. Our study is focused on magnesium in vitro degradation. Extensive in vitro experiments in a simulated physiological environment have been carried out to investigate the influence of proteins on the degradation rate in order to create a protein coating that prevents the fast initial corrosion and decreases the whole corrosion rate during the implantation period, which is the major problem of the use of magnesium and its alloys as biomedical implants.

Methods

Pure magnesium samples and samples of pure magnesium coated with bovine serum albumin were analyzed. In our experiments we used porcine plasma and a simulated body fluid (r-SBF) as corrosion fluids, to test the influence of proteins. Thus, we want to be able to compare the results with the in vivo experiments. The in vitro degradation studies were done in static conditions and therefore the samples were immersed in each model fluid in 6-well-plates and placed in the incubator in a 5% CO2 atmosphere at a temperature of 37°C. The magnesium concentration released in the fluid test during the experiment was measured photometrically and the pH was...
controlled regularly. The mass loss was also calculated and for that the samples were treated with chromic acid, following the ASTM-Standard G1-03 protocol, in order to remove the oxide layer and weighted after that. SEM/EDX-Analyses were also performed.

Results

Our results show that the degradation rate depends directly on the composition of the fluid which is used we revealed that the coating and the addition of proteins have a significant influence on the degradation rate. An increase on magnesium concentration can be seen in all cases for the initial days. However, a lower initial corrosion has been observed for the coated samples, either in plasma and r-SBF.

Conclusion

The value of the degradation rate for pure magnesium in plasma is much lower than in SBF's. However in the case of the r-SBF when the samples are coated with proteins the degradation rate decreases. These studies show a slower and decreased degradation of magnesium coated samples, leading to a positive influence from proteins on corrosion prevention.

Acknowledgements

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PS02.004 - Electrospinning of vascular prostheses with anti-kinking properties

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Introduction

One of the major challenges in developing appropriate vascular substitutes is to produce a graft that adapts to the biological and mechanical conditions at the graft site. One approach is the use of electrospun grafts pre-seeded with autologous cells using methods of tissue engineering. When transplanted in a graft site with high deformation, stiffness of the graft leads to kinking which may result in vascular obliteration. The aim of this study was to develop an electrospun vascular graft consisting of biodegradable polymers which additionally possesses a high flexibility to avoid kinking.

Methods

In order to improve the bendability of the grafts, various collectors with different geometries were structured using six different patterns (30°-, 60°-, 90°-, 120° V-thread, knuckle thread and acme thread). Subsequently, the grafts were examined with regard to fiber deposition, mechanical strength and bendability.

Results

It was shown that using a collector structured with a V-shaped thread (flank angle of 120°) leads to a homogenous and reproduce-able fiber deposition. The results of the tensile tests were comparable to the unstructured reference sample, proving the first observation. Studies on bendability were performed using a custom made flow-bending test setup. It was shown that the flow through the V-shaped grafts reduced to less than 45 % of the reference value even after bending the graft to an angle of 140° (Figure 1). Compared to this, the flow through an unstructured graft reduced to more than 50% after bending to an angle of 55°.

Conclusion

The presented data, which were obtained with the developed flow-bending test setup demonstrate the need for optimizing the bend-ability of the commonly used electrospun vascular grafts. In this regard a macroscopic v-shaped engineered collector seems to be a promising method to overcome the issue of graft kinking.

Figure 1 Comparison of two samples with different surface structures. Unstructured reference sample at 40° bending (A). Pleated sample with 120° V-thread at 90° bending (B).

Acknowledgments

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PS02.005 - Electrospinning of polycaprolactone/chitosan polymeric fibrous membranes as scaffolds for cardiovascular tissue engineering applications

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Introduction

Cardiovascular diseases only in the USA account for more than 30% of all deaths with costs exceeding 300 billion dollars, according to the 2013 American Heart Association report [1]. While heart transplantation is the only cure for end-stage heart failure there is need for new strategies to develop materials that can support cell re-population and functionality recovery. Electrospinning is a facile and cost-effective technique that can produce bio-compatible structures to serve as extracellular matrix (ECM)-like scaffolds where cells can be seeded and proliferate eventually forming a hybrid bio-artificial tissue [2]. Fibrous mats, tubes and more complex 3D shapes can be successfully engineered not only to induce cell proliferation but also to release in a controllable manner biomolecules (e.g. proteins, growth factors) that can further support tissue formation [3].

Materials & methods

Polycaprolactone (PCL) and chitosan (CS) were dissolved in 99.8 % 2,2,2-Trifluoroethanol (TFE) at concentrations of 190 mg/ml and 10 mg/ml respectively. The solution was stirred at room temperature for 24 hours. Electrospinning was performed at a custom made apparatus with flow rate of 4 mL/h and electrical field of 1 kV/cm. Morphology of the fibrous scaffolds was examined by scanning electron microscopy (SEM) having previously been sputter-coated with gold. Chemical characterization including Fourier-Transformed Infrared Spectroscopy (FTIR) and X-rays diffraction (XRD) was carried out in order to determine the physico-chemical state of the polymers in the fibers.

Results and Discussion

Structural and morphological analysis indicated that the created fibers have a smooth, “spaghetti-like” shape with an average diameter of 1.098 ±0.52μm and random orientation. The average value of Young’s modulus was 10 ±5 MPa and the hysteresis ratio 0.35.
the hydrophilic property of the coaxial PVDF/PCL scaffolds, which can possibly stimulate cell ingrowth with its electrical activity because of its proven biocompatibility and piezoelectric properties, which can possibly stimulate cell ingrowth with its electrical activity upon mechanical deformation [1]. This work reports the coaxial electrospinning of Polyvinylidenefluoride (PVDF) and Polycaprolactone (PCL) core/sheath nanofiber mats in order to enhance the mechanical and physical properties of the PVDF fibers.

Experimental methods

Coaxial electrospun scaffolds were produced from PVDF 20% dissolved in N,N-dimethylformamide and acetone (4:1) as a core and PCL 170 mg/ml dissolved in Tetrafluoroethylene as a sheath. In the electrospinning process flow rates of 0.5 ml/h for the core and 1 ml/h for the sheath and voltages of 22 kV were applied to produce defined fibers. The structures of the PVDF/PCL scaffolds were observed and analyzed with SEM to determine their morphology and fiber diameter. The mechanical properties of the scaffolds were tested using a tensile testing machine (BOSE-Electroforce-LM1-Test-Bench). To determine the configuration of the core/sheath structure in the coaxially electrospun scaffolds and their piezoelectric properties the scaffolds were compared with untreated/raw PVDF pellets with respect to the presence of the nonpolar α-phase and piezoelectric polar β-phase by using FTIR and DSC. The contact angles of the scaffolds surfaces were measured using deionized water. Subsequently all results were analyzed and evaluated comparing with single-jet electrospun PVDF scaffolds.

Results

Coaxial electrospun PVDF/PCL scaffolds exhibited a higher tensile strength of 1.9 MPa and strain at break of 130% as compared with the maximum tensile strength of the single-jet electrospun scaffolds of 138 kPa with 75% elongation at break. The PCL layer increases the hydrophilic property of the coaxial PVDF/PCL scaffolds, which could enhance the adhesion and proliferation of the neural cells on the scaffolds. Similar to single-get Electrospinning of PVDF scaffolds, the coaxial PVDF/PCL scaffolds resulted in a polar β-phase formation, which is relevant for the piezoelectric effect, and showed a β-phase adsorption ratio of 53% at 841 and 1277 cm⁻¹ in the FTIR-spectrum.

Conclusion

This study shows the ability to produce coaxial nanofibers of PVDF and PCL with better mechanical and physical properties. The FTIR and DSC results demonstrate the piezoelectric effect of the coaxial PVDF/PCL scaffolds. Next steps will be carrying out in vitro and in vivo experiments to evaluate the cytotoxicity of the coaxial scaffolds and to investigate the neural cells culturing on the piezoelectric PVDF/PCL scaffolds.

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References


PS02.007 - Bio rapid prototyping project: Evaluation of spheroid formation for cells construct

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In the field of regenerative medicine, 3-D tissue engineering, which intends to regenerate lost tissues and organs, is mainly focused. Formation of a 3-D construct outside the body has already been attempted by using combination of three elements, cells, growth factors or genes, and scaffold. We have already established a technique to make a 3-D construct only with cells. However, these constructs are usually made by skilled technicians who are familiar with cells, reagents, and cells culture methods. Therefore, we are developing a cell processing robot for regenerative medicine.

Cells construct is made by spheroid-culturing the cells and neatly arrange the spheroids. Therefore, quality of spheroids is important. The spheroids are manufactured by dispensing cell turbid liquid into a special multiwell plate. If there is a difference in the number of cells when dispensing the cells turbid liquid, spheroids in different sizes are generated. Moreover, spheroids are not generated if the number of cells is extremely small, and if large, spheroids in distorted shapes are generated. Therefore, this study was aimed to evaluate spheroids formation.

In this study, operations was performed by non-skilled technician and skilled technician. We used MSC (Mesenchymal Stem Cell) harvested from a Japanese white rabbit. Cultures of MSC were carried out on the culture dishes (Φ150 mm, H25 mm, FALCON). Upon reaching the required number of cells, they were dispensed into the
special multwell plate for forming spheroids can generate 96 spheroids per plate. Cell number of a spheroids was set at 2*10^4, 3*10^4, 4*10^4, 5*10^4, 6*10^4 and 7*10^4, were taken by the camera every 24 hours. We analyzed the quantitative evaluation, i.e., area, diameter and degree of circularity, with the images of spheroid.

The result of the experiment was that there are difference in the spheroids created by non-skilled technician and skilled technician. The handwork was conducted by a skilled technician and there was no failure in the spheroid generation. However, when it was conducted by a non-skilled technician, sometimes resulted in failure. This case could have happened because the cells were exposed to the external air for a long time or the pipettes were erroneously operated and resulted in the occurrence of contamination, death cells, or no uniform works. Incidentally, the size of spheroids formed by the number of cells was different. In particular, it was found that there is a range of cell number to form spheroids with high degree of circularity. Therefore, by adjusting the number of cells, it may be possible to control the size of the spheroids.

We are performing the development of a spheroid building system. In spheroid exfoliation by pipetting or stirring of cells turbid liquid, it is necessary to reconstruct the motions of skilled technicians with specialist knowledge and technique so as not to damage the cells. Therefore, by the system reproduces techniques of the skilled technicians, we can obtain the spheroids uniformity, and can adjust the size of the spheroids.

PS02.008 - Scaffold Prototype for Heart Valve Tissue Engineering: Design and Material Analyses
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Cardiac valves are specialized structures that ensure unidirectional flow through the heart. The aortic valve is the most frequently diseased and substituted. The current alternatives have reached a satisfactory level, but they still have their limitations, the most relevant one being the inability to remodel and grow, a critical problem especially for pediatric patients. Tissue engineering is expected to be the ultimate solution to this, for it creates viable structures. The aim of this work is to propose a scaffold prototype for heart valve tissue engineering using biodegradable polymers and analyze its design and materials through computational analyses. The scaffold design was based on existing biological valves and a 3D model was build using SolidWorks 2008. Poli(3-hydroxybutyrate-co-valerate) (P3HBV), poli(L-lactic acid) (PLLA) and poli(e-caprolactone) (PCL) were submitted to tensile tests in order to obtain their mechanical properties. The data collected was used to perform the computational simulation using ANSYS. The parts of the prototype were built using compression molding and airbrushing techniques. Results show that the designed geometry and the materials chosen allow the scaffold to withstand the stresses which they are subjected to. Also, the techniques chosen were indeed adequate for the manufacturing of the prototype, resulting in a very resistant structure. Some adjustments can and will be made in order to optimize mechanical behavior, but generally the scaffold seems to be adequate for heart valve tissue engineering.

PS02.009 - Unidirectionally-frozen silk/gelatin scaffolds for cardiac tissue engineering
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On a global scale, cardiovascular diseases (CVDs) remain to be the leading cause of death. Not only a pathological problem for the patient, CVDs are also an economic burden due to the prescribed maintenance medication and resulting decrease in physical productivity of the patients. One of the most common CVDs is the narrowing of the coronary artery that leads to ischaemia and tissue necrosis. Due to the heart’s limited capacity to regenerate, heart transplants have long been the gold standard if a full functional restoration of the organ is desired. However, organ donor shortage and transplant rejection remain as challenges faced by heart transplants, making a tissue engineering strategy a more promising alternative. In this study, unidirectional freezing was achieved using a custom mold, and together with freeze-drying to fabricate a silk fibrin/gelatin-based scaffold with an aligned structure in an effort to mimic the natural anisotropy of cardiac tissue. Silk fibrin was chosen for its biocompatibility, biodegradability, low immunogenicity and good mechanical strength. Gelatin was added to enhance cell attachment to the scaffold. Scaffold morphology transitioned from an isotropic structure to an aligned structure as the freezing temperature was decreased, whereas pore morphology transitioned from an elliptical shape to a lamellar shape. Average pore size for the aligned scaffolds decreased as the freezing temperature decreased. All scaffolds exhibited a high degree of swelling with magnitudes of 656-700%. Cell viability and attachment was also investigated. The application of the aligned silk/gelatin scaffold as a cardiac patch is the objective of future studies. Although unidirectional freezing has been explored in previous investigations, its application as a cardiac patch has received little attention as of yet. It is hypothesized that the structural anisotropy of the scaffold will help promote differentiation of stem cells into a cardiomyogenic lineage without further external stimuli.

PS02.010 - Engineering Mesenchymal Stromal Cells (MSCs) to be More Immunoevasive by Altering Cell Culture Conditions
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We demonstrate that by minimally altering culture conditions for adult human bone marrow (BM) mesenchymal stromal cells (MSCs) to serum-free, cytokine-supplemented, non-adherent conditions, we can change the expression of adhesion molecules and human leukocyte antigens (HLA-ABC). This change is not accompanied by any other phenotypic changes; cells maintain the expression of minimal MSC cell surface antigens (CD90 (99.9%), CD105 (98%), CD73 (99.9%), CD14 (0.2%), HLA-DR (0.1%), and CD34 (0.1%) and retain their ability to undergo trilineage differentiation. However, these cells show a decrease in HLA-ABC expression (d7: 47%, vs 99.9% d14: 10.4% vs 95.9%, and d21: 3.8% vs 90%), vascular cell adhesion protein-1 (VCAM-1) expression (d7: 14.6% vs 95.9%, d14: 1.4% vs 88% , and d21: 0.1% vs 80%) and Intercellular adhesion molecule-1 (ICAM-1) expression (d7: 13% vs 78.2%, d14: 0.5% vs 70%, and d21: 2.6% vs 62.3%). A standard 51Cr cytotoxicity assay showed that MSCs cultured in suspension, under serum-free, cytokine-supplemented conditions had reduced susceptibility to cytotoxicity from NK-92, a permanent allogeneic NK cell line under clinical investigation for treating hematopoietic malignancies (9.08% ±1.86% killing vs. 59.17% ±3.66% killing at a 40:1 NK-92:MSC ratio). Cytotoxicity at lower effector-to-target ratios (20:1, 10:1, and 5:1) was effectively 0% (SD <2%) for MSCs grown in altered conditions, compared to
approximately 30% (SD <3%) for traditional, adherent-grown MSCs. In vivo experiments in an acute inflammatory (lipopolysaccharide (LPS) paw edema) murine model are ongoing to examine effects on modified homing and anti-inflammatory properties when MSCs are grown in altered, suspension cultures vs. traditional cultures. We conclude that by subtly changing culture conditions we can alter adhesion molecules and HLA-ABC expression, which in turn affects immunoevasion, homing and migration of MSCs, equipping the cells for potentially more potent therapeutic effects in treating immune-related disorders.

PS02.011 - Novel zwitterionic polypeptides for improving resistance to non-specific protein adsorption

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In the past three decades, because of the potential applications in biomedical fields, numerous biomaterials have been widely studied, such as medical implants, drug delivery carriers, and biosensors. Protein adsorption is the first response from human body to foreign materials exposed to physical environment. However, non-specific protein adsorption often induces biological incompatibility, thus, it’s very urgent to explore new surface modification of different materials in medicine. Herein, we developed a good candidate coating material, zwitterionic dimethyl aminopropyl amine-grafted poly (α, β-L-aspartic acid) (DMAP-PASP), by performing the aminolysis of poly (succinimide) (PSI) with different amount of a cationic monomer dimethyl aminopropyl amine, followed by hydrolysis of the residual PSI.

The modified polypeptide derivatives composed of certain negative carboxylic acid and positively charged aminopropyl amine, and this is why DMAP-PASP could be considered as random zwitterionic copolymers. The 1H NMR spectrums were used to demonstrate the ratio of successful conjugated cationic units. A novel turbidity and zeta potential measurements were used to study the dilute solution behaviors of DMAP-PASP under different pH values. Each of the synthesized zwitterionic copolymer exhibited an isoelectric point (IEP) and showed opposite charges below and above the IEP. Compared to our previously reported zwitterionic polypeptide derivative, synthesized by amidation of Poly (α, β-L-aspartic acid) with L-histidine methyl ester, this synthesis route is more convenient and the number of dimethyl aminopropyl amine functionalitie could be controlled in a quantitative way. Therefore, the isolectric point of the zwitterionic polypeptides could be easily tuned from pH 3.8 to 9.5.

There the fibrinogen, a blood protein resulting in the blood coagulation cascade, was used as a model protein. Therefore the zwitterionic polymer with an IEP of 5.3 was firstly pre-coated on the positive silica surface NH²-SWVs for the purpose of evaluating its protein-resistant characteristics. The amount of protein adsorbed to each sample was quantized and compared with those on the NH²-SWVs without polymer modification. Compared with the unmodified surface, fibrinogen protein adsorption on surfaces was eliminated effectively by DMAP-PASP polymer film. Furthermore, the anti-biofouling behavior through electrostatic interactions was affected by the surface charge density, which means in a dose-dependent manner.

Due to the good biodegradability and superior anti-protein-fouling property, this series of pH-responsive zwitterionic polypeptides are promising candidates for serving as an anti-biofouling material for in vivo applications, including medical implants, drug delivery carriers, and biosensors.

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PS02.012 - Study on preparation and mechanical properties of polyurethane foam with negative Poisson’s ratio

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Auxetic foam was a new kind of material which exhibit negative Poisson’s ratio effect. It has a wide application prospect. However, auxetic foam would gradually expand to its original volume with time increasing, and the negative Poisson’s ratio effect will disappear. The practical use of the auxetic foam has been limited, and it becomes an urgent problem to be solved before its application. The preparation conditions and the recovery ability of auxetic foam, the 60 ppi open cell polyurethane (PU) foam was used as the parent material. The PU foams were compressed in three dimensions and been heat treated at setting temperatures. After cooling down, the auxetic foams were made. In this study, all samples were set with the same radial compression ratio, but three different axial compression ratios. During the heat treatment process, the setting temperatures were 140°C, 150°C and 160°C respectively. It was found that the setting temperature in the condition of this study should be heated until 150°C to obtain the re-entrant structure.

PS02.013 - Proliferation of cardiomyocytes in neonatal, future implication in heart regeneration

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Background- Human heart is a limited-mitotic organ that responds to injury with limited cell renewal. In young infants, study of the regenerative capacity of cardiomyocytes may provide an important approach for heart regeneration.

Methods and results- Human right atrial specimens were obtained during routine surgery for ventricle septal defect (VSD) and were divided into two groups: Young infant group (age, 1-3 months) and Old infant group (age, 4-6 months). Results showed that Ki67 is expressed in proliferating cardiac myocytes, and that the number of Ki67-positive cells in young infant group is significantly higher than old group. The Notch pathway was found to regulate cardiomyocyte proliferation and apoptosis during development. Current data showed that NICD expression is significantly higher in young age group and NICD was mainly expressed in cardiomyocyte nuclei.

Conclusions- Proliferating cardiac myocytes are more abundant in the young infant period (<3 months) and the Notch pathway is conserved in humans. Further understanding of their proliferative ability at different ages may provide novel therapeutic targets that can be used to enhance cardiovascular regenerative capacity.
540

of biodegradable potential medical implant alloy Mg₂Ca result from rapid solidification with four cooling rates by using the generalized nonlocal model pseudopotential (GNMP) theory. Results indicate that cooling rate plays important role in the formation of icosahedron local structure, the lower the cooling rate, the more icosahedron micro-cluster forms in the system. It is also found that cooling rate is also have important effects on the glass transition, the higher the cooling rate, the higher the temperature the glass transition happens at.

**PS02.014 - Synergetic effects of released ions from CaO-MgO-SiO₂-based multiphase bioceramics on osteogenic proliferation and differentiation**

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Bioceramics have great potential for bone regeneration and tissue engineering applications. A novel CaO-MgO-SiO₂-based multiphase glass-ceramic, composed of akermanite (Ca₂MgSi₂O₇), wollastonite (CaSiO₃), and dicalcium silicate (Ca₂SiO₄) crystalline phases, was designed and synthesized by sol-gel method. As reported, this glass-ceramic could induce the formation of bonelike-CHA layer when soaked in simulated body fluid (SBF), and obviously promote cell proliferation and differentiation of human osteoblasts. Further research confirmed that the ionic products released from this CaO-MgO-SiO₂-based ceramic played an important role in the modulation of cell proliferation and differentiation. In this research, the synergistic effects of its released ions (calcium ions, magnesium ions, and silicic acid radical ions, simply marked as Ca, Mg, and Si ions) on MG63 cell behaviors and their effective ion concentrations were systematically and thoroughly investigated. Original extract was prepared according to International Standard Organization (ISO/EN 10993-5), and then times diluted into 1/2, 1/4, 1/8, 1/16, and 1/160. The corresponding concentrations of Ca, Mg, and Si ions in different diluted extracts were detected by inductively coupled plasma optical emission spectroscopy (ICP-OES), and the diluted extracts were used for cellular experiments. All the results showed that released ions from CaO-MgO-SiO₂-based bioceramic could stimulate cell proliferation and osteogenic differentiation of MG63 cells at certain concentrations. Such effects were concentration-dependent, and 1/4 diluted extract (Ca 104.69 ppm, Mg 13.13 ppm, Si 33.36 ppm) was the most significant. Moreover, even 1/160 diluted extract also stimulated osteogenic proliferation and differentiation, which might be caused by additional trace amounts of Si ions (Si 0.92 ppm). It is suggested that trace amounts of Si ions could work accompanied with certain concentrations of Ca and Mg ions. Above results inferred that synergistic Ca, Mg, and Si ions played an important role in osteogenic proliferation and differentiation. However, results of MTT and FCM revealed that 1/2 diluted extract (Ca 119.15 ppm, Mg 10.99 ppm, Si 45.08 ppm) slightly inhibited MG63 proliferation by hindering the transition of cell cycle from G₁ to S phase in the first day. This phenomenon indicated that excessive concentration of Ca and Si ions could result in inhibiting effect on cell proliferation, and with the presence of Mg ions, the effective combination concentrations of Ca and Si ions can not exceed 119.15 and 45.08 ppm, respectively. In general, synergistic effect of various ions is crucial for cell proliferation and differentiation. To merely investigate the ion concentration range of single ion would be of lesser significance, because the beneficial ion concentrations with the existence of various ions are certainly not as the same as that with single ion. This research displayed the synergistic effects of Ca, Mg, and Si ions on the regulation of osteogenic proliferation and differentiation, and investigated the effective concentrations of Ca and Si ions released from bioceramics with the presence of Mg ions. It would be the basis to investigate the biological function of these bioceramics, and would be of great importance to design CaO-MgO-SiO₂-based bioceramics applied as bone tissue engineering scaffolds.

**PS02.015 - Cooling Rate Effects on the Microstructure Evolutions of Biodegradable Mg₂Ca Potential Medical Implant Alloy**

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The molecular dynamics simulation calculations have been performed to investigate the cooling rate effects on the microstructure evolutions of biodegradable potential medical implant alloy Mg₂Ca.
In practice the behavior of the Bow-Arrow-Archer system termed 'interior ballastics' and the arrow in flight termed 'exterior ballistics' are complicated. In order to understand the mechanics of archery computer models are required. The musculoskeletal simulation is becoming a popular method in the research field of biomechanics to estimate muscle activity from body motion. The objective of this study is to conduct biomechanical simulation for a musculoskeletal archery. This simulation aims to find the movement patterns in several working postures, stress induced on muscles and the amount of elongation of different muscles responsible for performing archery.

The work presented discusses the anatomical body arrangements and conducts biomechanically correct simulation. A design of experiment technique was utilized to find the optimum parameters such as muscle effort, angle, stress, strain etc to eliminate excessive stresses on glenohumeral, sternoclavicular & clavoclavicular joints. Initially a three dimensional model of bow and arrow is generated in Solidworks. Next stage of the experiment was performing musculoskeletal simulation using AnyBody software using "Any-script" language which is similar like other existing programming languages. During this simulation of archery, all the programming codes were taken care thoroughly to reduce errors.

The anatomy of the shoulder is unique – it has a relatively shallow socket which results in amazing flexibility and range of motion to the glenohumeral joint which is unparalleled elsewhere in the body. The dynamic forces and stress of arm shoulder using lagrangian mechanics approach which is verified using simulation in AnyBody software. The stresses found in the deltoid, trapezious and biceps and tricep muscles are analyzed along with the range of elongation is shown in Figure 1.

By simulating the model one can analyze the causes for most common shoulder pain observed in archer. For each analysis, the system stores the maximum stress of muscle at any point of the movement. The simulation estimates the optimum parameters to eliminate stress overloading on the muscles and investigates muscle efforts and joint forces depending on postures.
were found in the sagittal plane only. Changes in speed altered the angular kinematics of the calcaneus vs tibia, midfoot vs calcaneus, and forefoot vs calcaneus. In addition, planar angles of the hallux, metatarsals, and medial longitudinal arch also varied with speed.

Similar to the results of simple foot models, the results of this work suggest that walking speed has an effect on multisegment foot kinematics. The relative angles between foot subsegments changed as a function of gait speed. The midfoot segment, which is often ignored in multisegment studies, showed significant changes in angular data with respect to the calcaneus. Therefore, multisegment foot studies of clinical populations should use speed-matched control data for comparative purposes. This would facilitate the identification of pathological gait from speed-mediated effects. Future studies will examine the effects of walking speed on multisegment foot kinematics in varying age groups.

PS03.004 - Investigation of transfibular locking plate to treat open extra-articular distal tibia fractures

**Author(s):** Ryan Normore, Helena Greene, Allison Delong, Andrew Furey, Amy Hsiao, Stephanie Atkinson

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The current surgical treatments for extra-articular distal tibia fractures have significant limitations; therefore the structural stability of a novel trans-fibular method of fixation was investigated. The fracture site was secured using a locking plate attached to the lateral side of the fibula by threaded locking screws projecting through the fibula and securing into the tibia. Synthetic sawbone specimens, that have been shown to behave similar to human bone, were chosen for this initial construct testing because of their anatomic consistency. The specimens have had osteotomies to simulate distal tibia fractures and have undergone trans-fibular fixation. The specimens were then tested using a hydraulic load frame under three different axial loading conditions; linear loading to 700N, cyclic loading of 700N for 10,000 cycles, and a specimen load to failure. Failure was defined as vertical displacement of the fracture site greater than 5mm or an angular displacement of the specimen were recorded and a preliminary analysis was completed, including a comparison of the stability of this novel construct with that of previously investigated methods of fixation.

PS03.005 - Kinematic analysis after total hip arthroplasty during weight-bearing activities

**Author(s):** Satoru Ikehata, Hidehiko Higaki, Yoshitaka Shiraishi, Takeshi Shimoto, Yoshitaka Nakashima, Daisuke Hara, Satoshi Hamai, Yasuharu Nakashima, Yukihide Iwamoto

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The hip joint has a wide range of motion. It achieves various daily activities. In the field of biomechanics, kinematic analysis of the hip osteoarthritis (OA) and total hip arthroplasty (THA) is important. Motion capture system has been widely used as kinematic analysis *in vivo*. However, external markers attached to the skin would be affected by soft tissue artifact with substantial errors. There is 2D-3D registration method as the kinematic analysis technique of high accuracy. There are reported of kinematic analysis technique of the natural knee and artificial knee joint using window analysis technique and single plane X-ray images. This study was aimed to analyze weight-bearing activities before and after THA. It was confirmed to be utility of this technique by kinematic analysis during squatting and chair-rising.

In this report, the subject was one female before and after THA. Kinematic analysis at pelvis after THA was used image correlation between X-ray images and the computational simulating image. The image matching of the cup and stem was matched shape of implant in X-ray images and simulating image of 3D shape data. The accuracy of this analysis method is within 0.28 mm and 0.30 degree. We evaluated the hip joint, femoral and pelvic rotational motion. The rotational motion of the hip joint evaluates the relative motion of the femur for the pelvis, and femoral and pelvic rotational motion evaluates the tilt of the each bone for the vertical plane.

In flexion angle of the hip joint during squatting, difference between normal hip and a subject was about 23.3-32.0 degree at initial position. In femoral flexion angle during squatting, we confirmed difference of about 15.3-21.0 degree between normal hip and a subject. The posterior tilt of pelvis at a subject (16.9 degree at OA, 17.2 degree at THA) was larger than that of normal hip (10.0 degree) during squatting. In flexion angle of hip joint during chair-rising, we confirmed difference of about 6.0-12.7 degrees between normal hip and a subject. In femoral flexion angle during chair-rising, difference between normal hip and a subject was about 1.7-7.0 degrees at initial position. The posterior tilt of pelvis at a subject (16.0 degree at OA, 3.4 degree at THA) was larger than that of normal hip (9.1 degree) during chair-rising. The OA was limited range of motion in hip joints. And, range of motion became widely after THA. The pelvic posterior tilt at the OA permitted high-flexion of the femur.

In this report, we analyzed movement of the normal, OA and THA hip joints during squatting and chair-rising. The results of the study demonstrated that limited range of motion in OA hip joints was compensated by pelvic tilt. The limited range of motion in OA hip joint was become widely by THA. From these results, we were able to analyze movement of the hip joint in vivo using window analysis technique.

PS03.006 - Estimation of Compressive and Shear Forces on Lumbar Spine during Lifting by Wii Balance Board

**Author(s):** Hieyong Jeong, Kenji Yamada, Soichiro Watanabe, Moe Yokoyama, Michiko Kido, Taishin Nomura, Yuko Ohno

**1Robotics & Design For Innovative Healthcare, Graduate School of Medicine, Osaka University, Suita/Japan, 2Konoike Institute Of Technology, KONOIKE Transport Co., LTD., Osaka/Japan, 3Division Of Health Sciences, Graduate School of Medicine, Osaka University, Suita/Japan, 4Mechanical Science And Bioengineering, Graduate School of Engineering Science, Osaka University, toyonaka/Japan**

Compressive and shear forces on lumbar spine are recognized as a risk factor for low back pain. Previous studies of forces have shown how injurious stresses on the low back can be predicted by such biomechanical models of the torso during the early phases of designing materials handling tasks in industry, but there are little studies on posture analysis with measurement of combined center of mass between a worker and an object during lifting under realistic field conditions.

**[Purpose]**

The purpose of this study is to propose the evaluating method to estimate compressive and shear forces on lumbar spine during lifting by using the Wii Balance Board under realistic field conditions.

**[Methods]**

The Wii Balance Board is able to measure both the position and
weight of combined center of mass between a worker and an object, and also to estimate trunk kinematics through two-degree-of-freedom link model. The proposed method is to calculate compressive and shear forces on lumbar spine during lifting with measured results of the position and weight of combined center of mass and estimated results of trunk kinematics. To compare with the conventional method, we let the center of balance of posture in the conventional method correspond with the center of pressure in the Wii Balance Board. The system for estimating is portable and inexpensive because the system is composed of the Wii Balance Board and the laptop computer.

[Results]

Through comparison, we found that results of proposed method were familiar with results of conventional method during bending forward or unbending backward, however, there was the difference between two estimated results just before bending forward or unbending backward. We considered that this came from the difference between the measurement and the assumption for combined center of mass.

[Conclusions]

We propose the evaluating method to estimate compressive and shear forces on lumbar spine by using the Wii Balance Board under realistic field conditions, and our method shows the effectiveness through comparison with results of conventional method. Additionally, the proposed method shows the possibility to be used to let participants know whether the current own lifting posture is proper or not in order to prevent workers in industry from worsening low back pain under realistic field conditions.

PS03.007 - A biomechanical evaluation of a novel pedicle screw-based interspinous device used to stabilize the lumbar spine

Author(s): Yu-Shu Lai1, Hsin-Chang Chen2, Chi-Wei Chou1, Cheng-Kung Cheng2

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Interspinous spacers alters the load to be transferred through the spinal process instead of anterior column and the consequent fractures of the spinous process would be raised for patients with poor bone quality. In order to reduce the risk of spinous process failure, this study developed a novel pedicle screw-based supporting system with an "M" geometry, which was designed to overcome the previous disadvantages from spinal fusion, artificial disc replacement, and traditional interspinous devices.

The first part of this study was to evaluate the mechanical strength of the novel device by using a material testing machine (MTS Bionix 370.02). Six sets of titanium alloy-made devices were tested with a fixator referred to ASTM F2624 and ASTM F2790. The second part was to design a spine simulator for evaluating the range of motion in porcine lumbar spines (Fig. 1). Total of 24 sets of spine were tested (6 intact, 6 L3-L4 implanted with the new devices, 6 L3-L4 implanted with X-Stop, and 6 L3-L4 implanted with the posterior fixation).

The results of mechanical strength showed that there was no failure occurred in the new devices under the maximal loading of 15 Nm in the backward bending test. The new device group demonstrated a similar range of motion in forward bending (0.3°) and lateral bending (2.3°) compared to the X-Stop group and a higher of that compared to the posterior fixation group. As for backward bending, the new device was proved to possess a higher stiffness compared to X-Stop and posterior fixation.

In conclusion, the novel interspinous device has enough mechanical strength, and it constraint the spinal extension to avoid nerve root/spinal cord compression, unconstrained spinal flexion, and the lowered influence on adjacent levels.

Figure 1

PS03.008 - Hematological, Biochemical, and End-organ effects of the CH-VAD in Ovine Model

Author(s): Changyan Lin

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Background The CH-VAD is an implantable, fully magnetically suspended ventricular assist device developed by CH Biomedical Corporation for full cardiac support. This study was performed to evaluate the short-term (35 days) hematological, biochemical, and end-organ effects of the CH-VAD left ventricular assist device (LVAD) in a sheep model trial. Methods Six sheep underwent CH-VAD implantation without the use of cardiopulmonary bypass. The pump inflow was inserted into the left ventricle and the outflow graft was anastomosed to the descending aorta. Data on pump function and the health condition of the animals, including hematologic and biochemical tests, were collected during the study period. When each study was determined to termination, the sheep were humanely euthanized and the end organs were examined macroscopically and histopathologically. Hemolysis was evaluated based on the amount of free hemoglobin in the plasma. Results Except for one device that stopped operation on the 25th postoperative day because of thrombus formation, the planned date of termination (35 days) was reached in all the animals without complication and device failure. Gross examination of the pump interiors, inflow and outflow, and of the arterial anastomosis sites showed no signifi-
significant abnormalities. Hematologic and biochemical test results were within normal limits during the study period. Elevations observed in the levels of white blood cell count, and decreases in hematocrit, hemoglobin, and red blood cell count were of short duration, these parameters returned to normal within 20 days of surgery. Serum urea nitrogen, creatinine, SGPT(ALT), SGOT(AST), and lactate dehydrogenase levels showed transient increases within the first five days of surgery. Other biochemical parameters were within normal limits. Macroscopic and histopathologic examinations of the explanted organs revealed no evidence of ischemia or infarction associated with the device implantation, except for small foci of infarction in the kidneys of two sheep. The free hemoglobin level in plasma peaked at 9.5 mg/dL on the fifth postoperative day. Conclusions Hematological, biochemical, and end-organ functions were not adversely affected by short-term CH-VAD system.

**PS03.009 - Novel Low-Profile External Fixator with Simple Locking Mechanism Compared with Commercial Available External Device Could Provide Better Stability in Multicycle Dynamic Loadings**

**Author(s):** Kun-Jhih Lin1, Chih-Hui Chen2, Wen-Chuan Chen1, Hung-Wen Wei1, Jeu-Ying Li1, Cheng-Lun Tsai3, Kang-Ping Lin1

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Recently, the standard locking compression plate (LCP) as an external fixator was introduced and coined the term supercutaneous plating. However, there are some limitations of LCP external fixation, such as limited screw holes available and insufficient strength compared with traditional fixator. We developed a LCP-like large plate to provide more screw numbers and higher strength to withstand the force during walking. Conceptually, the novel plate fixator was based on a tibial locking plate (A Plus Biotechnology Co., Ltd., New Taipei City, Taiwan) which acts for internal fracture fixation. The plate fixator was developed with much less tendency for the frame to strike the contralateral lower leg in swing phase during ambulation. Therefore, we developed a simple low-profile external device to overcome these drawbacks. This novel external device is characterized as arced shape proximally and multi-directional screw insertion trajectory to enhance fixation stability of fracture. This study aimed to investigate the biomechanical performance of the novel device and to compare with commercialized traditional external fixator. The LCP-like large plate is demonstrated the ability of fragment stability. We expected this improvement may reduce the nonunion rate noted in the LCP application.

<table>
<thead>
<tr>
<th>Displacement (mm): mean±standard deviation</th>
<th>Novel fixator</th>
<th>Synthes fixator</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile</td>
<td>1.54±0.13</td>
<td>2.21±0.22</td>
<td>0.48</td>
</tr>
<tr>
<td>Compressed</td>
<td>0.66±0.05</td>
<td>0.83±0.11</td>
<td>0.55</td>
</tr>
<tr>
<td>Total</td>
<td>2.2±0.26</td>
<td>3.03±0.18</td>
<td>0.15</td>
</tr>
</tbody>
</table>

This dynamic load analysis revealed lesser fragment movement in the novel fixation. Additionally, the plate fixator was developed with low profile which is easily concealed under regular clothing and much less tendency for the frame to strike the contralateral lower leg in swing phase during ambulation. More importantly, this study demonstrated better stability in the novel fixator than traditional external fixator. The LCP-like large plate is demonstrated the ability of fragment stability. We expected this improvement may reduce the nonunion rate noted in the LCP application.

**PS03.010 - A simple external fixation technique for treating bicondylar tibial plateau fracture: a finite element study**

**Author(s):** Wen-Chen Lin1, Kun-Jhih Lin1, Chih-Hui Chen2, Bo-Hao Li1, Jeu-Ying Li1, Wen-Chuan Chen1, Hung-Wen Wei1, Cheng-Lun Tsai2, Sheng-Cheng Huang1, Kang-Ping Lin1

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Bicondylar tibial plateau fractures are difficult to treat with a high complication rate due to difficulties in achieving stable fixation. External fixation methods such as monolateral external fixator, circular external fixators, or a hybrid between a monolateral and a circular external fixator are considered to be good mechanical methods of stabilizing these complex fractures. However, main disadvantages of these traditional external fixators are bulky and cumbersome for the patient during daily activities. Therefore, we developed a simple low-profile external device to overcome these drawbacks. This novel external device is characterized as arced shape proximally and multi-directional screw insertion trajectory to enhance fixation stability of fracture. This study aimed to investigate the biomechanical performance of the novel device and to compare with commercialized traditional external fixator. Finite element method was employed to carry out all biomechanical analyses. Three CAD models of a normal tibia bone, the simple low-profile external device, and a traditional monolateral external fixator were reconstructed (Fig 1). Bicondylar tibial plateau fracture was simulated according to AO classification (AO/OTA type 41-C1; Schatzker type-V). A 1000N axial compression load was applied to the tibial plateau with fully fixed distal end of the tibia. Maximum von Mises stress on bone, screws, and fixators were calculated. The construct stiffness of both groups were calculated also.

![Fig. 1. Model of a novel plate external fixation with simulated tibia fragments apart.](image)
sensitivity, wide dynamic range and sharp frequency selectivity of our hearing.

Unfortunately, however, OHCs are vulnerable to noise exposure, ototoxic acid, aging and so on. Previous studies have shown that exposure to intense noise causes functional loss of OHCs from the innermost row (i.e., close to the modiolus) to the outermost row (i.e., close to the cochlear wall). On the contrary, by other traumatic stimuli such as ototoxic acid, aging and ischemia, such loss of OHCs has been reported to occur from the outermost row toward the innermost row. However, how the cochlear amplification changes when coordinated movement of OHCs is impaired remains unclear. Since the OC is vulnerable and sound-induced displacement amplitude of the OC is quite tiny, measurement of the dynamic behavior of the OC is difficult. Analysis using finite element method (FEM) is thus helpful.

In the present study, therefore, a finite element (FE) model of the gerbil cochlea, which takes the motility of OHCs into account, was developed based on our previous FE model. Using this model, changes in the displacement amplitude of the BM due to the functional loss of OHCs in one, two or all three rows were investigated and the effects of incoordination of the three rows of OHCs on cochlear amplification were estimated. Results showed that the displacement amplitude of the BM significantly decreased when either the innermost row or the outermost row of OHCs lost its function, suggesting that all three rows of OHCs are required for cochlear amplification.

The results showed that the maximum von Mises stress on implants was much lower than the yielding strength of the material for both groups. The construct stiffness of the novel device (4992.5 N/mm) was 49.8% higher than the traditional external device (3333.3 N/mm) (Fig 2). This study demonstrated that the fixation strength of the novel external device was higher than the traditional monolateral fixator. Clinical evaluation for the novel device is still necessary to further verify its usefulness.

**PS03.011 - Numerical analysis of the elaborate sound amplification mechanism of the mammalian inner ear**

*Authors*: Michio Murakoshi¹, Hiroshi Wada²

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Sounds are converted to the mechanical vibration by the tympanic membrane and this vibration is transmitted to the basilar membrane (BM) and the sensory organ of hearing named organ of Corti (OC) in the cochlea. The OC consists of one row of inner hair cells (IHCs), three rows of outer hair cells (OHCs) and other supporting cells, as shown in Fig. 1.

The process known as cochlear amplification is realized by coordinated movement of the OHCs in response to changes in their membrane potential. In this process, the displacement amplitude of the BM is thought to be increased, thereby leading to the high sensitivity, wide dynamic range and sharp frequency selectivity of our hearing.

Unfortunately, however, OHCs are vulnerable to noise exposure, ototoxic acid, aging and so on. Previous studies have shown that exposure to intense noise causes functional loss of OHCs from the innermost row (i.e., close to the modiolus) to the outermost row (i.e., close to the cochlear wall). On the contrary, by other traumatic stimuli such as ototoxic acid, aging and ischemia, such loss of OHCs has been reported to occur from the outermost row toward the innermost row. However, how the cochlear amplification changes when coordinated movement of OHCs is impaired remains unclear. Since the OC is vulnerable and sound-induced displacement amplitude of the OC is quite tiny, measurement of the dynamic behavior of the OC is difficult. Analysis using finite element method (FEM) is thus helpful.

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ABSTRACTS | IUPESM 2015 WORLD CONGRESS ON MEDICAL PHYSICS & BIOMEDICAL ENGINEERING

**PS04.001 - Image-Guided Intra-arterial Delivery of Yttrium-90 Radioactive Microspheres for the Treatment of Liver Tumors**

**Author(s):** Muthana Al-Ghazi1, Varun Sehgal2, Suhong Yu1, Garrett Green1, Glenn Samford1, Jeffrey Kuo1, Dayantha Fernando1, David Imagawa3

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Purpose: To outline the use of yttrium-90 (Y-90) for the treatment of liver tumors.

**Background:** Y-90 is a $\beta$-emitter with an energy of 2.28 MeV. It decays to Zr-90 with a half-life of 64 hours. It is produced from the decay of Sr-90; the latter in turn is produced by chemical high-purity separation from strontium-90, a fission product of uranium in nuclear reactors. The short range of the emitted $\beta$-makes Y-90 ideal for irradiation of tumors at very short range. Liver tumors arise as either primary tumors (e.g. hepatocellular carcinoma) or as metastases resulting from e.g. colorectal primaries. In the simplest form, these tumors destroy the local vasculature of the liver. As such, delivery of Y-90 coated microspheres through liver vessels will terminate at the tumor site enabling very high doses to be delivered locally.

**Methods:** Healthy liver tissue gets its blood supply from the portal vein. The hepatic artery supplies blood to the tumor. Therefore, delivery of a "radioactive drug" through the hepatic artery will lead to the site of the tumor leaving healthy liver tissue and its blood supply unaffected. A catheter is inserted intrafemorally under fluoro-microspheres from escaping to the gastrointestinal tract and meantime the descending gastric artery is coiled to prevent Y-90 artery. This intervention is performed under local anesthesia. In the simplest form, these tumors destroy the local vasculature of the liver. As such, delivery of Y-90 coated microspheres through liver vessels will terminate at the tumor site enabling very high doses to be delivered locally.

**Results:** This method of image-guided brachytherapy enables safe delivery of doses in the range 100 – 150 Gy to the tumor site with minimal normal tissue toxicity due to the short range of the emitted $\beta$-particles, taking advantage of the destruction of the vasculature by the tumor and the nature of the hepatic blood circulation. There appears to be a favorable dose response associated with this minimally invasive procedure for patients who are not surgical candidates and have exhausted other treatment options.

**Conclusion:** Y-90 radioactive microspheres can be safely used to deliver doses in excess of 100 Gy locally to liver tumors with minimal toxicity taking advantage of the low energy (2.28 MeV) of the emitted $\beta$-particles and the nature of the hepatic blood circulation. This advantage along with the short half-life of this isotope enables this minimally invasive procedure to be performed as a same day surgery. Preliminary evidence suggests a favorable dose response at this dose range.

**PS04.002 - Commissioning of an ASI EPID for patient specific IMRT QA.**

**Author(s):** David N. Alonso Fernández1, Rodolfo Alfonso1, Eduardo Larrinaga2, Jose L. Alonso Sanpera1, Rogelio Diaz Moreno1

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The use of the Electronic Portal Image Device (EPID) in an Elekta Linac for patient-specific Intensity Modulated Radiotherapy (IMRT) Quality Assurance (QA) is assessed and validated. A linac Elekta was used, with IMRT step&shoot capability using Multileave Collimator (MLC). An EPID image calibration was performed for a 6MV photon beam and a 10x10cm$^2$ field size. The EPID effective water scattering depth ($d_{\text{eq}}$) was assessed through the measurement of its response versus the field size variation; and compared to the output factor scatter at different depths calculated from Radiotherapy Treatment Planning System (RTPS) Elekta XiO data. A correction matrix was created from a 24x24cm$^2$ field profile paddy with radial symmetry.

The EPID $d_{\text{eq}}$ was found to be close to 5cm. Dose profiles and dose maps were calculated to $d_{\text{eq}}$ with the RTPS using a collapsed beam arrangement. Also they were measured with the bidimensional (2D) ion chamber array PTW Seven29. Octavius sandwiched in PTW RW-2946 slabs for validation purpose. Point measurements with an ion chamber PTW M30013 Farmer type were carried out also. The dose maps and profiles were compared to the processed EPID images for simple cases (i.e. open fields and wedged fields) and more complex cases (Head and Neck IMRT clinical cases).

The EPID obtained dose maps were compared with the RTPS calculated dose maps and the measured with the 2D-array. Comparison was performed using the PTW VeriSoft v5.1 software. Results showed that approximately 90% of all points passed using a 3% dose/4mm Distance to Agreement (DTA) for the gamma analysis for both methods.

**PS04.003 - Status of Radiotherapy Treatment in Lebanon**

**Author(s):** Ibrahim Duhaini1, Antar Aly2

1Radiation Oncology, Rafik Hariri University Hospital, Beirut/LEBANON, 2Hamad Medical corporation, Doha/QATAR

**Abstract:**

Lebanon is located in the heart of the Middle East Region with a population of 4.5 million and is considered one of the best places of Medical Hot Spot destination that attracts many of the neighboring Arab countries to seek medical treatment. This is due to the fact of the highly skilled medical professionals and advanced health infrastructure in the country. Radiotherapy started in the early 70’s with Cobalt Machines and has developed tremendously thought the years to include the highly technological and advanced Linac Systems. Now, there are 10 Hospitals that offer Radiotherapy Treatment with 14 Linacs equipped with the state of the art technology using 3-D Conformal, IMRT, Stereotactic Radiosurgery, IGRT and other modalities. In this presentation, an overview of the current cancer treatment in these 10 hospitals will be revealed. Detailed information will be unwrapped for the newly opened Radiotherapy Center at Nabih Berry Governmental University Hospital (NBUGUH) in South Lebanon, which covers one third of the Lebanese population in that region.

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A VMAT arc technique was designed to treat the full scalp for a patient with angiosarcoma of the scalp to a dose of 6000cGy in 25 fractions.

The CT of the entire head was acquired with the patient in supine treatment position with a 0.5 cm thick custom bolus-cap on the top and back of the head, an immobilization shell, and additional bolus attached to the shell.

A VMAT plan to be treated on a Varian True Beam LINAC was optimized in Eclipse using the photon dose AAA calculation version 11. Two full arcs with couch at 0° and collimator at +/- 10° where used along with two partial arcs with couch at 270° and collimator at 90°. The treatment was optimized to cover the skin, and a PTV margin, while sparing the underlying brain and limiting the dose to the optic apparatus and lacrimal glands. The dose to the brain was limited so that V20Gy, V30Gy and V40Gy were 710, 390 and 193 cm³ respectively. The mean dose to the brain was 2385 cGy.

On the 2nd treatment day, 13 TLDs where positioned on the patient’s scalp. The TLDs were spaced 2cm apart, 9 along the midline sagittal plane, and 4 along an axial plane. The dose measured by the TLDs was compared to the treatment planning calculation and it showed an excellent agreement. The mean difference between the measured and calculated dose was 1% with a standard deviation of 4%.

TABLE 1: Results of the TLD dose measurements compared to the treatment planning calculation for 13 positions spaced 2 cm apart on the patient’s scalp.

<table>
<thead>
<tr>
<th>Treatment Planning (cGy)</th>
<th>TLD Dose (cGy)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>245</td>
<td>247</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Minimum</td>
<td>236</td>
<td>231</td>
</tr>
<tr>
<td>Maximum</td>
<td>253</td>
<td>259</td>
</tr>
</tbody>
</table>
high dose gradient. However, Pinpoint chambers still have been used for the measurement of absolute dose in dosimetric quality assurance (QA) of stereotactic radiosurgery (SRS). The aim of the present study was to evaluate the applicability of Pinpoint ion chamber for the measurement of small photon beams in dosimetric QA under the actual SRS treatment circumstances.

A total 23 cases of SRS plans were used for the verification and the diameters of the target volumes were divided into two groups, the diameter of <10 mm (10 cases) and of ≥10 mm (13 cases). The PTW 31014 Pinpoint chamber was used to measure the absolute dose of small beams in SRS treatment and the chamber has an active volume of 0.015 cm³. To compare the dosimetric uncertainties for Pinpoint chamber, the PTW 60003 natural diamond detector was used as a reference dosimeter. A custom-made cylindrical acrylic phantom (15 cm diameter, 15 cm length) was designed for measurement. The noncoplanar arc plan was created to deliver a prescription dose (15-25 Gy) to 80% of the maximum dose of the target in a single fraction and then the calculated plan was project-ed on the CT images of the phantom as inserted each detector for verification planning. All irradiations were performed using a Varian Clinac IX 6MV equipped with a micro-multileaf-collimator designed by BrainLAB. The acceptability criteria of the dose difference at our institution is less than 3%.

The dosimetric uncertainty was represented as a percentage dose difference between planned and measured. For Pinpoint chamber in the target diameters of <10 mm, the maximum dose difference was 4.85%, the mean ± standard deviation (SD) discrepancy was 2.82±1.41%, and the number of the dosimetric uncertainty of >3% was 7 of 10 cases. For diamond detector in the same diameters, the values were 2.70% and 1.51±0.74% and all measured discrepancies were <3%. Statistical analysis indicates that the dosimetric uncertainties for Pinpoint chamber in the target diameters of <10 mm were significantly different from the uncertainties for diamond detector (p<0.05). On the other hand, the maximum difference was 1.56% and mean ± SD discrepancy was 0.81±0.44% for Pinpoint chamber in the target diameters of ≥10 mm and the values were 1.79% and 1.09±0.41% for the diamond detector. The correlations between the dosimetric uncertainties and the all target diameters in our study by determining the R² regression coefficient. A highly significant but moderate correlation was observed for Pinpoint chamber (R²=0.483, p<0.001), whereas the weak correlation was observed for diamond detector (R²=0.053, p=0.230). Based on the results of this study, Pinpoint chamber is unsuitable for the measurement of the absolute dose of SRS field designed by the target diameters of <10 mm, whereas the chamber can provide reliable and acceptable data for verifying the SRS fields created by the diameter of ≥10 mm. Photons generated by Bremsstrahlung in tungsten target are transported too. Percentage depth doses (PDD) and beam profiles were calculated for different field sizes. The MC calculated results were compared against measurement and good agreement was ob-tained. The comparison between MC calculations and measurement of PDD showed less than 5% of error for build up region. Also, there was a high coherence in beam profiles comparison. In the flat region was less than 3% of error and near to 10% difference was seen for penumbral region. In conclusion, our study showed acceptable results according to the reference criteria. The developed model will optimize the patient dosimetry in radiotherapy treatment planning.

PS04.009 - A Comparison of Dosimetric Characteristic Between Integrated and Cine Acquisition Modes of a-Si EPID

Author(s): Omemh Bawazeer¹, Siva Sarasananarajah¹, Sisira Herath¹, Tomas Kron², Shu Hui Hsu³, Pradip Deb³

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Electronic Portal Imaging Device (EPID) is currently used for the dosimetry purpose. There are two acquisition modes, integrated and cine mode [1]. The aim of this study is to compare the dosimetric characteristic between both acquisition modes. The a-Si 500 EPID that attached to Varian Synergy linear accelerator was used in this study. The comparison included the response of EPID to dose, reproducibility, field size dependence, ghosting effect, dose rate and multi-leaf collimator effect. In addition, the ionization chamber response under the identical setup was acquired to assess the dosimetric characteristic of EPID response with two acquisition modes. All acquired images were analysed using MATLAB programme. The preliminary results of comparison between acquisition modes for dose response and field size dependent represent in Figure 1 and Figure 2. The results indicated that the differences between two modes is because the difference in the pixel value range for each mode, however both modes have a comparable response to dose. In each mode, the ratio between following points is varied with the increasing MU. For example the ratio between 100 to 200 MU for integrated mode is slightly different from the ratio between 200 to 300 MU. In contrast, this ratio for integrated and cine mode is equal. In clinical application, even both acquisition mode has a relatively similar response, each mode required individual calibration factor for dosimetry purpose due to the difference in the range of pixel value intensity for each mode.

PS04.008 - Development of a VARIAN 600 C/D Linear Accelerator model using MCNPX 2.6 Monte Carlo code.

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In radiotherapy treatment planning, tools that improve the accuracy of patient dosimetry are valuable. The Ministry of Health of Brazil has near of 240 linear accelerators in the radiotherapy service. VARIAN is the main distribution company in the country and more than 60% are linear accelerators of low-energy (4-6 MeV). In this re-search work, a simple and useful model was developed for VARIAN 600 C/D linear accelerator using MCNPX 2.6 Mote Carlo (MC) code. The essentials components of VARIAN 600 C/D head was simulated for 6 MeV electron beam using MCNPX 2.6 MC code. In this study is considered a monoenergetic electron beam of 6 MeV as a source.

Figure 1: Response of a-Si EPID in both acquisition modes as a function of MU, error bars are too small to see.
Figure 2: Response of a-Si EPID in both acquisition modes as a function of field size.

Reference:

PS04.010 - Predicting clinical outcomes in locally-advanced non-small cell lung cancer using machine learning focusing on tumor and node imaging features

Author(s): Heyse Li1, Nathan Becker2, Srinivas Raman3, Timothy C.Y. Chan4, Jean-Pierre Bissonnette5

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There is evidence that computed tomography (CT) and positron emission tomography (PET) imaging metrics are prognostic and predictive in non-small cell lung cancer (NSCLC) treatment outcomes. We investigated the use of image features extracted from the radiotherapy target volumes to predict relapse in a cohort of NSCLC patients undergoing chemoradiation treatment (CRT). A prospective cohort of 25 patients with locally-advanced NSCLC underwent PET/CT imaging for radiation planning. Thirty-seven image features were derived from the CT-defined volumes and standard uptake values (SUV) of the PET image, for both the tumor and nodal target regions. The machine learning methods of logistic regression and repeated stratified five-fold cross-validation (CV) were used to predict local and overall relapse at two years of follow up. We selected features through an exhaustive search over all combinations of single- and two-feature classifiers. Classifiers were evaluated on their Matthew’s correlation coefficient (MCC) after CV.

For local relapse, the best classifier had a mean CV MCC of 0.42. The classifier was composed of two features: (1) the volume of tumor having an SUV greater than the 95th percentile of the SUV distribution and (2) the volume of the whole tumor based on the CT scan. For overall relapse, the best classifier had a mean CV MCC of 0.51. The classifier was composed of two features: (1) the volume of tumor having an SUV greater than half of the 95th percentile SUV and (2) the volume of the nodes having an SUV greater than half of the maximum SUV.

Adding node-specific SUV information to the classifier improved the ability to predict overall relapse two years following treatment in our cohort of NSCLC patients. Also two-feature classifiers outperformed single-feature classifiers in predicting both local and overall relapse.

S04.011 - Risk estimate of second primary cancers after breast radiotherapy

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Purpose: Induction of second primary cancers (SPCs) after breast radiotherapy (RT) has been known for some time and organs such as the lungs and the oesophagus have been identified as common sites for SPC formation. At present, breast cancer patients can be treated with a number of RT techniques that may have different morbidity risks. As a result, the current study investigated the risk of secondary carcinogenesis associated with particular radiotherapy techniques for breast cancer; these included 3DCRT whole breast, segmented breast, partial breast and mammosite brachytherapy.

Method: Seven breast cancer patients had all major organs contoured by a radiation oncologist on their planning CT images. Whole breast, segmented breast, accelerated partial breast irradiation (APBI) and mammosite boost treatment plans were generated for each patient using Pinnacle3 v 9.2 treatment planning system. Whole and segmented breast techniques used two tangential wedged fields; where the segmented techniques consisted of more MLC defined segments. Prescribed dose of 2 Gy for 25 fractions was used for calculations. APBI treatments were planned based on the Trans-Tasman Radiation Oncology Group (TROG) “trefoil” technique, using three non-coplanar fields. 6 MV photon beam was used for all treatment plans with a prescribed dose of 3.85 Gy for 10 fractions. Mammosite treatments consisted of a brachytherapy balloon (~35 mm diameter) inserted into the tumour bed inside a breast. Ir-192 source was positioned in the centre of the balloon to deliver the dose of 3.5 Gy for 10 fractions. Differential dose volume histograms were generated for a number of critical structures: bladder, brain and CNS, breast, colon, liver, lung, mouth and pharynx, oesophageous, ovary, salivary gland, small intestine, stomach, and uterus.

The lifetime attributed risk (LAR) of cancer induction was then estimated using the BEIR VII and Schneider et. al. excess absolute risk models and calculated dose volume histograms for the above organs.

Results: The sites with the highest LAR estimates were the ipsilateral and contralateral lungs, and contralateral breast for all treatment techniques. For all sites, the LAR estimates for the segmented breast and mammosite treatments were lower than those for the whole breast and APBI treatments. For right sided target volumes the liver also resulted in high LAR estimates, with all techniques having a LAR greater than 20 per 10,000 PY, except for mammosite with a mean LAR estimate of 13.2 per 10,000 PY, as calculated by the full model. For left sided target volumes the stomach also resulted in high LAR estimates, with both whole breast and APBI having a LAR greater than 20 per 10,000 PY, and mammosite the lowest with a LAR of 8.3 per 10,000 PY, calculated by the full model.

Conclusions: Whole breast, segmented breast, APBI and mammosite treatment plans were generated for seven breast cancer patients, and the DVHs were used to estimate the risk of secondary primary cancer induction. As expected from reported clinical studies; the lungs and contralateral breast showed high LAR estimates. Results show that mammosite technique results in the lowest risk estimate for SPC induction.
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Purpose: For deep seated targets in the lower pelvis, the highly conformal nature of proton therapy offers advantages in sparing organs at risk (OARs) located in the beam’s path. A sharp distal penumbra effectively reduces dose beyond the distal edge, completely sparing the OARs located beyond the distal edge. However, OARs located proximal to the beam’s distal edge may receive significant dose. Selection of an optimal proton pencil beam scanning (PBS) beam angle has the potential to reduce the magnitude of dose to OARs by minimizing the integral dose. This would ensure target coverage and minimize the number of treatment beams. The purpose of this work is to investigate if a single optimal proton PBS beam angle could be quantitatively determined for lower pelvic targets.

Methods: This study employed a cohort of ten consecutively enrolled patients with high risk rectal cancer. The clinical target volume (CTV) was delineated by an attending radiation oncologist. Three plans were created for each patient where each plan had a single beam oriented in the left lateral, right lateral, and posterior directions. For each of the three beam angles, a ray-tracing approach was used to calculate the values of optimization metrics. The optimization process was based on two objectives: path length and HU homogeneity. The goal was to minimize the path length of the proton PBS beam from the patient surface to the distal edge of the CTV, relative to the entry point, while simultaneously minimizing HU inhomogeneity along the path length. The path length of a ray was calculated as a straight-line Euclidean distance from the surface of the skin to the distal edge of the CTV. HU homogeneity, which is to say inter-ray HU variation, was quantitatively defined as the standard deviation of the average intra-ray HU intensity distribution of the several hundred beamlets which comprise one beam. Both metrics were assessed for normalcy with a Kolmogorov–Smirnov (KS) test where the criteria for a normal distribution classification was p<0.05.

Results: The KS test demonstrated that the distribution of path lengths were normally distributed in each beam angle. The average p-value was 0.03±0.01. 87.1% of the HU intensity distribution along individual rays was found to be normal with the average path length percentile p-value was 0.04±0.01. Over the entire cohort, the beam angle with the shortest mean path length was the posterior beam at an average of 132.7±18.1mm compared to the lateral beams at average of 232.7±25.4mm. The lateral beams had less HU intensity variation on average at 31.7±4.9HU compared to an average of 36.0±4.5HU for the posterior beam. Though lateral beams had less HU intensity variation than the posterior beam, the difference in HU intensity variation was much less than the difference between path lengths. Numerically, the posterior beam’s shorter path length resulted in its classification as the optimal beam angle.

Conclusion: A posterior PBS beam angle was found to be optimal for lower pelvis targets through an optimization approach that minimized the average path length and HU variation along multiple rays. The potential of GC analysis method to estimate both photon and slow neutron dose by using a single TLD-700 is shown, resulting in a dosimetric tool of great value. Using this method, whole body dosimetry results simple and precise, in contrast with the traditional method being used. Experimental validation for Monte Carlo (MCNP) calculation models of little animal irradiation setups were carried out successfully, especially when ionization chambers cannot be used because of instrument dimensions.

Author(s): Diana Feld1,2

Introduction. BNCT is a cancers cells selective, non-conventional radiotherapy modality to treat malignant tumors such as glioblastoma, melanoma and recurrent head and neck cancer. It consists of a two-step procedure: first, the patient is injected with a tumor localizing drug containing a non-radioactive isotope (Bor-10) with high slow neutron capture cross-section. In a second step, the patient is irradiated with neutrons, which are absorbed by the Boron-10 agent
with the subsequently nuclear reaction B-10(n,a)Li-7, thereby resulting in dose at cellular level due to the resulting high-LET particles. The Argentine clinical facility for superficial tumors treatment is located at the RA-6 Research Reactor (Bariloche Atomic Center). The neutron beam is defined as hyperthermal, designed as a combination of high thermal and epithermal neutron intensities, in order to provide a maximum of thermal neutron fluency at 1 cm depth. The clinical treatments were initiated in October 2003, having successfully completed 10 irradiations in 7 patients of cutaneous melanoma in extremities until 2007. In 2007, the highly-enriched fuel of the RA-6 reactor was replaced by the new low-enrichment uranium, which included a power upgrade and the reconfiguration of the core. This was the opportunity to improve the BNCT facility, mainly in terms of irradiation room size and beam port, protruding its end. Furthermore, the neutron beam was improved in specific irradiation parameters, such as an extended uniformity of the irradiation field.

Material and Method. The neutron beam and facility design process required the complete structural description for the calculation model in Monte Carlo (MCNP5). At the end of this process, the construction was executed, being completed in 2011. In order to ensure the new BNCT beam output, a Quality Assurance (QA) process was initiated by means of calculation model experimental validation. Usual activation techniques were employed to obtain thermal, epithermal and fast neutron fluxes, both with beam free-in-air and into standard water phantom. Gamma and fast neutron doses were measured in both configurations implementing the paired ionization chambers method, using tissue-equivalent and graphite miniature chambers. All measurements were carried out over the axial, parallel and transverse axis to the beam. A few modifications were performed to ensure essential parameters of the beam, and the full characterization was done and reported. Finally, the Quality Control (QC) protocol was developed and became effective before the restart of the clinical trials.

Results. QA process and its results will be shown in detail. Main beam parameters were compared and ensured with other techniques that have been implemented in the dosimetric characterization process.

Conclusions. Nowadays, under rigorous quality indicators, the Argentine BNCT Project is in conditions to restart the clinical trials in the short term.

PS04.015 - Improved Pareto navigation using a plan database with segmented plans
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Background Pareto surface navigation is a form of decision support for intensity-modulated radiation therapy that allows planners to browse through a space of possible dose distributions. This technique relies on interpolation of a number of pre-calculated plans’ doses. The standard for step-and-shoot delivery is to represent Pareto surfaces by a database of fluence optimized plans. Such a representation inevitably leads to perturbations of the navigated dose when it is converted to a deliverable plan, because non-restricted fluence modulation is an idealization that cannot be matched in practice. The aim of the present work is to minimize the presence of conversion errors. To this end, we investigate navigation with respect to segmented plans, i.e., plans that take the physical limitations of the delivery system into account.

Materials Navigation with segmented plans was assessed with respect to two head and neck cases obtained from Massachusetts General Hospital. The cases were selected because conversion errors had been a difficulty during the preparation of the clinical plan.

For comparative purposes, separate Pareto surfaces were generated with non-segmented (i.e., fluence-optimized) and segmented plans. Navigation was simulated by sampling 100 random points per surface. The associated navigated doses were converted to deliverable plans.

The magnitude of dose and dose-volume histogram (DVH) errors for organs at risk were quantified in terms of overdosage relative to the navigated dose: the error for a point that was nominated to receive 10 Gy but that received 11 Gy after the conversion is 1 Gy. Dose errors within targets were quantified analogously, but with underdosage also taken into account. All experiments were performed in RayStation v4.7 (RaySearch Laboratories).

Results Figure 1 summarizes the collected error measures for one of the patients, which are representative also for the second patient. With segmented plans, the dose error in percent of the prescription was within 1.4% on average and within 6.8% at the 98th percentile for all structures. The corresponding figures for the DVH errors are 0.9% and 3.3%. About a factor 2-3 larger errors were observed with non-segmented plans: the averages and 98th-percentiles of the dose errors were up to 3.5% and 15.9%, respectively, and up to 2.6% and 9.4% with respect to DVH. The smaller errors indicate that a representation with segmented plans has the potential to provide more informed and streamlined planning.

Figure 1: Averages (bars) and 98th percentiles (whiskers) of the dose (A) and DVH errors (B).

PS04.016 - Automated measurement of dwell and tandem position in ring HDR applicators
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Radio-oncologie, Centre intégré de cancérologie de Laval, Laval/ QC/CANADA

Accuracy and efficacy in measuring in house dwell and tandem positions in ring applicators is very important due to steep dose gradients encountered in HDR brachytherapy.

It is suggested that measuring those offsets should take place when commissioning/replacing a ring applicator and after every source change. For each applicator, the reproducibility of these positions must also be considered.

Previous work has failed to address the inter/intra-observer variability of measurements as well as the time required to commission a ring applicator.

This work describes a new approach to determine dwell and tandem positions for ring applicators in which the ring is imaged and its dwell and tandem positions automatically measured in the ring applicator coordinate system.
An image analysis computer algorithm was developed for this. It uses edge detection techniques and Hough transform for circle and ellipse detection to process axial and sagittal CT scouts of the ring applicator for each dwell position.

The algorithm performs the measurement of hundreds of dwell positions in seconds with an uncertainty below 0.2mm (CT Scout with up to 0.6mm pixel spacing) which allows us to speed up the ring applicator commissioning process along with removing inter/intra-observer variability.

Our results showed that source dwells and tandem within Elekta’s HDR CT/MR ring applicators can deviate from expected (Elekta’s) positions by up to 4 millimeters. These results reinforce the importance of developing an in house technique to accurately measure dwell and tandem positions.

**PS04.017 - eMU Whisperer: An application for assessing patient surface topology and its impact on monitor units in electron beam therapy.**

**Author(s):** Paule M. Charland1, Baochang Liu1, Shane L. Lawrence2, Natascha H. Van Lieshout1

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Standard quality assurance protocols of patient specific radiation treatment plans require that monitor units (MUs) be verified with an independent mean. While Monte Carlo methods for electron beam treatment planning have opened up a new era where we anticipate reasonable dose accuracy in complex irradiation geometry and media composition, an independent (MU) verification is still to be performed to evaluate, within tolerance, if the Monte Carlo predicted MUs could be endorsed. The intent is to flag suspicious dose calculation that would warrant further investigation. These independent methods to verify MUs are normally based on simpler calculations consisting of empirical multiplicative functions with shortcomings such that flat geometry and straight beam incidence have to be assumed. The decoupled functions nevertheless provide insightful values. In a logical extension of current methodology for routine independent MU check, we have exploited the multiplicative property to define a correction factor, CFtopo, to account for topology effects. It is defined as the ratio of the dose output on the central axis at a nominal depth of maximum dose (dmax) of a given surface topology relative to the dose to a flat phantom, for the same irradiation conditions.

We have characterized CFtopo for a variety of phantoms on a TrueBeam linac (Varian). Phantoms were constructed of different rounded masses of tissue equivalent material superposed to solid water slabs to create different surface topologies where the beams are incident. Point dose measurements were performed with a Markus-type ionization chamber inserted into one of the solid water slabs from the central axis at nominal dmax for a constant source-surface-distance of 100 cm. Energies under consideration were 6, 9, 12, 16 and 20 MeV and cone sizes ranged from 6 cm x 6 cm to 25 cm x 25 cm. It was found that the magnitude of CFtopo could drop as low as around 80%, the lowest energies 6, 9 and 12 MeV being generally the most impacted.

This motivated the development of a methodology to provide CFtopo from any arbitrary surface topology for our routine patient-specific plan quality assurance. We have developed the application “eMU Whisperer” in Matlab (MathWorks) which takes as input the three-dimensional patient surface topology based on the external body contour according to the CT image exported from the Eclipse treatment planning system (Varian). A cropped area in the beam’s-eye-view, function of the range of the electron energy under consideration is used by the application to analyze and quantify the topology. A function for a given energy, previously determined from the aforementioned measurements, is used to map the topology parameter to the corresponding CFtopo.

The propounded methodology has been carried out on different clinical cases. The “eMU Whisperer” application provided CFtopo to help reconcile MUs. Data showed the marked impact of topology change, which if unaccounted for would lead to an unintended dosage. Detailed user evaluation demonstrates the strengths, limitations and practical value of the proposed quality assurance method.

**PS04.018 - Beam modeling of the flattening filter-free beams for VMAT SBRT using the collapsed cone convolution superposition algorithm**

**Author(s):** Samiu Cho1, Woohoon Choi1, Ho Lee1, Kwangwoo Park1, Jungil Lee2, Jeongmin Yoon1, Eungman Lee1, Suk Lee1, Sang Hoon Lee1, Juree Kim3, Jinho Choi3, Sangwook Lim3, Ki Chang Keum1

1Radiation Oncology, Yonsei University, Seoul/KOREA, 2Radiation Oncology, Korea University, Seoul/KOREA, 3Radiation Oncology, Catholic Kwandong University, Seoul/KOREA, 4Radiation Oncology, Gachon University, Seoul/KOREA, 5Radiation Oncology, Kosin University College of Medicine, Busan/KOREA

Flattening filter-free (FFF) megavoltage beam has a highly forward peaked beam profile, increased dose rate from 1200 MU/min up to 2400 MU/min, less variation of off-axis beam hardening, less photon head scatter and less leakage outside of beam. In SBRT, high dose rate reduce the delivery time with benefit inpatient discomfort and with potential limitation of intra-fraction motion. The volumetric modulated arc therapy (VMAT) technique with FFF megavoltage beam have recently started to be used in the SBRT. The aim of this study is to create accurate FFF megavoltage beam model with the collapsed cone convolution superposition (CCCS) dose calculation algorithm for VMAT SBRT implementation.

The beam data sets of off-axis profiles, depth dose and relative output factor for photon 6 and 10 MeV were measured in a PTW MP3 water phantom with a surface to source distance of 90 cm SSD. The off-axis profiles and depth dose were acquired with LA 48 linear chamber array at dose rate 300 MU/min from 1x1 up to 30x30 cm2. The relative output factors were measured with the Farmer chamber for field size 10x10 cm2 and larger, and the 0.004 mm2 microDiamond detector for less than 10x10 cm2 field size. Absolute calibration was performed according to IAEA TG 398 with 0.6 cm2 Farmer chamber using dose rate 1000 MU/min. Extra audit for output verification was carried out using OSLD with IORC Houston. The beam models were evaluated by making point dose measurement using cheese phantom and verifications of dose distribution using Sun Nuclear ArcCheck phantom with 3 mm/3% Gamma criteria.

The verification of CCCS beam modeling results showed that the point dose measurements were within 5% agreement between computed dose data and cheese phantom measured dose data. The ArcCheck phantom evaluation results were well within the accepted clinical tolerance level. Our results show that beam modeling of CCCS algorithm could provide reliable FFF beam model for the VMAT SMRT treatment.
Table 2: Dose-volume criteria, mean and maximum doses.

<table>
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<tr>
<th>No</th>
<th>Energy</th>
<th>Dose @ Ray (cGy)</th>
<th>Dose @ ArcCheck (cGy)</th>
<th>Dose @ 3DVH (3mm/3%)</th>
<th>3DVH (3mm/3%)</th>
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<tr>
<td>1</td>
<td>6MV</td>
<td>1403.000</td>
<td>1386.848</td>
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<td>92.40%</td>
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<td>2</td>
<td>6MV</td>
<td>1407.000</td>
<td>1405.213</td>
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<td>97.30%</td>
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<tr>
<td>3</td>
<td>6MV</td>
<td>1555.000</td>
<td>1520.735</td>
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<tr>
<td>4</td>
<td>6MV</td>
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<td>1505.051</td>
<td>0.14%</td>
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</tr>
<tr>
<td>5</td>
<td>10MV</td>
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<tr>
<td>6</td>
<td>10MV</td>
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<td>1620.996</td>
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<td>7</td>
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<tr>
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<td>1621.000</td>
<td>1620.996</td>
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PS04.019 - Dependence of Collimator Angle on Prostate VMAT: A Treatment Planning Study

Author(s): M Isa1, J Rehman1, M Afzal1, James Chow2

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This study investigated the dose-volume dependences of planning target volume (PTV) and organs-at-risk (OARs) on prostate volumetric modulated arc therapy (VMAT), when the collimator angle is varied. Single-arc VMAT plans at different collimator angles (0°, 15°, 30°, 45°, 60°, 75° and 90°) were created systematically based on a Harold pelvis phantom and the 6 MV photon beams. The conformity index (CI), homogeneity index (HI), gradient index (GI), machine monitor units (MUs), dose-volume histogram and mean and maximum dose of the PTV were calculated and analyzed (Table 1). The dose-volume histogram and mean and maximum doses of OARs such as bladder, rectum and femoral heads for different collimator angles were determined from the plans (Table 2). From our dosimetric results, there was no significant difference, according to the planned dose-volume evaluation criteria, found in the VMAT optimizations for all studied collimator angles. However, a higher CI (0.53) and lower HI (0.064) resulted from the 45° collimator angle. The 15° collimator angle provided a lower value of HI similar to the 45° angle while collimator angles of 75° and 90° were found to be good for rectum sparing. In addition, collimator angles of 75° and 30° worked well for sparing the right and left femur. The PTV dose coverage for each plan was comparatively independent of the collimator angle. The dosimetric results in this study provide support and guidance in the collimator angle selection for prostate VMAT to improve the PTV coverage and OARs sparing.

Table 1: Dosimetric results of PTV for different collimator angles.

<table>
<thead>
<tr>
<th>Collimator angles</th>
<th>Dmax (Gy)</th>
<th>D95 (Gy)</th>
<th>CI</th>
<th>HI</th>
<th>MUs</th>
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</thead>
<tbody>
<tr>
<td>0°</td>
<td>72.41</td>
<td>72.59</td>
<td>72.60</td>
<td>72.60</td>
<td>72.86</td>
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<tr>
<td>15°</td>
<td>72.41</td>
<td>72.44</td>
<td>72.79</td>
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</tr>
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<td>30°</td>
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<td>72.44</td>
<td>72.79</td>
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<td>45°</td>
<td>72.41</td>
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PS04.020 - Dosimetry of Pacemaker in VMAT for Lung SBRT

Author(s): James Chow1, R Jiang2

1Princess Margaret Cancer Center, Toronto/CANADA, 2Grand River Regional Cancer Center, Kitchener/CANADA

This study investigated the possibility to include the pacemaker in volumetric modulated arc therapy (VMAT) plan optimization for lung stereotactic body radiotherapy (SBRT) to reduce the pacemaker dose. Moreover, dose distributions of the planning target volume (PTV) and organs-at-risk (OARs) with and without lowering the pacemaker dose in VMAT plans were compared with the PTV close to and far away from the pacemaker. Patients with PTVs in their left and right lung were selected in lung SBRT. VMAT plans with pacemaker regarded as an OAR or not in the plan optimization were created. Dose-volume histograms (DVHs) of PTVs and OARs were determined and compared. Our results of VMAT plans (Figure 1(a): left lung and 1(b): right lung) showed that no significant deviation of dose-volume criteria of OAR was found, whether the pacemaker was or was not regarded as an OAR. This demonstrated that it is possible to reduce the pacemaker dose by including it as an OAR in the VMAT plan for lung SBRT. This is especially important for patient depending seriously on the pacemaker, as VMAT beams for SBRT are directly on the device with a very high dose per fraction.
microchamber. A model of the CyberKnife G4 head was created in BEAMnrc with initial electron energy and spatial distribution tuned by matching measured PDDs and OFs to simulations performed in egs_chamber with detector response effects modelled based on manufacturer specifications.

This beam model was used to calculate dose-to-detector ($D_{\text{det}}$) to dose-to-water ($D_w$) CFs for the A16 in six different composite fields (5 isocentric, one non-isocentric) using the 5 mm collimator. The first three used all the standard beams employed by CyberKnife for skull lesions (average SAD= 800 mm), while the last three used a set of beams optimized for the treatment of trigeminal neuralgia (TN) (average SAD=700 mm). The point of intersection of the beams varied between different fields using the same beam set. The final field was a non-isocentric optimized clinical TN plan, where detector off-axis position varied between beams.

**Results:** Calculated and measured PDDs for the 60 mm collimator are in good agreement (root mean square deviation=1.1%) after tuning the electron energy. Figure 1 shows measured OFs and calculated $D_{\text{det}}$ ratios used to select the beam’s spatial distribution. The $D_{\text{det}}$ to $D_w$ CFs for the skull lesion fields were calculated to be 1.2464±0.0023, 1.2391±0.0022, and 1.2598±0.0024. The CFs for the isocentric TN fields were calculated to be 1.2565±0.0021, and 1.2495±0.0021; the CF for the non-isocentric field was 1.2103±0.0028.

**Conclusions:** CFs for the skull lesion fields varied by no more than 2% as a function of the location of the point of intersection of the beams. For “isocentric” TN fields, they varied by no more than 1%. If the non-isocentric field is included, the variation increases to 4%, demonstrating that a clinically-optimized plan requires larger CFs.

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**PS04.021 - Determination of ion chamber correction factors for small composite fields used by the CyberKnife radiosurgery system**

**Author(s):** Eric J. Christiansen¹, Bryan R. Muir², Jason Belec³, Eric Vandervoort³

¹Medical Physics Unit, McGill University, Montreal/QC/CANADA, ²Measurement Science And Standards, National Research Council, Ottawa/CANADA, ³Medical Physics, Ottawa Hospital Cancer Center, Ottawa/CANADA

**Purpose:** A dosimetry formalism has been proposed to determine ionization chamber correction factors (CFs) for small and non-standard fields. Small field ionization chamber CFs have been shown to depend on off-axis position and source-to-axis distance (SAD). In this study, CFs were calculated using the EGSnrc user code egs_chamber for six composite fields delivered by the CyberKnife system with varying SAD and off-axis position.

**Methods:** Percentage depth dose (PDD) curves and output factors (OFs) for CyberKnife’s largest (60 mm) and three smallest collimators (5 mm, 7.5 mm, and 10 mm) were measured with an Exradin A16 microchamber. A model of the CyberKnife G4 head was created in BEAMnrc with initial electron energy and spatial distribution tuned by matching measured PDDs and OFs to simulations performed in egs_chamber with detector response effects modelled based on manufacturer specifications.

This beam model was used to calculate dose-to-detector ($D_{\text{det}}$) to dose-to-water ($D_w$) CFs for the A16 in six different composite fields (5 isocentric, one non-isocentric) using the 5 mm collimator. The first three used all the standard beams employed by CyberKnife for skull lesions (average SAD= 800 mm), while the last three used a set of beams optimized for the treatment of trigeminal neuralgia (TN) (average SAD=700 mm). The point of intersection of the beams varied between different fields using the same beam set. The final field was a non-isocentric optimized clinical TN plan, where detector off-axis position varied between beams.

**Results:** Calculated and measured PDDs for the 60 mm collimator are in good agreement (root mean square deviation=1.1%) after tuning the electron energy. Figure 1 shows measured OFs and calculated $D_{\text{det}}$ ratios used to select the beam’s spatial distribution. The $D_{\text{det}}$ to $D_w$ CFs for the skull lesion fields were calculated to be 1.2464±0.0023, 1.2391±0.0022, and 1.2598±0.0024. The CFs for the isocentric TN fields were calculated to be 1.2565±0.0021, and 1.2495±0.0021; the CF for the non-isocentric field was 1.2103±0.0028.

**Conclusions:** CFs for the skull lesion fields varied by no more than 2% as a function of the location of the point of intersection of the beams. For “isocentric” TN fields, they varied by no more than 1%. If the non-isocentric field is included, the variation increases to 4%, demonstrating that a clinically-optimized plan requires larger CFs.

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**PS04.022 - One-year review of a real-time, ultrasound-based, single-fraction prostate HDR program – the Halifax experience**

**Author(s):** Krista Chytyk-Praznik¹, Amanda Cherpak¹, David Bowes², Nikhilesh Patil³, Mammo Yewondwossen¹

¹Medical Physics, QEII Health Sciences Centre, Halifax/NS/CANADA, ²Radiation Oncology, QEII Health Sciences Centre, Halifax/NS/CANADA, ³Radiation Oncology, Dalhousie University, Halifax/NS/CANADA

**Introduction:** The QEII Health Sciences Centre began a high-dose-rate prostate brachytherapy program in March 2014. As of January 2015, 25 prostate cancer patients have been treated under general anaesthetic using the real-time Oncentra Prostate (v. 4.2) treatment planning system (Elekta), with ultrasound imaging (BK Medical).
**Materials and Methods:** Two radiation oncologists and three physicists have been trained in the procedure. The patients were prescribed 15 Gy in a single fraction to the entire prostate (dose constraints listed in Table 1). The planning method for the first 10 cases involved 1) obtaining initial US image set 2) detailed contouring of the prostate, urethra and rectum 3) choosing virtual catheter positions 4) pre-plan dose optimization (using DVHO algorithm) 5) catheter insertion 6) catheter tip reconstruction 7) final imaging 8) final contouring 9) catheter reconstruction and catheter free length measurement and 10) final dose optimization. By the 11th patient, this planning flow was redesigned by replacing the first six steps with four: 1) obtaining initial US image set 2) choosing catheter positions 3) simultaneous needle insertion and preliminary contouring of prostate, urethra and rectum and 4) needle tip reconstruction. The remaining steps follow in the same order as the original planning method.

**Results:** Average treatment time (US probe insertion until the start of treatment delivery) was 177 ± 24 min (114 min – 216 min). Eliminating pre-planning steps for later patients increased efficiency of the treatment, with an improvement in average treatment time from 193 min for the first five patients to 155 min for the last five patients. The average prostate volume treated was 32.4 ± 9.4 cc (21.2 cc – 58.0 cc) with the average number of needles used equal to 15.1 ± 1.4 (11 – 17). A standard template for needle placement was not used, however general guidelines have been developed and are consistently followed. Prostate coverage for all patients was met, with an average V100% = 96.44% and a V90% = 99.35%, as were the constraints for the urethra and rectum (see Table 1). Comparing the dose constraints achieved for the first five patients and the last five patients, prostate coverage was consistent, but the quality of the plans improved by the last five patients (achieved lower V150% and V200% values).

**Conclusion:** Careful commissioning and practice runs of the procedure aided in a successful start to the program which has evolved and been refined over the initial 12 months.

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<tr>
<td>V80% (goal: &lt;0.5 cc)</td>
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</table>

Table 1: Summary of dose constraints and average results over all patients, the first five patients and the last five patients.

**PS04.023 - Retrospective evaluation of visually monitored deep inspiration breath hold for breast cancer patients using edge detection**

Authors: Leigh Conroy¹, Rosanna Yeung², Sarah Quirk¹, Tien Phan², Wendy L. Smith²

¹Department Of Medical Physics, Tom Baker Cancer Centre, Calgary/AB/CANADA, ²Department Of Oncology, University of Calgary, Calgary/AB/CANADA

**Purpose:** Deep inspiration breath hold (DIBH) can reduce cardiac dose during left-sided breast cancer radiotherapy. This study uses cine imaging with edge detection to evaluate a visually-monitored DIBH technique (VM-DIBH).

**Methods:** Cine images were acquired weekly during the medial tangent field of patients treated with VM-DIBH. Edge detection was used to identify the field borders and chest wall edges in digitally reconstructed radiographs (DRRs) and cine images of 15 patients. The distance between the field border and chest wall was measured at the center of the field and used as a surrogate for patient position during breath hold. Setup uncertainties were found by comparing DRR measurements to the first cine image measurement for each fraction. Intra-beam motion during individual breath holds was assessed by comparing the first cine image measurement to all subsequent cine image measurements for each fraction.

**Results:** The mean setup uncertainty (M) was 1.2 mm; random (σ) and systematic (Σ) setup errors were both 2.0 mm. The chest wall position was within 5 mm of the DRR position in 92% of cine images. Intra-beam motion was within +/- 2 mm in 98% of images, and was slightly skewed in the posterior direction, indicating that patients tend to relax or exhale during breath holds.

![Fig. 1 Chest wall edge detection of field borders (green), chest wall (pink) and chest wall position measurement (blue) for a DRR (a) and cine image (b).](image-url)
PS04.024 - DECT Tissue Characterisation and Artefact Suppression Method for Improved Dose Calculations in Brachytherapy Treatments.

Author(s): Nicolas Cote, Stephane Bedwani, Jean-Francois Carrier
Radio-oncologie, CHUM- Notre-Dame hospital, Montreal/QC/CANADA

Doses in brachytherapy, for many years now, have been evaluated using the TG-43 formalism which make use of standard equations determined from a full water based medium. However, the accuracy of these calculations, particularly in Low Dose Rate (LDR) brachytherapy, are misleading, as they are highly dependent on inter-seed attenuation and patient tissue heterogeneities due to its low energy range (20-30 keV). This Monte Carlo study allows the evaluation of the dose distribution in individual cases by encompassing patient specific tissue information with a voxel by voxel determination of the effective atomic number (EAN) and electron density (ED). Using a dual energy computed tomography (DECT), these physical parameters can be extracted using the stoichiometric calibration method. The DECT is also be used to minimize the presence of metallic artifacts contributed by sealed radioactive sources containing materials of high atomic number. This new technique is quick and simple as it uses a mixture of both distinct energy scans. The concept behind the suppression is manipulating the differences in Hounsfield Units (HU) variations between different structures in order to find an image describing the artifacts alone. Thereafter, the initial image can be treated from metallic artifacts by subtracting it from the latter (Figure 1). The dose calculations have been accomplished using BrachyDose from the EGSnrc series. Using this software, variations in the dose have been analyzed from inter-seed attenuation and show differences ranging roughly 5.8% to 6.2% in the dose at 90 % of the target volume ($D_{90}$). Also, with the stoichiometric method, the extraction of ED and EAN, using DECT suppressed artifact images, allows for a voxel-to-voxel tissue characterization depicting a better reality of patient anatomy. This would in consequence be integrated in the Monte Carlo simulation to analyze further variations from TG-43

Conclusion: Edge detection of field borders and the chest wall in cine images and DRRs was successfully used to evaluate inter-fraction and intra-beam uncertainties for a VM-DIBH technique. Setup uncertainties and chest wall position measurements indicated adequate breath hold setup reproducibility for the majority of patients. Intra-beam motion measurements showed excellent stability of breath hold during treatment.

PS04.026 - Impact of increasing irradiation time on the treatment of prostate cancers

Author(s): Alexandru Dasu1, Iuliana Toma-Dasu2
1Department Of Radiation Physics, Linköping University Hospital, Linköping/SWEDE, 2Medical Radiation Physics, Stockholm University and Karolinska Institutet, Stockholm/SWEDE

This study aimed to investigate the expected impact of intra-fraction repair during increasing irradiation times for the treatment of prostate cancers. Lengthy sessions are indeed expected for some cases. The authors accurately reproduced 3D conformal radiotherapy treatment plan beamlet and patient configurations using a treatment planning system (Varian Medical Systems, Palo Alto, CA). These planning were carried out with seven radiation fields of X-ray using a Therac-20 Neptune linac. All fields were calculated with a source surface distance of 100 cm, symmetric collimators in the X-axis and asymmetric in the Y-axis, and with a total field of 12 x 10.5 cm². The nominal energy was 18 MV except for a one field, which was chosen 6 MV. The initial parameters to perform the calculation were complemented with the inclination angles of the couch and gantry. Were used a set of Computerized Tomography images obtained of an anonymous patient with prostate cancer diagnosed and indication for radiotherapy (the prescribed dose was 58.5 Gy). Isodose contours maps, normal tissue complication probability (NTCP), and dose-volume histograms (DVHs), are shown and discussed. The results show that on the gross tumour volume (GTV), there is 99 % of its volume receiving 56.67 Gy. It is observed that the TV receive the prescribed dose. The PTVHD and PTVD that includes the GTV with margins also show high probabilities of receiving the prescribed dose. The risk organs, bladder and rectum has a probability of 68 % and 89 % of its volume to receive an equivalent dose of 27 Gy and 36.76 Gy, respectively. Comparing the planning results obtained from two codes, it is observed that both are consistent with the established standards. The results shown that the CERR is appropriate to be use in clinical treatment planning.

PS04.025 - Radiotherapy Planning using CEER and CADPLAN in a Prostate Cancer Patient

Author(s): Juan Alberto L. Cruz1, Maíra Mariana C. Uchôa1, Diego S. Dolci1, Ernando S. Ferreira2, Wilfredo G. Infante3
1Department Of Physics, State University of Feira de Santana, FEIRA DE SANTANA/BRAZIL, 2Radiotherapy Section, Hospital Aristides Maizé, Salvador/BRAZIL, 3Department Of Atomic Molecular And Nuclear Physics, University of Granada, Granada/SPAIN

The authors accurately reproduced 3D conformal radiotherapy planning beamlet and patient configurations using a treatment planning system (Varian Medical Systems, Palo Alto, CA). These planning were carried out with seven radiation fields of X-ray using a Therac-20 Neptune linac. All fields were calculated with a source surface distance of 100 cm, symmetric collimators in the X-axis and asymmetric in the Y-axis, and with a total field of 12 x 10.5 cm². The nominal energy was 18 MV except for a one field, which was chosen 6 MV. The initial parameters to perform the calculation were complemented with the inclination angles of the couch and gantry. Were used a set of Computerized Tomography images obtained of an anonymous patient with prostate cancer diagnosed and indication for radiotherapy (the prescribed dose was 58.5 Gy). Isodose contours maps, normal tissue complication probability (NTCP), and dose-volume histograms (DVHs), are shown and discussed. The results show that on the gross tumour volume (GTV), there is 99 % of its volume receiving 56.67 Gy. It is observed that the TV receive the prescribed dose. The PTVHD and PTVD that includes the GTV with margins also show high probabilities of receiving the prescribed dose. The risk organs, bladder and rectum has a probability of 68 % and 89 % of its volume to receive an equivalent dose of 27 Gy and 36.76 Gy, respectively. Comparing the planning results obtained from two codes, it is observed that both are consistent with the established standards. The results shown that the CERR is appropriate to be use in clinical treatment planning.
advanced irradiation techniques capable of delivering the large fractional doses required by the increased fractionation sensitivity of the prostates. For this purpose, clinically-derived parameters characterizing repair rates and dose response curves for prostate tumors have been used to calculate the expected loss of effectiveness when increasing the irradiation time. The results have shown that treatment sessions lasting more than about 20 to 40 minutes could reduce the probability of biochemical control of prostate tumors by more than 20 to 30 percentage points. These results are in agreement with some observed clinical results and therefore they suggest that treatment durations in prostate radiation therapy should be carefully recorded in order to explicitly account for intrafraction repair, especially when irradiation techniques make use of multiple beams and imaging sessions. Failure to do so might overestimate the expected effectiveness of the treatment and could lead to disappointing clinical results precisely from the demanding treatment modalities expected to increase the therapeutic gain in prostate radiotherapy.

**Conclusion**

Electron HBI technique delivers the prescribed dose in the portion of the skin which needs treatment. This will minimize the dose delivered to healthy skin and allow us to handle each case differently and provide more choices for each individual.

**Materials and Methods**

A linear accelerator of the radiotherapy division of Attikon Hospital (Athens Greece), used to produce electron beams, a custom crafted chamber (used for TSEB in “Attikon” hospital) and an additional and adjustable (for Upper and Lower HBI taking patient’s height into consideration) Pb shielding placed before patient are used for this new treatment. Custom standing technique is used both for lower and upper body cases. Parameters and characteristics of the beam which are measured and evaluated are: PDD on treatment plane and surficial and in reference depth absorbed dose in plain phantom and human like phantom. The above resulted in a calculation of the monitor units needed for the delivery of the prescribed dose.

**Results**

The results are different especially close to the points of high dose spikes, to those extracted for the TSEB techniques driving to different homogeneity of dose distribution on upper or lower extremities optimized for different metrical characteristics of patients and their clinical cases.
COLOMBIA,

Dynamic techniques for dose delivering used in external radiotherapy such as modulated radiation intensity (IMRT) and enhanced dynamic wedges (EDW) tend to be used with more frequency due to the benefits in terms of higher treatment dose to the tumor while preserving the exposure of healthy tissues and reduction in treatment times needed in wedged beam techniques, respectively. In seeking to ensure accuracy in dose delivery in dynamic techniques are several the measurement methods and systems developed. One of the factors of interest to medical physicists who daily use these techniques in the clinic routine is the quick and easy configuration of measurement systems and analysis to carry out QA tests.

This paper presents the results of tests of acceptance for Intensity Modulated Radiation Therapy and Enhanced Dynamic Wedge Commissioning made on a Varian iX with 6 and 10 MV energies using a 2D array ionization chamber Octavius2D. This paper presents the results of acceptance tests for IMRT and EDW commissioning made on a 6 and 10 MV Varian iX using a 2D array Octavius2D PTW ionization chamber. Acceptance factors considered were: absolute dose delivery, reproducibility and exactitude fluence patterns, dose profile and QA of specific patient. The results obtained show a good accordance with the field parameters having higher acceptance percentages to 90% in all realized tests.

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Results in Figure 1 show the adaptive planning tends to over-estimate the Dice index for many organs, thus generating not as large a deformation as required. Figure 2 shows the ratio of Dice indexes tends to diverge from 1 if the structure shrinks during treatment. Such deformations, especially for the bladder and independent of the method, would wrongly indicate the organ had not moved or deformed during the treatment.

To conclude, automatic contouring on CBCTs depends on the organ, the method and the deformation. Looking at Dice indexes, organs such as the intestines show good agreement with manual contours, but the variability is larger for the seminal vesicles. Ultimately, the decision to re-plan treatments could be based on thresholds for selected indices and organs.

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Figure 1. Dice index for structures generated by automatic contouring (Adaptive planning and Auto-contouring) with respect to the expected Dice index as given by the manually contoured structures (Intestine, GTV, Rectum, Bladder and Seminal vesicles) on the reference CT and CBCT. The dashed line y = 1 indicates a perfect registration, where manual Dice index = automatic Dice index.

Figure 2. Ratio of the automatic contouring Dice index (Adaptive planning and Auto-contouring) on the manual contouring Dice index given by the reference CT and CBCT structures (Intestine, GTV, Rectum, Bladder and Seminal vesicles) with respect to the variation in volume of the structures between the reference CT and the reference CBCT. The vertical dashed line at y = 0 indicates no variation in volume between the reference CBCT structure and the reference CT structure. The horizontal dashed line at y = 1 corresponds to a perfect registration, where manual Dice index = automatic Dice index.

Intracavitary brachytherapy with high dose rate (HDR) is nowadays one of the complementary specialties for the treatment of cervical cancer. This work presents results of an application for the deposited dose calculation in brachytherapy treatments for cervical cancer using distributed tools in the GAMOS and Geant4, aimed at studying the effects on dose distribution considering the variation of tissue inhomogeneities and decay characteristics for an mHDR-v1 Nucletron Classic source. The anatomy of the patient is included in the developed Monte Carlo simulation using CT images of a typical HDR brachytherapy for cervical cancer treatment defining a voxel grid which contains the composition and density information due to body tissues, extracted from CT images, and converted to material voxels through the CT Number characteristic curve. The results obtained are in agreement with values reported by the planning system used, showing a difference possibly due to overestimation due to AAPM Task Group No. 43 formalism, the effect due to variation in tissue and the noise contained in the image.

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1Techna Institute, University Health Network, Toronto/ON/CANADA, 2Computer Science, University of Toronto, Toronto/ON/CANADA, 3Radiation Oncology, Princess Margaret Cancer Centre, Toronto/CANADA, 4Mechanical And Industrial Engineering, University of Toronto, Toronto/ON/CANADA, 5Radiation Medicine Program, Princess Margaret Cancer Center, Toronto/ON/CANADA

We developed an inverse treatment planning module for the Leksell Gamma Knife Perfexion™ using 3D Slicer as the interface. Perfexion™ is a cobalt-60 system that delivers stereotactic radiosurgery treatments for head-and-neck tumours. Inverse treatment planning for Perfexion™ has been previously shown to produce quality treatment plans [1], however, a medium to easily use and test the inverse plans does not exist. Our module provides a layout that simplifies input/output format and the result illustration process for any Perfexion™ inverse treatment planning algorithm that is written in MATLAB.

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The Gamma Knife Perfexion Inverse Treatment Planning (GK-Inverse-
Plan) module is developed in Python and MATLAB using 3D Slicer (v4.3.1 r23560) and its SlicerRT (v0.14.5) and MatlabBridge (v0.11.0) extensions. GK-InversePlan provides the inverse planning optimization algorithm with inputs, such as, tumour volumes, organs-at-risk (OARs), and clinical prescriptions and guidelines. It also captures and illustrates the outputs including dose-volume matrices and final shots.

The GK-InversePlan module is divided into five stages of (a) Load Image, (b) Select Target, (c) Inverse Planning, (d) Isodose Illustration, and (e) Dose-Volume Histogram (DVH) Illustration (Figure 1). In Stage (a), the user can load DICOM formatted images, as well as other data including target volumes, OARs, and other organs of interest, which are all typically contoured previously in Perfexion™’s treatment planning environment (GammaPlan). Once the images and the organs are imported, the user will be prompted to Stage (b) where the target volume(s), their prescription dose, and other clinical guidelines can be specified. In Stage (c), the inverse treatment planning algorithm is performed by calling the optimization model from MATLAB. Any MATLAB figures, interfaces, and scripts that are contained in the inverse plan algorithm will be shown to the user at this point. Once the inverse treatment plan is obtained, the user can use Stages (d) and (e) to illustrate the isodose lines and DVH graphs, respectively.

GK-InversePlan is a module in 3D Slicer that provides a platform for integrating MATLAB-written inverse treatment planning tools for Perfexion™ with clinical visual interface and easy input and output access. Figure 1 depicts a snapshot of GK-InversePlan and a conformal plan [1] (Paddick CI of 0.83) for a synthetic acoustic neuroma on a sample MRI image, and shows the obtained DVH graph and isodose volumes.


PS04.032 - Bladder and rectum DVH prediction: a statistical approach for prostate treatment

Author(s): Frédéric Girard, Martin Hinse
Département De Radio-oncologie, Centre intègré de cancérologie de Laval, Laval/CANADA

Purpose: To predict bladder and rectum DVH values for prostate treatment based on the intersection of these structures with the PTV.

Methods: DVH values for the rectum (V50, V60, V65, V70 and V75) and the bladder (V40, V65, V70 and V75) were extracted from prostate and post-operative prostate bed treatment plan. All the planification process of these plans from the contouring of OAR and target volume to the VMAT inverse planning technique was performed using a standard procedure. For convenience, all plans are optimized at the total treatment dose and then scaled down to the specific plan dose. Correlation of each DVH value with relative volume of bladder and rectum that are within the PTV or an 18 mm expansion of the PTV was verified using multi-linear regression. The correlation with a parameter was judged significant if the p value is inferior to 0.05. In order to improve the correlation of the regressions with the parameters, treatment plans were divided in three categories that shared common target morphology: treatment of the prostate with or without seminal vesicles (N = 191, 2 Gy per fraction, prostate receives 78 Gy, seminal vesicles receive 54 Gy); treatment of the prostate that included both seminal vesicles and the lymph nodes (N = 37, 2 Gy per fraction, lymph nodes receive 44 Gy); and post-operative prostate bed treatment (N = 62, total dose of 66 Gy in 33 fractions). Post-operative prostate bed treatments that included lymph nodes were removed from the analysis due to the small sample size. Outliers were removed from each distribution.

Results: DVH values that are close to the total treatment dose showed the best correlation with the intersection of bladder and rectal volume with the PTV and only marginally or not at all with the intersection of the expanded PTV. The overall regression models showed better results with tighter confidence intervals than the ones for low dose values. This is to be expected since the highest isodoses are tailored almost perfectly around the PTV. Correlation with the PTV intersection decrease gradually as the DVH dose values get further away from the total dose and the correlation with the expanded PTV intersection because more significant. Rectum V50 and bladder V40 showed the poorest correlation which suggest that there is a great variability in the optimization of these parameters due to the patient morphology and/or planner decision. The use of the statistical models in clinical practice is in the early stage but we can already see an improvement in planification time and overall better rectum and bladder sparing.

Conclusion: Building a statistical model of bladder and rectum DVH values against intersection of these structures with the PTV provides a simple mean to predict the DVH outcome of future plan, to prevent planification error and to guide beginning dosimetrist.

PS04.033 - Retrospective evaluation of applicator localization for HDR cervix brachytherapy – A comparison of MR versus CT

Author(s): Lisa Glass1, Daron Owen2, Daxa Patel3, Aaron Vandermeer4, Cathy Neath2
1Department Of Radiation Oncology, University of Toronto, Toronto/ON/CANADA, 2Medical Physics Department, R.S. McLaughlin Durham Regional Cancer Centre, Oshawa/ON/CANADA

The international standard for treating cervix cancer with brachytherapy is 3D volume-based planning. Currently at the Durham Regional Cancer Centre (DRCC; Oshawa, Canada) CT and MR imaging are acquired and fused for each fraction. The MR image is used to aid target contouring and the applicator is reconstructed on the CT dataset using an applicator model provided in our brachytherapy planning software.

Although MR-only planning would reduce patient transfers, thereby lowering the risk of applicator motion or uterine perforation, a limiting factor is the inferior visibility of the applicator in MR versus CT imaging. In this retrospective study, applicator placement with MR versus CT imaging using the applicator model is compared. In order to assess the relative applicator position in a single coordinate system, the applicator is contoured on the CT image set and copied to the fused MR image set. The applicator model is then placed on the MR image set first using the CT applicator contour, and then using the MR image only. Fifteen cervix cancer brachytherapy treatments at the DRCC were evaluated.

As demonstrated in Figure 1, the source dwell positions vary by an average of 1.3 ± 0.5 mm in the ring and 1.0 ± 0.3 mm in the tandem,
when comparing CT to MR. Furthermore, we investigate the dose equivalency between CT and MR-based applicator model placement. As shown in Table 1, there is no significant difference in D90 to the CTV and in D2cc to the OARs between CT and MR, varying on average by less than 3%. Other dose indicators and individual treatment DVHs also support the conclusion that doses to target volumes and OARs are comparable between applicator model placement on CT versus MR image sets.

Table 1: Dose difference in MR-based applicator model placement compared to placement on CT

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<thead>
<tr>
<th></th>
<th>Δ(D90)</th>
<th>Δ(D2cc)</th>
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<tr>
<td>CTV</td>
<td>-0.5 ± 1.8 %</td>
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</tr>
<tr>
<td>Bladder</td>
<td>+0.6 ± 2.6 %</td>
<td></td>
</tr>
<tr>
<td>Rectum</td>
<td>0.0 ± 2.7 %</td>
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<tr>
<td>Sigmoid</td>
<td>-0.2 ± 2.4 %</td>
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</tbody>
</table>

PS04.034 - A general source model for clinical linac heads in photon mode

Author(s): Wilfredo González, Marta Anguiano, Antonio M. Lallena
Department Of Atomic Physics, Molecular And Nuclear, University of Granada, Granada/SPAIN

In this work a general source model has been developed to describe clinical linac heads when operating in photon mode. Six different linacs (three operating at 6 MV, one at 15 MV and two at 18 MV) have been studied. The construction of the model as well as its validation have been carried out on the base of the virtual linac approach in which the complete linac geometries have been simulated with the Monte Carlo code PENEOPE. The model includes a primary and a secondary sources for photons and two sources for electron contamination whose geometrical characteristics are determined from a set of simulated fluence distributions in air. The energy distributions are obtained from the Monte Carlo energy distributions, for photons of the photons moving along the beam axis, and for electrons of electrons below the flattening filter. To verify the model, output factors, percentage depth doses and transverse profiles in water obtained from a calculation performed with the complete geometry are compared to those found with the source model. A reasonable agreement is obtained in all cases analyzed.

PS04.035 - Measurement of the beam quality TPR 20,10 of small radiotherapy fields: Comparison of experimental measurements and Monte Carlo simulations

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Laboratorio De Física Médica, Instituto Nacional de Neurología y Neurocirugía, México city/MEXICO

Purpose. To measure the beam quality of small radiotherapy fields by using several detectors commonly used in small beam dosimetry and to verify the accuracy of these measurements by means of Monte Carlo simulations.

Material and Methods. The detectors employed in this work were a PTW-Farmer ionization chamber (to measure TPR 20,10 in reference conditions), PTW-31014, and PTW-60019 (PTW-Freiburg, Germany), and IBA-CC01 and IBA-SFD (IBA-Dosimetry, Germany). The experimental measurements were performed in a water scanning phantom MP3-XS (PTW-Freiburg, Germany). The irradiation of the detectors was carried out with a Novalis (BrainLAB, Germany) linear accelerator operating in x-ray mode at 6 MV with an exposition rate of 480 UM/min. The reading instrument used was a PTW UNIDOS-emline electrometer. TPR 20,10 was determined as the ratio of doses at 20 and 10 cm in a parallel beam with a source to axis distance of 100 cm. The data were acquired for conventional field sizes of 10 x 10, 5 x 5, and unconventional field sizes of 3 x 3, 2 x 2 and 1 x 1 cm. The DOSRZnrc code was used for Monte Carlo simulations of photon transport through the linear accelerator and for the calculation of absorbed dose in water. Phase spaces data were used to calculate dose profiles in water for the conventional and unconventional field size (José Lárraga, Phys. Med. Biol. 60 905, 2015).

Results. For the PTW-31014 TPR 20,10's differences between Monte Carlo Simulation were 0.2 to 5.5%. For the IBA CC-01 were 0.2 to 4.0%. For the IBA-SFD were 0.2 to 2.3%, and for the synthetic diamond PTW-60019 were 0.2 to 2.3%. The uncertainty measurements for conventional fields were 0.1% and for the unconventional small fields were 0.2%. The major difference that was taken into the field 10 x 10 cm was in SFD IBA-Dosimetry, and for the field 1 x 1 cm was in PinPoint PTW-31014.

Conclusions. The best matches between Monte Carlo and measured detectors TPR 20,10 were the stereotactic field diode and the synthetic diamond detector. The high deviation present in the measurement of beam quality of small radiotherapy beams may be related to the partial volume averaging. Further research in needed to establish if this results may be applied to small beam corrections factor determination for small beams.

PS04.036 - The Effect of Assessment Criteria on Inter-rater Variability in the Evaluation of Skin Reactions following Breast Cancer Radiation Therapy

Author(s): Riya Goyal1, Alexander Blood1, Louis Potters2, Ajay Kapur3
1Hofstra North Shore LIJ School of Medicine, Hempstead/UNITED STATES OF AMERICA, 2North Shore LIJ Cancer Institute, Lake...
Purpose: Although the Common Terminology Criteria for Adverse Events (CTCAE) grading scales are utilized to assess adverse reactions to radiation therapy, few studies have investigated their reliability. In our previously reported image-based retrospective study, variability between caregivers (radiation oncologists, nurses) in assessing skin reactions in breast cancer radiation therapy using this scale was found to fall within a “moderate” range of concordance (Fleiss kappa score 0.43) per the Landis-Koch criteria. In this work, the potential impact of specific toxicity assessment terms documented by raters in our previous study on overall scale reliability was evaluated.

Methods: In an institutional-review board approved retrospective study, clinical notes documented by 8 caregivers were interpreted to assess how discords among grades of skin lesions following radiation therapy potentially related to the use of freehand terms to describe the adverse events. 25 terms commonly used in the commentary were identified and categorized into those that were and were not outlined in the CTCAE scale. The percentage incidence and free marginal kappa scores for each term was calculated.

Results: The free marginal kappa scores for the terms stated in the CTCAE scale ranged from 0.333 to 0.565, suggesting a fair-to-moderate level of concordance between grades given by caregivers who used such terms. Certain terms not included within the CTCAE scale such as “hyperpigmentation” exhibited a higher rate of incidence (80%) and concordance (free marginal kappa score of .512) than those included explicitly in the scale.

Conclusion: The low kappa scores associated with terms in the CTCAE scale suggest variability in caregivers’ interpretation of assessment criteria. Revision of the wording of the scales may be needed to make definitions unambiguous and ensure a reliable grading scheme. The high frequency and kappa scores of terms including “hyperpigmentation” suggests revisions may also require inclusion of new clinical toxicity assessment criteria.

**Figure 1a** Normalized histogram data with a fitted three-mode Gaussian curve.

**Figure 1b** Anterior–posterior direction. A Product-Mixture model of the multivariate probability density function PDFm&tw which includes both the motion of the rectum (axis X [mm]) and the rectal wall thickness variability (axis Y [mm]).

**PS04.038 - Unbiased Assessment of Detail Detectability in Image Guided Radiation Therapy**

**Author(s):** Victor A. Gurvich¹, Lester L. Greer², George Davydenko³

¹Government Contractor In Radiology Clinic, Fort Belvoir Community Hospital, Fort Belvoir/VA/UNITED STATES OF AMERICA, ²Fort Belvoir Community Hospital, Fort Belvoir/VA/UNITED STATES OF AMERICA, ³Society of Euro-American Medical Physicists, Alexandria/UNITED STATES OF AMERICA

The accuracy of delineation of targets and organs at risk during radiation therapy treatment planning as well as precise verification and localization for image guided beam delivery considerably depends on detectability of small and low contrast details. The assessment of detail detectability with Las Vegas phantom, Leeds test objects and some other standard test tools recommended by vendors is very subjective because of fixed disposition of test elements known to an observer. On the other hand, physical parameters of the image obtained with instrumental tools often do not adequately reflect its clinical quality. The proposed method allows fast, simple and unbiased evaluation of detectability using standard phantoms and special StatPhan software.

An observer should estimate the likelihood of pathology simulator presence in the image of selected phantom areas. Then the results of the estimation are compared with real locations of the simulators. The number of selected areas and locations of test elements can be changed so that they are not known to the observer beforehand. StatPhan software calculates sensitivity, specificity and accuracy of test elements detection, signal-to-noise ratio, areas under receiver operating curves that define overall decision performance, and the factor of observer’s tendency to overestimation or misses. For our experiments we used Las Vegas phantom, Leeds test objects, ALVIM statistical phantoms with pathology simulators in aluminum, tissue and bone equivalent materials, aluminum step-wedge with holes of different diameter, and Catphan phantom for computer tomography.

The detail detectability was measured for CT simulators, electronic portal image devices with 6 MV and 16 MV photon beams, and for on-board imager system in radiographic and cone beam CT modes. The smallest test elements (pathology simulators) distinguished with Pdet ≥ 0.9 was assumed as a measure of image quality.
In all experiments we selected at least 10 areas with identical test elements and equal amount of areas with and without simulators when the accuracy had the most meaningful value. Low contrast resolution of Phillips Big Bore CT simulator and Varian On-Board Imager in cone beam mode was defined as detectability of supra-slice cylinders with 1% and 0.5 % contrast, for 100 kV at the X-ray tube, narrow window width (100 or less) and appropriate window level, so that low contrast disks were distinguished as well as possible. Cylinders of 3.0 mm, 1% contrast and 6 mm, 0.5% were detected in CT-sim images. The results for CBCT systems were 6.0 mm cylinders with 1% contrast and 9 mm, 0.5%. In images taken in On-Board imager radiographic mode 16 Leeds test disks and holes with diameter 1.1 mm in aluminum, 1.2 mm in bone and 1.4 mm in tissue equivalent material respectively were distinguished. Data for contrast-detail curves were obtained with aluminum step-wedge phantom.

The suggested method and StatPhan software were used for unbiased rapid statistical evaluation of therapeutic image quality using phantoms with fixed disposition of test elements and can be helpful for acceptance testing, establishment of QA base line, maintenance of excellent image quality, teaching and training of physicians and technical staff.

**PS04.039 - Assessing radiation protection of members living close to patients with implanted 125I seeds in prostate**

**Author(s):** Takashi Hanada1, Atsunori Yorozu2, Sachiko Shinya2, Shiro Saito3, Toshio Ohashi1, Naoyuki Shigematsu1

1. Department Of Radiology, Keio University School of Medicine, Tokyo/JAPAN, 2. Department Of Radiology, Tokyo Medical Center, National Hospital Organization, Tokyo/JAPAN, 3. Department Of Urology, Tokyo Medical Center, National Hospital Organization, Tokyo/JAPAN

**Purpose/Objective(s):** Permanent seed implant treatment using 125I is currently a common procedure for localized prostate cancer. For using the isotopes, we are frequently asked for more detailed information regarding the true exposure rates and associated risk that patients pose to the members living close to patients. However, there are few data for specific measurements situations, or considering lifestyle habits. In this study, a direct measurement was performed to determine the expected lifetime exposure from the patient with 125I seed brachytherapy prostate implant to members living close to patients.

**Materials/Methods:** Measurements were obtained from 25 consecutive unselected patients at Tokyo Medical Center, Japan. After a permanent brachytherapy implant with 125I seeds, patients and their member living close to patients were provided radiation monitors to measure direct radiation exposure at lifestyle. Each patient and their members were given a monitors to hang it on the neck, continuously, 24 hours a day. Monitors were returned approximately 1 week after the start of day measurements, and lifetime exposure were calculated based on the reading from the dosimeters. In addition, same measurements were performed after approximately 4 weeks after the first measurement for correctness verification of exposure monitoring.

**Results:** Based on dosimeter readings, the calculated mean lifetime dose to members living close to patients was 0.19 mSv (range, 0.02-0.54). There were no correlations between the calculated mean lifetime dose from patients of 7.61 mSv (range, 0.45-20.44) and their members. The average of calculated mean lifetime dose of second/first measurement ratio was 1.05 (range, 0.44-3.18) for patients. Results for the members, on the other hand, were 1.82 (range, 0.21-7.04). Radiation exposure to the members were differ in two measurements term, even when measured under the same conditions. That is to say, spending time the members contact with patients were not always the same in a day, leading to the non-negligible uncertainty of occupancy factors, used in calculating the lifetime dose.

**Conclusions:** There were no correlations between the measured radiation dose from patients and their members. However, radiation exposure to members living close to patients receiving a permanent prostate brachytherapy implant with radioactive 125I is very low and well below the limits recommended by the general guideline.

**PS04.040 - Improvement of MV planar image by elimination of Compton scattered photons and re-projection as primary photons**

**Author(s):** Masatsugu Hariu, Atsushi Myojoyama, Hidetoshi Saitoh

Radiological Sciences, Tokyo Metropolitan University, Tokyo/JAPAN

**Introduction**

For the IGRT technique of the radiation therapy, a MV planar image is acquired with an electronic portal imaging device (EPID). And displacement of patient position will be adjusted by image registration between the MV planar image and a reference image that digitally reconstructed from 3D X-CT image. Arbitrary structures, e.g. bone, soft tissue and lung, on the MV planar image are guide for image registration, therefore high image quality is required. However, density distribution of the MV planar image is deteriorated because of Compton scattered photons.

**Purpose**

To compute information of Compton scattered photons impinged on the EPID aiming to real time processing, an original Monte Carlo (MC) was coded. Then energy spectrum distribution of scattered photons was acquired using the MC code. Improvement of image density was attempted by eliminating contribution of scattered photons from the MV planar image and re-projecting as primary photons from Compton interaction point.

**Method**

The original MC code and the image-processing program were coded with the integral development environment Qt 5.0. This MC code can simulate Compton interaction within voxels that reconstructed from 3D X-CT image. Mean absorbed dose by scattered photons (D), primary photons (D) and total photons (D) to the EPID were estimated using energy and fluence and mass energy absorption coefficient of the EPID. It is assumed that the pixel value (P) of the EPID is proportional to absorbed dose (D) of Gd2O2S:Tb scintillator. To process the image excluding scattered photons (P), the image by scattered photons (P) was subtracted from the raw MV planar image (P). The P image was processed by multiplying the P and the ratio of D/D. To improve image density of arbitrary structure, which is guide for image registration, scattered photons were back projected to interaction point and re-projected as primary photons on the assumption that Compton scatter did not take place. Finally, corrected image density (P) was processed by adding P and P.

**Result and Conclusion**

A chest phantom was modeled in this study. As a result of bone-weighted image, it was obvious that P image was easier to distinguish the spinous process of vertebra, the intervertebral disks and the ribs than the P image. Additionally, by the soft tissue-weighted image, the bone structure was suppressed and Bronchi were observed clearly. Consequently, usability of proposed image density processing was clarified.
PS04.041 - Determination of exit fluence by MCNP4 code for IMRT treatment fields and its validation with a conventional EPID system

Author(s): Benjamin Hernandez Reyes, Modesto A. Sosa Aquino

Physical Engineering, University of Guanajuato campus Leon, Leon/ MEXICO

Dosimetry in intensity modulated radiotherapy (IMRT) is a fundamental process in quality control assurance. The electronic portal imaging devices (EPID) are widely used in IMRT dosimetry to measure the fluence of a radiation field and compare with the expected value calculated by a prediction algorithm. The objective of this work was to determine by Monte Carlo simulation the exit fluence of a treated patient with IMRT fields using MCNP4 code for a Varian linear accelerator Clinac iX model and then validate the simulation with fluences measures in the Varian aS1000 EPID system. Portal dosimetry configuration was previously performed by measuring output factors and dose calculation kernel. Comparisons between the simulated and the measured were made with a gamma evaluation (acceptance criterion ΔD=3% and Δr=2 mm), finding that over 95% of the points fall within the acceptance criteria. Verification with radiochromic film was also evaluated, also found correspondence >95% of the points evaluated between the simulated and measured. This work will assist in the implementation of 3D in-vivo IMRT dosimetry.

PS04.042 - Accuracy in simulating tumor translation and rotation: Commissioning a motion platform, Hexamotion for tumor motion management QA

Author(s): Chen-Yu Huang1, Jeremy T. Booth2, Jin A. Ng1, Adam Rice2, Paul Keall1

1Radiation Physics Laboratory, Sydney Medical School, The University of Sydney, Camperdown/AUSTRALIA, 2Northern Sydney Cancer Centre, Royal North Shore Hospital, Sydney/AUSTRALIA

Purpose: The success of gating and tumor tracking requires rigorous QA and validation to meet the goal of better coverage of the target and sparing of organs at risk. The Hexamotion 5 degree-of-freedom (DoF: 3 DoF translation and 2 DoF rotation) programmable motion platform uniquely uses the patient specific tumor motion trajectory and reproduces it in 5 dimensions (Fig 1). The purpose of this study is to commission the Hexamotion that to be served as an end-to-end tumor motion tracking or gating system QA device.

Methods: Three Calypso electromagnetic transponders were fixed to Hexamotion to record its real-time position. Range, velocity, acceleration were measured for each of the 5 DoF. Representative lung patient motion trajectories were selected and input into the Hexamotion to measure the dynamic accuracy. The tolerances for all tests are that both the mean and standard deviation of the difference between the programmed trajectory and the measured data are <0.5 mm as the accuracy of tumor motion detection and adaptation methods reach submillimeter accuracy.

Results: Hexamotion's range, velocity and acceleration are adequate to reproduce prostate and lung tumor motion during treatment (Table 1). Hexamotion demonstrated a high mechanical accuracy of 0.5 mm. In the dynamic accuracy test, the mean and standard deviation differences between the input lung trajectory and Calypso measured continuous position are less than 0.5 mm. Hexamotion has been used in our center to perform QA for the tumor motion detection system - Kilovoltage Intrafraction Monitoring (KIM) and the tumor motion tracking system - Dynamic MLC tracking.

Table 1. Hexamotion range, velocity and acceleration meet the requirement of reproducing tumor motion.

<table>
<thead>
<tr>
<th>Range (mm or deg)</th>
<th>Velocity (mm or deg/s)</th>
<th>Acceleration (mm or deg/s²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X (LR)</td>
<td>-43 ~ 43</td>
<td>-30 ~ 30</td>
</tr>
<tr>
<td>Y (SI)</td>
<td>-43 ~ 43</td>
<td>-30 ~ 31</td>
</tr>
<tr>
<td>Z (AP)</td>
<td>-40 ~ 41</td>
<td>-37.5 ~ 22</td>
</tr>
<tr>
<td>Tilt</td>
<td>-3.5 ~ 8</td>
<td>-7 ~ 7.5</td>
</tr>
<tr>
<td>Roll</td>
<td>-11 ~ 11</td>
<td>-10.5 ~ 10</td>
</tr>
</tbody>
</table>

Conclusion: The Hexamotion platform is capable of reproducing individual patient-specific tumor trajectories with a high degree of accuracy. It can be served for end-to-end tumor motion management systems QA device including 4DCT imaging, monitoring, gating and tracking.

PS04.043 - Dosimetric impact of the Acuros XB Algorithm for 25 lung SABR patients treated using the TrueBeam FFF 6MV

Author(s): Derek Hyde1, Tony Teke1, Matthew Schmid2

1Medical Physics, BC Cancer Agency - Centre for the Southern Interior, Kelowna/BC/CANADA, 2Medical Physics, BC Cancer Agency - Southern Interior, Kelowna/BC/CANADA

Purpose:

Stereotactic Ablative Radiotherapy (SABR) requires the delivery of a high biologically effective dose in only a few fractions. The Varian Truebeam has optional Flattening Filter Free (FFF) modes which greatly increase the dose rate and reduce treatment times. We previously commissioned the 6MV FFF beam (1400 MU/min) in Eclipse using Varian’s Analytical Anisotropic Algorithm (AAA), but have recently commissioned the Acuros XB algorithm (AXB). To examine the clinical significance of the new algorithm, we have retrospectively recalculated the dose distributions for the 25 patients that we have already treated.

Methods:

The standard commissioning data was acquired for Varian’s AAA and AXB beam models, and then MLC-defined fields were acquired for verification. Measurements were completed with the IBA Blue Phantom, using the CC13 and CC01 ion chambers and PTW diode. Heterogeneous dose calculations were then independently verified.
using Monte Carlo Simulations and Gafchromic film (EBT3, Ashland), confirming that the heterogeneous dose calculations were improved with the AXB algorithm. We have treated 25 lung patients, in which we used 4D-CT to define an ITV, added a 5mm expansion for the PTV, and then forward-planned on the fast-helical image, using a 3D conformal, non-coplanar technique to deliver 48 Gy (covering 95% of the PTV) in 4 fractions. The original MU from the AAA plan was used to calculate the ‘dose to medium’ as well as ‘the dose to water’, using the new AXB algorithm. Finally, both AXB plans were rescaled to the volume-based prescription, as per clinical practice.

Results:

When the dose distribution was recalculated with same MU for the dose to water, the difference of the PTVmean (avg=+1.1%) was statistically significant (P=.02). Neither the difference of the PTVmin (avg=-1.0%) nor the difference of the PTVmax (avg=0.3%) were statistically significant.

When the AXB dose to medium was calculated (with the same MU), the difference of the PTVmean remained similar (avg=+1.1%), but the difference of the PTVmin (avg=-1.3%) became significant (P=0.04) and although the difference of the PTVmax increased (avg=+0.37%), it was still not significant. It should be noted that the maximum differences for the PTVmin, PTVmax and PTV mean were -10.1%, 5.6% and 4.3% respectively.

When the AXB dose calculations were renormalized with the standard prescription of 48Gy covering 95% of the PTV, on average there was almost no affect on the calculated dose to water, but some effect on the calculated dose to medium. The maximum differences for the PTVmin, PTVmax and PTV mean were -5.2%, 16.2% and 4.3% respectively, for the dose to medium.

Conclusions:

The PTVmin is typically lower with the AXB calculation. Consequently, any volume based prescription will tend to increase the PTVmean as well as the PTVmax. Although the average differences for this patient set were only about 1%, individual patients illustrated the potential for much greater differences.

Conclusions:

Neither the minimax distribution nor the population average distribution allocate more than nine beams to any patient in the cohort. Thus, adding more than nine beams does not make significantly better plans for any patient in the cohort.

The minimax distribution and population average distribution lead to different resource allocations between the patients in the cohort. As expected, the population average distribution lowers the population average compared to the equal distribution, and the minimax distribution improves the plan quality to the three patients with the worst plan quality in the equal distribution. Even though no distribution dominates any other distribution in both worst case and population average measures, the results show that if there exists an objective on population basis apart from giving all patients the same resources, then dynamic resource allocation should be considered.

### Table 1

<table>
<thead>
<tr>
<th>Patient</th>
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<th>Minimax Population</th>
<th>Average dose rectum</th>
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### PS04.044 - Dynamic resource allocation: Investigating ways to distribute resources in a patient cohort based on plan quality

**Author(s):** Elin Hyning
Department Of Research, RaySearch Laboratories, Stockholm/SWEDEN

Radiation therapy is a resource intensive type of treatment and resources are always limited. This study aims at investigating ways to dynamically allocate resources among a cohort of patients. The idea is to take into account the plan quality that can be achieved for the individual patients with regard to the considered resource when allocating the resources.

A cohort of 13 prostate patients has been investigated, and the considered resource is the delivery time for a treatment fraction. The delivery time for a treatment fraction was represented as the number of beams used in the treatment plan. For each patient, six SMLC plans were automatically generated, with 5, 7, 9, 11, 13 and 15 beams respectively. All plans were required to fulfill a set of clinical goals and moreover to achieve as low average dose to the rectum as possible. The average dose to the rectum was used as the measure of plan quality. The available treatment time for all patients in the cohort was 91 beams, i.e. all patients in the cohort could receive a plan with seven beams. Three different schemes to allocate the available resources were considered; equal distribution, minimax distribution and population average distribution. In the equal distribution, all patients received a plan with seven beams. In the minimax distribution, resources were allocated to improve the plan quality for the patients with the worst plan quality. In the population average distribution, resources were allocated to achieve the best average plan quality for the cohort.

The resulting allocations of treatment time stemming from the different allocation schemes are shown in table 1.

### PS04.045 - Physical plan evaluation of Head and Neck Cancer at Square Hospital, Bangladesh.

**Author(s):** Md. Anwarul Islam1, Md.Mahmudul Hasan1, Golam Abu Zakaria2
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**Purpose:** To compare the physical parameters of Three Dimensional Conformal Radiotherapy (3D CRT) with Intensity Modulated Radiotherapy (IMRT) for Head & Neck cancer and the dose profiles of primary tumors, electively treated organ (Lymph node) and Organ at Risk (OARs).

**Materials and Methods:** From January 2010 to October 2014, total 473 patients were diagnosed with head and neck cancer in Square
and a sheet of radiochromic EBT3 film from the IAEA. The participants were asked to choose a highly modulated single treatment field by comparing the relative dose distributions delivered to the parotid gland, spinal cord and mandible have been contoured as OARs. The beam direction of 3DCRT plans were selected laterally parallel opposed with wedge and Field in Field (FIF) technique either co-planar or non co-planar to avoid shoulder. The beam weights were adjusted in order to minimize tumors dose inhomoegenity. The beam arrangement of IMRT plans were nine and seven equispaced non-opposed coplanar beams. The same dose volume constraints were used for all IMRT plannings during inverse optimization. The physical parameters, Target Coverage (TO), Conformity Index (CI), Conformation Number (CN), Lesion Under dose Factor (LUF), Healthy Tissue Over dose Factor (HTOF), Homogeneity Index (HI) and DVHs have been calculated for each treatment plan. The 100% is the perfect TC coverage, whereas if the 95% isodose covers all of the clinical and pathologic target volume, treatment is considered to comply with the protocol. A CI equal to 1 corresponds to ideal conformation. The CN ranges from 0 to 1, where 1 is the optimal conformity and value close to 0 indicates less conformal plan. The lower the values of LUF and HTOF, the higher is the conformal plan. Smaller values of HI correspond to more homogeneity and 0 corresponds to absolute homogeneity. According to the RTOG and QUANTEC guideline, mean and maximum doses (1cc and 1%) have been considered for Organ at Risk (OARs) dose evaluation.

Results: The mean values for 3DCRT and IMRT were 95.07 and 95.33 for TO, 0.466 and 0.895 for CI, 0.441 and 0.795 for CN, 0.045 and 0.028 for LUF, 1.115 and 1.00 for HTOF and 0.145 and 0.085 for HI respectively. The mean dose for parotid glands were 47.28 and 23.80, maximum dose for spinal cord 43.78 and 39.63 for mandible 64.20 and 59.17 Gy correspondingly for 3DCRT and IMRT.

Conclusion: IMRT is superior to 3DCRT in dose delivery and critical structure sparing for the treatment of Head & Neck cancer. The primary tumor can get higher equivalent dose by IMRT techniques.

PS04.047 - Electron Density Measurements of Metallic Implants with Cobalt-60 Computed Tomography

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Introduction: The photon starvation and beam-hardening artifacts produced by high density and atomic number objects in kilovoltage CT images are a well known phenomenon in radiation therapy planning. Metal artifacts can obscure anatomy and impact dose calculation accuracy as the quantitative information in CT images is used to provide a map of relative electron density (RED) within the patient’s body. Further calculation perturbations arise when the range of allowed CT values is constrained to 12 bits. In this work we investigate the importance of these effects in treatment planning.

Methods: Our group has developed a benchtop cone-beam CT system to investigate the potential for patient alignment on a cobalt-60 teletherapy unit. The high energy (~1.25 MeV) and nearly monoenergetic gamma ray spectrum of cobalt-60 reduces metal-induced artifacts, suggesting cobalt-60 CT (CoCT) may be useful for evaluating RED information derived from kVCT images acquired in the presence of metal objects. Images of metal rods of varied RED and atomic number within water phantoms were gathered via CoCT and conventional kVCT including images reconstructed using a commercial metal artifact reduction algorithm. To demonstrate the importance of accurate electron density information, large field (6MV, 25x25cm2) dose profiles were measured with an ion chamber in a water phantom containing metal rods and compared to treatment planning system calculations based on kVCT and CoCT images. Results/Conclusions: Converting images from CT number to RED and comparing with known electron density distributions shows that the starburst artifacts surrounding the metal rods in kVCT are absent from CoCT (Figure 1a-b). In kVCT images, pixels above a threshold electron density are assigned the same CT number, the maximum of the allowed range. This leads to an
ambiguos condition where different high density materials cannot be differentiated in kVCT images (Figure 1c). Reduced artifacts in regions surrounding metal objects and the lack of a limit on CT number range enable a more faithful representation of electron density information with CoCT. Compared to ion chamber measurements at a point downstream of a titanium rod, calculations based on kVCT and CoCT images differed from measurements by -12.7% and 3.2%, respectively. This result is likely attributable to the treatment planning system’s assumption that threshold value kVCT pixels are approximately equivalent to stainless steel, a 76% overestimate of the true electron density of titanium. CoCT imaging enables the evaluation of metal artifact perturbations in planning CT and work assessing vendor correction algorithms is underway.

**PS04.049 - The Use of Boron Neutron Capture Therapy in the Treatment of Cancer Tumours in the Czech Republic**

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Boron neutron capture therapy is an experimental method of the treatment of malignant tumors of today. The study first gives a comprehensive overview of the state of the art both in the Czech Republic and abroad. It describes a low power research nuclear reactor which will be utilized as the radiation source used in the therapy. The feasibility study introduces the project proposal and the approximate cost of the facility construction. The feasibility study further quantifies the reactor’s operating cost and summarizes the cost of treatment with neutron capture therapy. Based on the market analysis, the marketing strategy and the marketing mix are devised. The professions needed for the facility operation are defined. The study assesses the project’s impact on the environment, presents the risk analysis and sensitivity analysis. Boron neutron capture therapy has a great potential to become a successful therapy in the treatment of some types of malignant tumors under certain conditions in the future.

**PS04.048 - A Systematic Analysis Of The Error Sources Within The CyberKnife M6 Daily AQA Test**

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**Objectives:** To determine and critically analyze the sources of error within the daily Automatic Quality Assurance (AQA) test used on the CyberKnife M6 system.

**Methods:** A systematic analysis of the inherent uncertainties involved in the CyberKnife M6 AQA test was conducted to quantify the uncertainty in each of the components making up the AQA process. The identified components included the robot positional uncertainty, film scanning precision, film response and the kV imaging system uncertainty, film scanning precision, film response and the kV imaging system uncertainty. These results suggest an uncertainty of less than 0.1 mm for the film, film scanner, and robot components of the AQA test. The kV imaging system uncertainty could reach 0.3 mm, which is the main source of uncertainty. This information explains greatest weakness in daily CyberKnife QA and may be useful in establishing realistic expectations of daily AQA results.

**PS04.050 - Partial Arc Breast Boost**

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Adjuvant radiotherapy to the excised tumour bed following radiotherapy of the entire breast is routinely used to reduce risk of local recurrence in select patients. Boost treatments are generally delivered via conformal radiation therapy (CRT) with 2-3 fields, making use of tangential geometry. This study explores volumetric modulated arc therapy (VMAT) as an alternative to conventional CRT. A modulated partial arc was planned, spanning the angles between the tangential fields used in the initial phase of treatment to the entire breast.

The plans of 15 previously treated patients (7 left-sided, 7 right-sided, one bilateral) were retrospectively re-planned in Pinnacle (Philips, v9.0). The left-sided patients were all CT simulated in a breath hold position using the active breathing control system. The average volume of the tumour cavity was 19 cc (range: 4-57cc). A class solution for beam geometry and optimization objectives of the arc plans was achieved, and plan comparison was based on coverage of the tumour bed by 95% of the prescription (950 cGy) and doses to the pertinent organs at risk. All plans were normalized to achieve target coverage equivalent to or better than the original plans. Robustness of the two techniques was evaluated by simulating breast contour changes in Pinnacle.

The arc plans achieved significant improvements in dose conformality, as exemplified in Figure 1. Doses to 10 cc of heart increased in the arc plans, while the volume of ipsilateral lung receiving >2 Gy did not show a consistent trend. The maximum point dose to skin (a 3mm thick rind contracted from the external contour) increased, particularly in superficial targets, however the maximum dose to 10cc of skin decreased. The low-dose exposure to the contralateral breast in the arc plans was controlled with a medial optimization structure and was equivalent with the CRT technique. The overall maximum point dose was higher in the arc plans, however the volume receiving 105% of the prescribed dose did not vary monotonically when compared with CRT plans. Arc plans were equivalent
or superior in retaining target coverage following breast contour changes when compared with conformal plans. Based on the performance of arc plans in this small cohort of patients, an investigation involving a larger retrospective dataset is warranted.

**Figure 1.** Comparison of a conformal (above) and arc (below) breast boost plan. Target is shown in brown colourwash, along with the 100% (blue), 95% (green), 50% (cyan) and 10% (violet) isodoses by time when the values obtained before and after breathing were compared ($p < 0.05$); 30% and 40% of the duty cycle, respectively, was determined to be the most effective, and the corresponding phases were 3060% (duty cycle, 30%; $p < 0.05$) and 3070% (duty cycle, 40%; $p < 0.05$).

**Conclusions:** Respiratory regularity was significantly improved with the use of the RPM with our visible guiding system; therefore, it would help improve the accuracy and efficiency of RGRT.

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**PS04.052 - Dosimetric Verifications of the Output Factors in the Small Field less than 3 cm$^2$ using the Gafchromic EBT2 films and the Various Detectors**

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The small field dosimetry is very important in modern radiotherapy because it has been frequently used to treat the tumor with high dose hypo-fractionated radiotherapy or high dose single fraction stereotactic radiosurgery (SRS) with small size target. But, the dosimetry of a small field ($< 3\times3$ cm$^2$) has been great challenges in radiotherapy. Small field dosimetry is difficult because of (a) a lack of lateral electronic equilibrium, (b) steep dose gradients, and (c) partial blocking of the source. The objectives of this study were to measure and verify with the various detectors the output factors in a small field ($< 3 \times 3$ cm$^2$) for the 6 MV photon beams.

Output factors were measured using the CC13, CC01, EDGE detector, thermoluminescence dosimeters (TLDs), and Gafchromic EBT2 films at the sizes of field such as $0.5 \times 0.5$, $1 \times 1$, $2 \times 2$, $3 \times 3$, $5 \times 5$, and $10 \times 10$ cm$^2$. The differences in the output factors with the various detectors increased with decreasing field size.

Our study demonstrates that the dosimetry for a small photon beam ($< 3 \times 3$ cm$^2$) should use CC01 or EDGE detectors with a small active volume. And also, Output factors with the EDGE detectors in a small field ($< 3 \times 3$ cm$^2$) coincided well with the Gafchromic EBT2 films.
**PS04.053 - Methodology to Evaluate Combined EBRT and HDR Brachytherapy for Cervical Cancer using Equivalent Uniform Dose (EUD) and Tumor Control Probability (TCP)**

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**Purpose:** In order to predict tumor control for patients receiving both external beam radiotherapy (EBRT) and high-dose-rate (HDR) brachytherapy, we present a methodology of evaluating overall radiobiological parameters of equivalent uniform dose (EUD) and tumor control probability (TCP). The current tumor coverage metric is D90 for HDR cervical cancer by assuming the shape of DVH is reasonably same. EUD, accounting for whole DVH has potential as an additional plan quality evaluation tool.

**Methods & Materials:** A total of 6 biopsy proven cervical cancer patients with FIGO stage I were retrospectively analyzed. All patients received EBRT (45Gy with 1.8 Gy/fx) and Point-A based HDR plans (7Gy x 4fx or 5.5Gy x 5fx). Two patients received a parametrial boost (5.4 or 9Gy). The EBRT and HDR dose maps were converted into equivalent dose in 2Gy fraction (EQD2) dose maps with alpha/ beta = 10 using an in-house tool. EUD values were measured from EQD2-DVHs using two different formulae: 1) Using alpha value = 0.15 and 2) Using survival fraction in 2 GY (SF2) = 0.48. TCP values were calculated using Logistic and Poisson TCP models. The positional input parameters (D50) of TCP for stage I cervical cancer were modeled from long-term clinical data: D90 = 59 Gy and 75.7 Gy with gamma50 = 2 and 8, respectively.

**Results:** It was feasible to estimate the predicted TCP of the combined EBRT and HDR plans by combining differential EQD2-DVHs. The predicted TCP values for 6 patients were recorded as 100% when using the individual-patient based TCP (gamma50 = 8), and ranged from 88 – 100 % with the population-based TCP (gamma50 = 2). The TCP values were robust with respect to the two different TCP models with correlation coefficients of 0.99 – 1.0. EUD values were on average 124 ± 8 Gy and 110 ± 7 Gy using alpha-based and SF2-based formulae, respectively, with a correlation coefficient of 0.98. All EUD values were recorded as higher than their corresponding D90 values.

**Conclusion:** It was feasible to estimate the predicted TCP and overall EUD of combined EBRT and HDR plans by combining differential EQD2-DVHs. TCP values were robust regardless of Logistic or Poisson model.

**Figure.** Upper panel: TCP values calculated from the combined EUD values of EBRT and HDR. Lower left: The combined EUD values compared with combined D90 and D100 values. Lower right: TCP models with gamma50 = 2 and 8.

**PS04.054 - International Multi-Institutional Bench Mark Study on Dosimetric and Volumetric Modulation using Helical TomoTherapy Treatment Planning for Malignant Pleural Mesothelioma Tumors**

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**Purpose:** To determine the most desirable and achievable target dose and organ at risk (OAR) sparing using helical TomoTherapy planning system for mesothelioma treatment plans.

**Introduction:** Mesothelioma is an incurable cancer involving the lining of the lung. Treatment options currently available are chemotherapy and external radiotherapy. TomoTherapy’s ability to treat unusually shaped tumors, particularly those wrapped around sensitive normal tissues (e.g. lung), enables higher doses of radiation to be delivered to the target while sparing the normal lung. This, in theory, should improve the treatment’s effectiveness.

**Materials and methods:**

Academic and clinical participants (from US, Canada, France, Sweden, Belgium, Malaysia, Thailand, Mexico and Saudi Arabia) were given CT images and structure sets of a patient having mesothelioma with mediastinal nodes. The planning target volume (PTV) was created using margins of 3 mm inner and 1cm outer and was prescribed a dose of 54 Gy to 95% of the volume. Each of participants was asked to create a helical TomoTherapy IMRT plan following same planning guidelines. They were given the goal of either (1) keeping the prescribed dose to the targets while reducing the dose to the OARs or (2) escalating the target dose while maintaining the original level of healthy tissue sparing.

**Results:**

The resulting treatment plans in primary lesion and nodal mass varied in coverage (95-98.7%) with PTV V54Gy (90.5-96.1%) with Max dose of (57.73-63.46 Gy). Conformality index were (0.950-1.730) and homogeneity index varied from (1.087-1.217) among the participating TomoTherapy centers. The most variable OAR constraint was mean total lung dose (16.4 – 98.15%). Other OAR constraints varied less; total lung V5Gy (28.4-58.5%), total lung V20Gy (15.6-33.21%), contralateral lung V5Gy (0.87-39.45%) and heart V45Gy (20.7-28.9%). A range of planning parameters were used; pitch (0.22 - 0.43) and delivered modulation factor of (1.143-2.084), and treatment time of (302.1 – 778.2 seconds). The reviewers’ ranking assessment (Ranking in Groups: 1 = Good, 2 = Above Average, 3 = Average, 4 = Poor) varied with 3/9 treatment plans rated Good (rank = 1) in at least one category by at least one reviewer. The overall rankings revealed that a plan with balanced trade-off among all planning objectives was preferred by most participants and reviewers.

**Conclusion:** Helical TomoTherapy is a promising technique in the multimodal-ity treatment of malignant pleural mesothelioma. Based on many
studies on the comparison of 3DCRT, IMRT and TomoTherapy, it is has been recommended that helical TomoTherapy provide bet- ter target coverage and sparing of OARs. Other studies found low doses to the contralateral lung to be limiting. This was not the case in our study, with TomoTherapy we found the dose to contralateral lung be as low as V5Gy=0.87%. A pitch value of 0.287 or 0.43 and a delivered modulation factor of above 1.7 will be beneficial consider- ation in planning.

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PS04.055 - Factors predicting of local relapse in irradiated patients with breast cancer: A Syrian Cohort study
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Background: Breast cancer is the most common cause of cancer death in women. Better understanding of cell biology and behavior may lead to improvement of disease control and prolongation of both disease free and overall survival rate.

Objective: The study is aiming to determining the factors implicated in local relapse in breast cancer patients treated with radiotherapy on chest wall.

Materials and Methods: The study is retrospective one, where we collected data from 2440 Syrian women with breast cancer during the period between 2007 to 2012 at Al Bairouni University Hospital, Damascus. Syria.

Results and Discussion: Among the 2440 patients, 1213 patients experienced local relapse with median period of 14 months. Fac- tors associated with local relapse were: Tumor volume ( P. Value 0.002), lymph\ Vascular invasion (P. Value 0.005), quadrectomy (P. Value 0.0004) and Her-2 positive status (P. Value 0.0001). Patients with total mastectomy, small tumor volume and estrogen, recep- tors positive did not correlated with local relapse. Data showed that the most of our locally relapsed patients presented with locally advanced disease and big tumor volume which correlates with high rates of lymph\ vascular invasion, the thing can clarify the tendency for local relapse in this group of patients.

Conclusion: Our results showed that big tumor volume, lymph vascular invasion and Her-2 status are the main factors correlated with local relapse after radiotherapy irrespective of the dose and method of radiotherapy.

PS04.056 - Automated Routine Quality Assurance of VMAT
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Purpose: The purpose of the work was to develop a standard-
ized picket fence equivalent for Volumetric Modulated Arc Therapy (VMAT) QA, and to automate the analysis method such that the tests can be performed in routine fashion.

Materials & Methods: An in-house software program was de-veloped using Matlab to automatically analyze delivery to a portal imager using VMAT with varying MLC speed, dose rate and gantry speed. The testing was separated into two cases: the first in which the dose rate and gantry speed are varied and the second in which the MLC speed is varied. For each case two files were delivered: (1) a dynamic field in which MLCs and gantry moved and (2) a static open field in which the MLCs were retracted and the gantry was stationary. A ratio of the two fields was taken in order to remove field non-uniformities (i.e. horns). The software analyzed the completely irradiated area on the portal imager.

Results: An example of a delivered MLC speed file is shown in Figure 1. The analysis was separated into two regions (the 2.5mm & 5mm MLC widths) due to higher leakage in the 2.5mm region. The image intensity ratio in the 2.5mm MLC region, between the VMAT delivered field and the open field, is shown in Figure 2. The average of the image intensity ratio was scaled to 100 for ease of visibility. The data collected over a six month time frame illustrate that the spread in image intensity ratio is less than 2.5% in all delivered cases. Approximately 95% of the points are within 1.5% of the mean image intensity ratio.

Conclusion: The work herein illustrates that automated VMAT de-

livery analysis can be performed in a routine fashion while generat-
ing reproducible results. The results can be tracked and obtained quickly after delivery.
**Purpose:** To determine if a linac-based intensity-modulated radiation therapy (IMRT) technique is comparable to helical tomotherapy (HT) for the treatment of craniospinal volumes in terms of planned dose to the planning target volume (PTV) and organs at risk (OARs).

**Methods and Materials:** A retrospective planning study was performed on 11 patients (3 female, 8 male) who received treatment at this center in the past. The IMRT plans consisted of three sets of beams (with each set having a separate isocenter) - five cranial, three upper spine, and three lower spine fields - and were inverse-planned using Pinnacle³ (v.9.2, Philips). Helical tomotherapy plans were generated with the TomoTherapy Hi-Art (v.4.0.4) planning system. All patients were prescribed 36 Gy in 20 fractions, and plans were optimized to achieve similar goals across both platforms, namely 95% volume coverage of both the brain and spinal PTVs, and reduced dose to all OARs. We compared the performance of each technique through dose-volume histogram (DVH) statistical parameters, mean and maximum doses, and conformity index, testing for significance using the Wilcoxon signed-rank test at a level of p < 0.05.

**Results:** We find that multi-isocentric IMRT generally produces comparable plans to those of HT in terms of PTV coverage and homogeneity. We find that $D_{\text{mean}}$ to the optic nerves, optic chiasm, lenses and eyes and $D_{\text{mean}}$ to the heart are equivalent in our patient sample. Slight differences are noticeable in the larger organs. The volume of lung receiving low dose is less for IMRT (average $V_{5\text{Gy}} = 27.9\%$) than HT ($V_{5\text{Gy}} = 37.2\%$, p < 0.005), while the opposite is true for higher doses ($V_{10\text{Gy}} = 11.4\%$ for IMRT vs. 9.1\% for HT, p < 0.005; $V_{20\text{Gy}} = 3.1\%$ for IMRT vs. 1.8\% for HT, p < 0.001); this is perhaps unsurprising considering the three chosen IMRT spinal beam directions compared to the possible 360° field delivery of HT. Similarly, a decreased low-dose wash to the whole body from the linac-based IMRT is reflected in its ability to spare kidney dose, resulting in a lower mean dose and volume exposed to low dose (average $D_{\text{mean}} = 3.2\text{ Gy}$ for IMRT vs. 4.4 Gy for HT, p < 0.005; $V_{5\text{Gy}} = 15.9\%$ for IMRT vs. 26.1\% for HT, p < 0.02). Further differences we observed were a marginally higher mean dose to the parotids and esophagus, as well as higher $D_{\text{mean}}$ to the esophagus in the IMRT plans.

**Conclusions:** Based on our 11 patient sample set, the linac-based multi-isocentric IMRT treatment technique is able to produce comparable plans to helical tomotherapy in patients receiving craniospinal irradiation, with only minor tradeoffs in plan quality. This technique may provide an attractive alternative at treatment centers looking for a more conformal and homogeneous approach than conventional methods (ie. cranial lateral parallel opposed pairs with spinal posterior junctioned fields) but without access to HT.

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**PS04.058 - A comparison of linac-based IMRT with helical tomotherapy for craniospinal irradiation**

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To compare the dosimetric performance of three different arc treatment techniques; modulated arc (m-ARC), tomotherapy, volumetric modulated arc therapy (RapidArc, RTA). The purpose of this study is to evaluate the clinical usefulness of mARC treatment techniques. The mARC treatment was selected patients with non-small cell lung cancer (NSCLC) for clinical usefulness of mARC. In order to do this, a study to find the most suitable plan condition of mARC treatment was performed and the usefulness was evaluated by comparing it with the other Arc treatment plans such as Tomotherapy and RapidArc. Three different arc treatments were performed on patients with NSCLC. To compare the dosimetric performance of three different main factors– An photon energies (6MV or 10MV), and segment number per each spacing angle were considered. The treatment plans produced using the three different techniques were compared based on the following parameters: conformity index (CI), homogeneity index (HI), target coverage, dose in the OARs, monitor units (MU), treatment time and the normal tissue complication probability (NTCP). As a result, the best dosimetric performance of mARC was observed with the main factors of 10MV photon energy and the spacing angle 6 degree, 59 segments. The target coverage was similar in three different treatment techniques. The RapidArc produced the best dose homogeneity index. However, the conformity index for RapidArc was 1.51 and 1.63 with an absolute difference of 1.07 and 1.52 than tomotherapy, 1.1 and 1.16 lower than mARC. The mARC produced the lowest V20. However, RapidArc produced the best mean lung dose. Both mARC and RapidArc plans had a shorter treatment time, compared with tomotherapy, with a relative fast of 62% and 77% in treatment time. As a result, this study has shown satisfactory result about the clinical usefulness of mARC plans.

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**PS04.059 - A Hardware-Accelerated Software Platform for Adaptive Radiation Therapy**

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A critical requirement of successful adaptive radiotherapy (ART) is the knowledge of anatomical changes as well as actual dose delivered to the patient during the course of treatment. While cone-beam CT (CBCT) is typically used to minimize the patient setup error and monitor daily anatomical changes, its poor image quality impedes accurate segmentation of the target structures and the dose computation. We developed an integrated ART software platform that combines fast and accurate image registration, segmentation, and dose computation/accumulation methods. The developed platform automatically links patient images, radiotherapy plan, beam and do-
simetric parameters, and daily treatment information, thus providing and efficient ART workflow. Furthermore, to improve the accuracy of deformable image registration (DIR) between the planning CT and daily CBCTs, we iteratively correct CBCT intensities by matching local intensity histograms in conjunction with the DIR process. We tested our DIR method on six head and neck (HN) cancer cases, producing improved registration quality. Our method produced overall NMI of 0.663 and NCC of 0.987, outperforming conventional methods by 3.8% and 1.9%, respectively. The overall ART process has been validated on two HN cancer cases, showing differences between the planned and the actually delivered dose values. Both DIR and dose computation modules are accelerated by GPUs, and the computation time for DIR and dose computation at each fraction is ~1min.

Preliminary Results:
14 test patients were run with an EOR of 87.2%±5.9% for gross-total resection (GTR) patients, and 63.8%±29.5% for sub-total resection (STR) patients. KPS was slightly higher (p over 0.05) in STR (81±8) than GTR (75±14), supporting our first aim.

Conclusions:
Preliminary findings indicate that the pipeline can successfully segment the tumor for EOR calculation, and volumetric measurement of TAS.

PS04.060 - Predicting the Impact of Surgery on Quality of Life and Risk Management in Patients Afflicted with Glioblastoma Multiforme
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Introduction:
Glioblastoma multiforme (GBM) tumors are the most common brain malignancy with an average prognosis of 12-18 months with treatment. Surgical reduction of tumor volume by 78% or more increases patient life expectancy, and can be further extended by adjuvant radio/chemotherapy. However, the effect of treatment on patient Quality of Life (QOL) remains unknown. This study investigates: 1) the impact of more aggressive surgery on patient function, and 2) the utility of a tumor assessment score (TAS) to optimize treatment options by using tumor location and size to predict if the patient is healthy enough for adjuvant therapy. We hypothesize that: 1) there is a threshold between 78% and 98% resection where survival time will continue to increase but functional performance score will start to decrease, 2) a lower TAS based on anatomical location of tumour will reliably predict a lower post-operative functional score.

Methods:
Approximately 90 patients with GBM have gadolinium enhanced and non-enhanced T1 MR images taken pre- and post-surgery. Image pairs are registered and subtracted to highlight active tumor tissue and have their volume measured to calculate the extent of resection (EOR) (Figure 1). Patient QOL is measured with the Karnofsky Performance Scale (KPS) score. The TAS has a value between 1 and 10 based on: 1) which lobes the tumor infiltrates, 2) left vs. right hemisphere, and 3) the volume of tumor within each region. The impact of surgery looks at the relationship between EOR and postsurgical KPS. The predictive ability of TAS is determined by how closely it can estimate post-surgical KPS.

Figure 1: Tumour segmentation pipeline. (A) Registration of gadolinium contrast enhanced and non-enhanced axial T1 images. (B) Subtraction of the image pair highlights active tumour tissue. (C) Brain extraction removes skull and erosion reduces blood vessel connectivity. (D) Floodfill algorithm segments the tumour and provides a volume measurement.

Preliminary Results:
14 test patients were run with an EOR of 87.2%±5.9% for gross-total resection (GTR) patients, and 63.8%±29.5% for sub-total resection (STR) patients. KPS was slightly higher (p over 0.05) in STR (81±8) than GTR (75±14), supporting our first aim.

Conclusions:
Preliminary findings indicate that the pipeline can successfully segment the tumor for EOR calculation, and volumetric measurement of TAS.

PS04.061 - A memetic algorithm for body gamma knife stereotactic radiotherapy treatment planning
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Abstract—Body gamma knife stereotactic radiotherapy (SBRT) is an effective treatment for non–small-cell lung cancer (NSCLC). Treatment planning is both tedious and time-consuming due to its complexity. In order to address this issue, we present a memetic
optimization algorithm for body gamma knife SBRT treatment planning. Different from currently available methods, the memetic approach performs the optimization on relative dosimetric distribution, which results in an enlarged search space. Taking advantage of the prior knowledge about the interaction between the focuses, a heuristic initialization strategy and a set of genetic operators are developed. During optimization, the most time consuming part is accelerated by graphic processing unit (GPU). Three typical targets arising from real patient data are used to test the efficiency of this approach. Experimental results demonstrate that the memetic optimization could generate a feasible treatment plan quickly (84.6 sec for the largest case).

PS04.062 - Gamma evaluation of dose distributions from newly developed dosimetry system for helical tomotherapy
Author(s): Sangwook Lim, Sangwook Lim, Sun Young Ma
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To see the reliability of the newly developed dosimetry system using phosphor screen for arc therapy such as helical tomotherapy. The cylindrical water phantom was fabricated with the rounded phosphor screen emitting the visible light, that is phosphorescence during the exposure. Three types of virtual targets were defined, one is a small rounded target, another is C-shaped target, and the other is multiple targets. All the targets were to be irradiated at 10 Gy respectively by tomotherapy. Every frame captured from the camera was integrated and the doses were calculated in pixel by pixel. The dose distributions from the phosphorescence images were compared with the calculated dose distribution from the TPS. The discrepancies were evaluated as gamma index for each treatment. The curve for dose rate versus pixel value was not saturated until 900 MU/min. The dosimetry system with the phosphor screen and the camera is respected to be useful to verify the dose distribution of the tomotherapy if the linearity correction of the phosphor screen improved.

Acknowledgements: This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2010-0013701 and 2013R1A1A2012013)

PS04.063 - Suitability of a Light Transparent and Electrically Conductive Glass Plate for Construction of a Beam Monitor for Radiation Therapy
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Introduction: Due to increasing complexities in radiation therapy technology and associated processes, several real-time independent beam monitoring systems have recently been proposed to minimize treatment errors. Proposed systems utilize a large area detector system or ion chamber mounted after the final beam forming collimator on medical linear accelerators. Some of these devices block light fields, disrupting workflow as therapists are required to remove and re-install the dosimetry device before and after patient setup. In this presentation we describe the suitability of electrically conductive and light-transparent glass plates for use as electrodes in a large area ion chamber.

Method: Plates’ suitability was assessed based on four properties: (1) surface electrical conductivity (2) light intensity attenuation (3) light field boundary deviations due to refraction (4) stability to radiation exposure.

A commercially available 30x30 cm² conductive glass plate from Sigma Aldrich (Oakville, Canada) was investigated. The plates are 2 mm thick Soda-Lime Glass, coated with 0.5 microns thick conductive layer of Fluorine-doped Tin Oxide (FTO).

Glass surface conductivity was measured and a prototype parallel plate ion Chamber was created using 2 such plates and tested in radiation for functionality. Light attenuation caused by the prototype was measured using the light probe accessory from the Xi system manufactured by RaySafe (Bilddal, Sweden). Light field deviation was calculated using Snell’s law; incident angle needed for 1 mm deviation was determined for red and green light, and experimentally confirmed with red and green lasers. Finally, plates’ effect on the light field’s usability and impact on equipment and patient setup in clinical settings was evaluated by an independent observer using eQA – a commercially available light field and radiation congruence validation tool by Modus Medical (London, Canada) – with and without the prototype. Exposure history is documented and periodic inspections performed to assess radiation damage.

Results: Glass surface resistance was measured to be 51.2 Ω from corner to corner. Basic performance of the prototype was satisfactory. Light field intensity from a Varian linear accelerator was reduced by 35.6% with the 2-plate prototype. According to Snell’s Law a 2 mm glass plate causes 1 mm deviation in ray-line with incident angles of 61.3° and 58.6° red and green light respectively. Experimental results confirmed calculated values. The boundary of a 40x40 cm² light field makes 15° incident angle with the prototype when mounted at the collimator; therefore only 0.74 mm deviation in field size is expected. Field congruence value comparison measured by eQA with and without the prototype also showed no measurable changes to 24x24 cm² light field. No structural changes were observed after testing sessions where the prototype was exposed to radiation doses exceeding 1000 MU.

Conclusions: A commercially available electrically conductive glass plates was found to be suitable for construction of a transmission area ion chamber. The deviation in light-field boundary was found to be negligible. The reduction in light field intensity with 2 glass plates did not limit the usability.

PS04.064 - Objective assessment of skin erythema caused by radiotherapy
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Skin toxicity of normal-tissue is unavoidable side effect in external-beam radiation therapy. Degree of skin toxicity has been visually categorized into discrete grades with having uncertainty owing to subjective evaluation by physicians. Skin dose irradiated in treatment is controlled for skin condition not to get worse than being erythema. This indicates that radiation-induced skin toxicity can be represented by degree of skin erythema. Skin erythema is caused by expansion of capillaries because of increase of blood flow, hemoglobin, owing to biological response for repair. The present study focuses on such physiological response in order to continuously assess skin toxicity.

Two kinds of non-invasive techniques to detect hemoglobin quantity have been developed. One is a Doppler laser flowmeter, which measures reflectance and wavelength-modulation of laser light scattered by skin. It detects skin blood flow in absolute value. The other is skin color pigments decomposition on digital image using independent component analysis (ICA) which is one of multivariate statistics methods. It decomposes a full-color skin image into color tones of hemoglobin, melanin, and others in relative value. Com-
Six patients who had carbon beam therapy on lung cancer were treated. Prescription dose of 50 GyE were irradiated from four ports in one day. Photography and skin blood flow measurement were done at 3 h, 1 and 3 month(s) later since the irradiation for study of time series. A conventional compact digital camera was used, but special instruments and lightning condition were not prepared. A fast fixed-point algorithm was employed for ICA. Skin colors were successfully decomposed as shown in Fig. 1.

The results obtained are that relationship between skin dose and blood flow and relationship between skin blood flow and pixel values in hemoglobin image have been observed with their correlation coefficients being larger than 0.9. It was shown that skin toxicity can be represented by change of skin blood flow which is objective quantity. Because the present study quantitatively connects pixel values in hemoglobin image with skin dose, it would be promising to predict skin condition after irradiation in advance by making use of artificial synthesized image processing.

Fig. 1 Typical example of the color decomposition on a skin image which represents two-ports-irradiation erythema. An original image is (A). Color tones of hemoglobin, melanin, and others are (B), (C) and (D), respectively.

PS04.065 - Nasopharyngeal carcinoma tumor response to induction chemotherapy followed by concurrent chemo-radiotherapy: A volumetric magnetic resonance imaging study

Author(s): Nevin Mcvicar1, Joshua Giambattista2, Benjamin Maas2, Cheryl Ho2, Monty Martin1, Eric Berthelet1

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Purpose: Sequential induction chemotherapy followed by concurrent chemo-radiotherapy is currently under investigation for treatment of locally advanced nasopharyngeal carcinoma (NPC). Using magnetic resonance imaging (MRI), we have assessed tumor response at various stages of treatment for NPC patients prescribed with induction and concurrent chemo-radiotherapy. This study represents the first detailed volumetric analysis of primary gross tumor volumes (GTVP) in sequential treatment of NPC.

Methods: Fourteen locally advanced stage III-IV NPC patients who received treatment within the British Columbia Cancer Agency between 2011 and 2014 were used for this study. The induction phase included two cycles of gemcitabine combined with cisplatin. The concurrent phase included 5-7 cycles of cisplatin with radiation therapy delivered using volumetric modulated arc therapy (VMAT). All patients received a total dose of 70 Gy over 35 daily fractions given five days per week. All patients received three MRIs at specific stages of treatment (T0: before treatment, T1: after induction phase and T3: three months after concurrent phase). A subset of three patients also received an MRI approximately mid-way through concurrent phase (T2). GTVP and RECIST long (RL) and short (RS) diameters were calculated based on MRIs acquired at 1.5 Tesla using a gadolinium-enhanced fat-saturation T1 weighted spin-echo pulse sequence. GTVP were contoured in each MRI. Mean values are reported ± one standard deviation.

Results: In this preliminary analysis, we report on the subset of 3 patients who underwent 4 sequential MRIs. Before treatment, the mean GTVP was 69.6 ± 26.4 cc and the mean RL and RS diameters were 7.9±1.7 cm and 5.1±1.0 cm respectively. GTVP and RECIST diameters measured at each stage of treatment are shown for the in Figures 1a,c respectively. Figure 1b,d displays the average change in GTVP and RECIST diameters (as a percent of initial values calculated at T0) between each treatment phase with error bars equal to one standard deviation (N=3).

Discussion: Preliminary results indicate that two cycles of induction chemotherapy consistently reduced GTVP (15.1±6.7%) as well as RECIST diameters (long: 10.2±5.1%, short: 7.6±13.7%). NPC is very radiosensitive and tumor sizes reduced significantly throughout concurrent chemo-radiotherapy (~75%). RECIST diameters were more variable than GTVP measurements and were not accurate indicators of GTVP. NPC tumors are often irregular shapes making RECIST diameters not ideal markers of NPC tumor size. Analysis of the entire NPC patient dataset and quantification of tumor response during induction phase is ongoing.
PS04.066 - Volumetric Modulated Arc Therapy of Pancreatic Cancer: Dosimetric Advantages as Compared to 3D Conformal Radiation Treatment

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Volumetric modulated arc therapy (VMAT) has been gaining wider adoption in radiation treatment of various cancer sites, and some recent studies have shown benefits of VMAT to the treatment of pancreatic cancer. This study is to show dosimetric advantages of VMAT with our planning strategies when compared to 3D conformal radiation therapy (3D-CRT) of pancreatic cancer.

The VMAT planning was performed retrospectively on 8 selected pancreatic cancer patients treated using a 3D-CRT technique. The 3D-CRT plans used mostly 4-fields (except one case of 5-fields) with 15 MV photon beams, and the beams arranged to maximally avoid left and/or right kidneys, while keeping sufficient dose coverage to PTV. Dynamic wedges were used for dose inhomogeneity compensation in cases of oblique beam arrangements. Both VMAT and 3D-CRT plans were planned using the Eclipse treatment planning system v.10 for delivery on a Varian Clinac iX/Trilogy linear accelerators (Varian Medical System, Palo Alto, CA, USA). The prescription dose was 4500 cGy in 25 fractions for all cases. The VMAT optimization objectives were designed to achieve maximal sparing to organs at risks, including left and right kidneys, liver and spinal canal with very strong weighting on both left and right kidneys, while ensuring sufficient dose coverage to CTV and PTV. Double arcs of two full rotations (one from 181° to 179°, and the other from 179° to 181°) with 6 MV photon beams were used for all VMAT plans. The PTV volume of these patients was 736 ± 213 cm³. The VMAT plans were normalized such that 99.5% PTV volume is covered by at least 95% of prescription dose (i.e. D99.5% =4275 cGy).

The plan evaluation comparisons between VMAT and 3D-CRT are shown in Table 1. From these results we show that, with our planning objectives, VMAT plans can achieve significantly better dose sparing to both kidneys and liver with lower V20 Gy and/or V30 Gy, lower max spinal canal dose, and better dose conformity to PTV than 3D-CRT plans.

<table>
<thead>
<tr>
<th>Volume</th>
<th>Dose parameter</th>
<th>3D-CRT</th>
<th>VMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTV</td>
<td>99.5% (cGy)</td>
<td>4379±38</td>
<td>4492±29</td>
</tr>
<tr>
<td>Mean dose (cGy)</td>
<td>4545±19</td>
<td>4595±21</td>
<td></td>
</tr>
<tr>
<td>PTV</td>
<td>99.5% (cGy)</td>
<td>4212±22</td>
<td>4275±0</td>
</tr>
<tr>
<td>Mean dose (cGy)</td>
<td>4518±23</td>
<td>4568±19</td>
<td></td>
</tr>
<tr>
<td><strong>Conformity number</strong></td>
<td>0.72±0.04</td>
<td>0.91±0.02</td>
<td></td>
</tr>
<tr>
<td>Right-Kidney</td>
<td>V20Gy</td>
<td>32.4±20.6%</td>
<td>7.7±7.8%</td>
</tr>
<tr>
<td>Mean dose (Gy)</td>
<td>15.1±7.1</td>
<td>10.9±3.1</td>
<td></td>
</tr>
<tr>
<td>Left-Kidney</td>
<td>V20Gy</td>
<td>23.2±9.4%</td>
<td>10.2±5.5%</td>
</tr>
<tr>
<td>Mean dose (Gy)</td>
<td>12.3±3.4</td>
<td>11.6±2.6</td>
<td></td>
</tr>
<tr>
<td>Liver</td>
<td>V30Gy</td>
<td>11.2±10.2%</td>
<td>8.3±7.5%</td>
</tr>
<tr>
<td>Mean dose (Gy)</td>
<td>28.9±14.6%</td>
<td>21.5±13.5%</td>
<td></td>
</tr>
<tr>
<td>Spinal canal</td>
<td>Max dose (Gy)</td>
<td>33.1±6.3</td>
<td>27.7±7.4</td>
</tr>
<tr>
<td>Mean dose (Gy)</td>
<td>12.2±5.0</td>
<td>11.5±2.4</td>
<td></td>
</tr>
</tbody>
</table>

* D99.5% means the minimum dose that covers 99.5% of the volume.

** Conformity number was calculated as the ratio between PTV and the 95% iso-dose volume.

*** V20 Gy means the fraction of the specified volume that receives at least 20 Gy of dose.

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PS04.067 - Application of ExacTrack BrainLab system for Choroidal melanoma treatments using Stereotactic Radiotherapy and a not invasive immobilization system

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Ocular melanoma is an aggressive skin cancer with metastatic behavior that can lead to death1. External beam radiation therapy is an option to treat medium size lesions (2.5 - 10 mm) not eligible for brachytherapy (tumors close to the optical disk)2.

The best results are only achieved if the position of the patient’s eye during the computed tomography simulation (CT) can be reproduced during delivery of the radiation dose3. Jaywant et. al4 developed an elaborated system for treatment of ocular melanomas, comprising of an attachment systems, miniature camera, light emitting diode (LED) and image processing software. Although a high degree of sophistication, these systems are possibly associated with a high cost. In this regard, we describe an alternative methodology to provide a low cost system that enables correct positioning and fixation of the eye.

Patients were immobilized with BrainLAB's frameless thermoplastic mask. Eye movement was monitored with a camera mounted on a free end of a plastic rod, and the other end was rigidly fixed in the mask. A cavity in the mask was performed at the level of the treated eye, so the images could be viewed from outside the treatment.
and CT rooms. To fix the patient’s eye, we used a LED, next to the camera, and the patient was instructed to keep their eyes fixed on the bright spot to keep the eyeball static during the CT scans and the treatment delivery. The planning was carried out using a dose prescription of 50 Gy over 5 fractions, usually with 9 radiation fields.

References


PS04.068 - Dosimetric evaluation of deliverable and navigated Pareto optimal plans generated with Multi-Criteria Optimization

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Multi-Criteria Optimization (MCO) is an optimization technique providing decision makers (radio-oncologist and medical physicist) with a wide range of clinical choices. It can help unfold the trade-offs involved in the treatment planning problem. MCO generates a set of fluence based Pareto optimal plans, for which no criterion can be improved without deteriorating another. This allows for continuous real time navigation among these optimal solutions. The solution selected by decision makers in the navigation step is converted to a deliverable dose distribution after a second optimization step, which includes direct machine parameter optimization and a final dose calculation. As a consequence, the final deliverable plan might not represent the clinical choices made during the navigation. The purpose of our study was to address this concern by exploring the dosimetric differences between navigated and deliverable plans.

Navigated and deliverable VMAT plans for five prostate and five lung cancer cases were created with RayStation TPS (RaySearch AB, Stockholm, Sweden). Two-dimensional Pareto fronts were created, representing the trade-off between PTV under-dosage vs. healthy tissue sparing. PTV under-dosage was evaluated through the volume of PTV receiving less than 95% of the prescribed dose, while healthy tissue sparing was evaluated through the volume of PTV receiving more than 95% of the prescribed dose.

The Pareto front evaluation (see examples in Fig. 1) demonstrated a disagreement for the trade-off parameters between navigated and final deliverable plans for eight of our ten cases. For two prostate cases the deliverable Pareto fronts were improved compared to the navigated ones. For the other prostate cases the disagreement proved more random. In all lung cases, the deliverable plans deteriorated compared to the navigated ones, i.e. the PTV under-dosage increased (up to 17%). Our results show that the final deliverable plan quality may be substantially different than that of the navigated plan selected by clinical decision makers, particularly for small target volumes in lung.

Real time navigation on a wide range of treatment plans offer more and potentially better options during clinical decision making. However, dosimetric differences between navigated and deliverable plans due to the two-step approach may limit the practical use of MCO.

Expert interrogation (EI) remains the ‘gold-standard’ in many medical applications, excelling at identifying occult abnormality and disease, particularly under threshold conditions where noise dominates a region of interest. Sophisticated regularity metrics have only been developed to help clinicians identify threshold structural changes in 1D data streams, e.g. approximate entropy ($\text{ApEn}_1$) for physiological monitoring. This in the knowledge that the order in which the data appears, not just its variability, can indicate clinically significant perturbations [1].

Today, very large image data streams almost intractable to EI are commonplace. 3D data volumes are fast becoming 4D with the proliferation of dynamic scanning in both diagnostic and therapeutic imaging settings c.f. X-ray fan-beam and cone-beam CT (FB/CBCT). Hitherto, the ApEn$_1$ algorithm has not been formally developed for routine use with higher dimensional data, though iterated deploy-ment of 1D calculation [2] and promising pilot work towards an approach for differentiating cell and clinical images has been reported by the authors [3, 4].

The purpose of this work is to show that it is feasible to rapidly compute a statistical measure of pattern regularity associated with all image points and their immediate surroundings, which is self-calibrating to represent simplistic through to random structural content. This is a first step towards understanding EI ‘threshold working’ in medical imaging in general, and manual radiotherapy structure delineation in particular, from an evidence based viewpoint with an associated single metric.

This paper formally presents approximate entropy algorithms in 2D and 3D forms ($\text{ApEn}_2$/$\text{ApEn}_3$) for imaging. The concept of spatial divergence in the context of considering nearest neighbour pixel lattices is introduced as fundamental to the development of these algorithms. Observations of the mechanics of EI during interactive image interrogation are also shown to be consistent with this approach.

Pilot software to calculate ApEn$_1$ for 3D image data was written using the scientific programming language IDL (ITT VIS, Boulder, CO). The time taken to compute ApEn$_1$ for each of the 512×512 voxels in a single CT slice image was approximately 3 minutes using a PC with 3GHz CPU (note that the calculation operates in 3D, hence a
block of adjacent slices is processed to compute ApEn values for the block’s central slice. Optimised recoding in C reduces this to 10 seconds, making on-line use feasible. Still faster implementation using an Intel Xeon Phi card’s MIC architecture is current work in progress.

For illustration the new ApEn2D/3D algorithms are applied to FBCT progress. Using an Intel Xeon Phi card’s MIC architecture is current work in progress in 10 seconds, making on-line use feasible. Still faster implementation using an Intel Xeon Phi card’s MIC architecture is current work in progress.

Still faster implementation block of adjacent slices is processed to compute ApEn values for the block’s central slice. Optimised recoding in C reduces this to 10 seconds, making on-line use feasible. Still faster implementation using an Intel Xeon Phi card’s MIC architecture is current work in progress.

The CAX calculated doses at depths of 6 mm and 12.3 mm differed for the non-water material of the phantoms.

The CAX calculated doses at depths of 6 mm and 12.3 mm differed for the non-water material of the phantoms.

The difference in dose statistics accumulated over 5 fractions for each of the three image sets is shown in Figure 2. For this particular disease presentation, the effect on dose difference is significant. When comparing the equivalent ones measured using film by 8-16%. The difference in dose statistics accumulated over 5 fractions for each of the three image sets is shown in Figure 2. For this particular disease presentation, the effect on dose difference is significant. When comparing the equivalent ones measured using film by 8-16%. The difference in dose statistics accumulated over 5 fractions for each of the three image sets is shown in Figure 2. For this particular disease presentation, the effect on dose difference is significant. When comparing the equivalent ones measured using film by 8-16%. The difference in dose statistics accumulated over 5 fractions for each of the three image sets is shown in Figure 2. For this particular disease presentation, the effect on dose difference is significant. When comparing the equivalent ones measured using film by 8-16%. The difference in dose statistics accumulated over 5 fractions for each of the three image sets is shown in Figure 2. For this particular disease presentation, the effect on dose difference is significant. When comparing the equivalent ones measured using film by 8-16%. The difference in dose statistics accumulated over 5 fractions for each of the three image sets is shown in Figure 2. For this particular disease presentation, the effect on dose difference is significant. When comparing the equivalent ones measured using film by 8-16%. The difference in dose statistics accumulated over 5 fractions for each of the three image sets is shown in Figure 2. For this particular disease presentation, the effect on dose difference is significant. When comparing the equivalent ones measured using film by 8-16%. The difference in dose statistics accumulated over 5 fractions for each of the three image sets is shown in Figure 2. For this particular disease presentation, the effect on dose difference is significant. When comparing the equivalent ones measured using film by 8-16%. The difference in dose statistics accumulated over 5 fractions for each of the three image sets is shown in Figure 2. For this particular disease presentation, the effect on dose difference is significant. When comparing the equivalent ones measured using film by 8-16%. The difference in dose statistics accumulated over 5 fractions for each of the three image sets is shown in Figure 2. For this particular disease presentation, the effect on dose difference is significant. When comparing the equivalent ones measured using film by 8-16%.
ABSTRACTS | IUPESM 2015 WORLD CONGRESS ON MEDICAL PHYSICS & BIOMEDICAL ENGINEERING

Vmat with Partial Arc (PA) or static 3D Conformal Radiation Therapy treatment for locally advanced lung tumors.

MATERIALS AND METHOD

3D CRT and Vmat planning were done applying the 3A algorithm and the Vmat optimization module implemented on Eclipse workstations (v. 11 from Varian).

The treatment machine consists of a Varian high energy linac Silhouette with a 120 Multileaf collimator, on-board imaging (OBI) system including CBCT feature, IMRT and RapidArc capabilities.

Six patients with locally advanced NSCLC tumor were treated either by using 3D Conformal Radiation Therapy or Vmat (RapidArc) technique. Dose to Organs At Risk (OARs); such as the spinal cord, heart, esophagus, brachial plexus and lung were determined by performing and optimizing a 3D CRT plan and compared to those obtained with VMAT plans (FA Vmat and PA Vmat). All the Vmat plans were generated using the same dose constraints and planning objectives compiled from a systematic literature.

RESULTS

The VMAT plans delivered a significantly lower dose to the spinal cord, to brachial plexus, to lung and heart than do the 3D CRT plans. In addition, they show more optimal PTV coverage with better Conformity Index (CI) and more homogenous dose in the target. In contrast, the 3D CRT plans are obviously more efficient in dose delivery and the volumes of low dose are less important than those generated with Vmat plans.

The results demonstrate that using VMAT instead of static 3D CRT offers improvements in OARs sparing without detriment to PTV coverage. While both methods can result in conformal plans, the VMAT plans were found to conform more ideally to the target volume.

The PA Vmat plans show better OARs sparing and decrease of low dose to surrounding normal tissue compared to FA Vmat plans while both are leading to comparable PTV coverage, conformity and dose homogeneity.

PS04.073 - Dosimetric and clinical considerations for implementing CBCT based adaptive planning using RayStation

Author(s): Bongile Mzenda, Rochelle Hiscock, Angela Wells

Auckland Radiation Oncology, Auckland/NEW ZEALAND

Introduction

This study reports on the implementation of a CBCT (Elekta XVI) adaptive replanning technique for pelvis, chest and H&N treatments at our centre.

Method

Density tables for use in replanning were compared between the bulk density correction method for the RayStation TPS (Fig1a) and user-defined density tables derived from Catphan and Gammex 467 phantoms (Fig1b). These were applied to Rando phantom plans as well as patients having no contour changes to determine their dosimetric accuracy.
For XVI adaptive planning additional presets were created for sufficient image quality and patient field of view. In the clinical implementation for 10 patients who required replanning as a result of weight changes the CBCT method was compared to the repeat CT planning. Contouring was performed on both the repeat CTs and the CBCT images by the Radiation Oncologists and new plans generated. Contour comparisons of the CBCT generated volumes against the CT volumes were performed. Plan dosimetric metrics reviews and quantitative checks of gamma indices for phantom and real test patients. Good agreement was seen in the comparison between the plan metrics from repeat CT and computations on the CBCT datasets.

Results
For the pelvis region the bulk density method was found to be more consistent and accurate in real patients than the user-defined density table which gave higher discrepancy for the Rando phantom. For H&N and chest/thorax region the user defined density table consistently resulted in closer dosimetric agreement to the expected for phantom and real test patients. Good agreement was seen in the comparison between the plan metrics from repeat CT and computations on the CBCT datasets.

Conclusion
The implementation of CBCT plan adaptation for efficient clinical workflows requires critical assessment of the uncertainties due to imaging, density corrections and contour propagation on the resulting treatment plans.

PS04.074 - A Statistical Study based on comparison between two treatment planning systems while exporting RT structure set

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¹Department Of Radiotherapy, Delhi State Cancer Institute, Delhi/INDIA, ²Department Of Radiotherapy, Mohan Dai Oswal Hospital, Ludhiana/INDIA

Introduction: An RT structure set (RTSS) comprises of delineated target and OARs drawn on DICOM images by radiation oncologist. In a big radiation therapy department having many treatment planning systems (TPSs) and a huge patient load, it is a common practice to maximize the throughput by contouring on any available TPS irrespective of the TPS where actual planning is to be done. But when an RTSS is drawn on one TPS and is exported to other, volume of contoured structures gets modified. The objective of this study is to analyse such changes in volume on statistical basis in case of IMRT patients.

Material and Methods: In this study we have used two TPSs – CMS-Xio (v4.7) and Oncentra (v1.0). Thirty patients were selected from each TPS. RTSS volumes given by original TPS (on which RTSS was drawn) were recorded. After which all patient’s DICOM images along with RTSS were sent to other TPS. Then, RTSS volumes given by new TPS were also noted down. These volumes were categorized organ wise. Thereafter, these original volumes and altered volumes were compared on the basis of percentage variation analyses. Moreover, range, measure of central tendency and absolute dispersion of percentage variation were determined for each category. Subsequently, scatter diagrams were plotted for each of the category, keeping originally drawn volumes on X-axis and altered volumes on Y-axis. Relationship between these volumes was estimated from respective approximating curve via least square fitting. With the help of such regression curve of Y on X, value of altered volume corresponding to a given original volume can be estimated. Measure of scatter about regression curve had also been found for each category. Total variation of altered volume, including explained variation and unexplained variation was also found for each categories and hence coefficient of determination and coefficient of correlation were determined. Further, this sample correlation coefficient r was used for estimating the value of theoretical population correlation coefficient p at 95% and 99% confidence level for each category on the basis of sampling theory of correlation.

Results and Discussion: High percentage variations had been estimated for small volume structures. Contours which had been drawn originally on Oncentra and CMS-Xio were found to have altered volumes greater than and less than originally drawn volumes respectively. But a few exceptions had also been noticed for both TPSs. In most of the cases nearly perfect linear correlation between volumes had been observed, except for a few cases like lens, indicating to the fact that the total variation of altered volumes in these cases comprise of a significant part of unexplained variation. Application of sampling theory of correlation further revealed that there is no linear correlation between original (drawn on CMS-Xio) and altered volumes for optic nerve.

In summary, it may be concluded that change in volume of RT structures on export between different TPSs may or may not be significant in other disease sites but is particularly important in case of brain and head and neck patients.
The purpose of this study is to compare the dosimetry characterization of XR-RV3 to EBT2 gafchromic film and also to implement both films in order to verify the dose of radiotherapy on IMRT and VMAT. The film response of each energies (foton 6 MV, 10 MV and Cobalt-60) was measured over the dose levels from 50 cGy to 10 Gy. Each film piece was scanned using EPSON Perfection V700 flatbed scanner, 48-bit color, 75 dpi spatial resolution. The data were analyzed using FilmQA Pro for each images with ROI size 3 x 3 cm². Furthermore, the evaluation of targeted dose is determined by putting films of Gafchromic XR-RV3 and EBT2 on Rando Alderson slab phantom to simulate prostate cancer. The experiment was performed with Varian Clinac Trilogy, Inc. Two cases of IMRT and VMAT plans were made using Eclipse TPS ver. 10. Exposed Gafchromic films were scanned using Epson Perfection V700 into (.TIF) format in 720dpi and RGB 48 bit was analyzed by using in-house algorithm and FilmQA pro. The comparison between EBT2 and XR-RV3 Gafchromic films were used to obtain average dose in the form of histogram curve. From this study, the result revealed that there was no significant difference in characteristics response between XR-RV3 and EBT2 films with standard deviation of ±3%. The energy dependence of XR-RV3 and EBT2 film was found to be relatively small within measurement uncertainties ±1%. The dependence of XR-RV3 film side orientation is negligibly small with the standard deviation of 0.2. On the other hand, the percentage of errors in the case of verification of prostate cancer toward the planned dose were -4.85% in EBT2 Gafchromic films and -1.94% in the XR-RV3 Gafchromic films on IMRT technique, whereas for VMAT were -4.48% on EBT2 Gafchromic films and -7.47% on XR-RV3 Gafchromic films.

**Cancer dosimetry calculation by the use of different film and CBCT images**

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The comprehensive registration factors (CRF) was defined as follows, while the CRF values 100 meant all specific structures registered 100%.

\[
CRF = \frac{E_{\text{GTV}} \times E_{\text{D}} \times (1 - D_{\text{GTV}} \times w_{\text{GTV}} + \sum_{i} (D_{\text{DTR}} \times w_{i}))}{E_{\text{GTV}} \times E_{\text{D}} \times (1 - D_{\text{GTV}} \times w_{\text{GTV}})}
\]

**Results:** For the tested lung cases, the bony registration had less accuracy in almost all evaluated specifications, especially when registered the target only. The coverage ratio of PTV1 to GTV1 of bony and gray registration in the three groups of registering target only, ipsilateral structure, body were 66%±35% and 97%±8% (P=0.005), 98%±5% and 99%±2% (P=0.034), 98%±4% and 98%±4% (P=0.478), respectively. Using gray registration to register the ipsilateral structure had the best result, with the DSC of GTV and OARs of 0.86±0.10 (GTV), 0.71±0.10 (Esophagus), 0.76±0.10 (Spinal cord), 0.89±0.05 (Heart), and the deviation of GTV center of 2.5mm±1.6mm, while the CRF was 55.28±40.59.

**Conclusions:** CBCT guided positioning is able to ensure that the GTV covered by PTV, which is the first goal of IGRT, when suitable image registration strategy is applied. Using gray registration and registering the ipsilateral structure is recommend for CBCT guided lung cancer radiation treatment positioning. The weighted comprehensive scoring is helpful for evaluating the image registration of IGRT.
PS04.078 - Dosimetric comparison between RAPIDARC and 3DCRT planning in extremity soft tissue sarcoma

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**Introduction:** Soft-tissue sarcomas presenting in extremities are usually treated with neo-adjuvant radiation therapy prior to limb-preserving surgery. These sites often present with large planning target volumes (PTVs) that are challenging to treat as they can envelop weight-bearing bone (e.g. femur). Limiting the dose to bone and skin reduces the risk of fracture and lymphedema or delayed post-surgery wound healing, respectively, but is difficult to achieve using traditional 3-D conformal radiation therapy (3D-CRT). The purpose of our work was to investigate the ability of RAPIDARC volumetric modulated arc therapy (VMAT) to improve coverage and spare organs at risk (OARs) compared to 3D-CRT plans, and to assess the sensitivity of VMAT plan quality to arc parameters.

**Materials and Methods:** VMAT plans were generated for five patients with extremity soft tissue sarcoma. The PTV average longitudinal length was 20.6 ± 6.8 cm with a range of 10.1–30.8 cm. The sites were planned using two partial arcs designed to avoid irradiation through the contralateral extremity or the rest of the body. Complimentary collimator angles (e.g. 30°/330°) were used to maximize optimization flexibility. Patients with PTV longitudinal length >20 cm were planned using a four-arc technique to avoid large segments of open fields. First, the original two arcs were duplicated. Then, the size of each field was decreased to a maximum of 20 cm such that the PTV was partially covered by two arcs overlapping near the middle of the PTV for each collimator angle. We assessed the sensitivity of VMAT plan quality to collimator angles by generating alternate plans with varying collimator angles from (0°/0°) to (90°/270°) in increments of 15°. A standard prescription of 50 Gy in 25 fractions was used for every plan.

Plan quality was assessed using objectives from the SRC-6 protocol: namely, CTV V95%Rx = 100%, PTV V100%Rx > 95%, V100%Rx < 10%, infeld-skin and longitudinal skin strip V20Gy < 50%, and in-field bone V50Gy < 50%.

**Results:** The generated VMAT plans satisfied all planning objectives for each patient. When renormalized to offer similar coverage, the VMAT plans outperformed the clinical 3D-CRT in dose homogeneity and OAR sparing. On average, PTV V95%Rx was 5% ± 5% higher in VMAT plans than in 3D-CRT plans. While bone V50Gy was only 3% ± 1% lower in VMAT plans compared to 3D-CRT, VMAT offered much superior skin sparing by 10% ± 16% for total skin V20Gy and 59% ± 11% for skin strip V20Gy, respectively.

VMAT planning was insensitive to collimator variation, as metrics showed variations of <1% for coverage and ±3% for OARs except for the extreme (0°/0° or 90°/270°) cases.

**Conclusions:** A VMAT planning method was devised and validated for the treatment of extremity soft-tissue sarcoma. Collimator angle had minimal impact on the quality of the plan. Long (>20 cm) PTV volumes were successfully planned using a four-arc single-isocentre technique. VMAT plans were able to spare more of the circumference of the skin compared to 3D-CRT.
cerebral function. Paired T test was used to compare the cerebral functional alterations and neurocognitive tests scores before and after intensity-modulated radiation therapy in NPC patients while independent T test was used to compare the alterations between patients and controls before intensity-modulated radiation therapy. Significance was set at P=0.05, corrected by AlphaSim program.

Results: Compared with the patients before and after RT, decreased ALFF were observed in right cerebellum including temporal gyrus, limbic lobe, hippocampal gyrus, fusiform gyrus, inferior frontal gyrus and cerebellum while increased ALFF in left cerebellum including occipital gyrus, middle temporal gyrus, fusiform gyrus, both sides medial and superior frontal gyrus. However, these brain regions were not observed significant changes when compared with the normal controls before RT. There was no significant results of neurocognitive tests scores.

Conclusions: Our findings firstly demonstrated that the function of cerebellum, temporal gyrus, hippocampal gyrus, occipital gyrus and frontal gyri were altered right after the RT, suggesting the function of cerebrum is sensitive to RT which could explain the cognitive deficits in NPC patients after RT. Thus, efforts should be made to protect the cerebral function by reduce the radiation dose and irradiated volume of functional regions without compromising the coverage of target volume. There were no significant results of cognitive tests may be due to the observe time was too short after RT, long-term follow-up would be needed. Our study also proposed that functional MRI could be used as a potential method to monitor the effect of RT on cerebral function.


Purpose: A study of VMAT portal dose acquisition based on comparison of patient specific QA of clinical VMAT plan with Varian Portal Dosimetry and Monte Carlo simulation using BEAMnrc is performed.

Methods: In our study, 29 cases of VMAT plan for patient specific QA are verified by Varian Portal Dosimetry. For this verification, treatment planning system (Eclipse) calculates the portal dose predicted image for each case and to be compared with the image produced by portal imager. To evaluate the result of verifications for every VMAT plan, gamma analysis of 95%(3%/3mm) is used as produced by portal imager. To evaluate the result of verifications, QA are verified by Varian Portal Dosimetry. For this verification, comparison of measurement and simulation will be presented in the Monte Carlo simulation. The result for using the bolus, in the BNCT studies for oropharynx and hypopharynx. The estimation was performed not only for the merits of thermal neutron distribution, tumor dose rate etc., but also for the demerits in the increase of the mucosal and skin dose rates, etc..

Results and Discussion: For one of the BNCT studies, it was confirmed that the dose rate was increased almost at 15% near the tumor part by mounting the bolus on the neck. In the while, the mucosal dose rate was increased almost at 15% and the skin dose rate was increased almost at 50%. The reason for the increase of the mucosal dose rate in the same level for the tumor dose rate is that the tumor and the mucosa are contiguous in this study. For the increase of the skin dose rate, the increase of 50% is acceptable because the mucosal peak dose is set to the tolerant dose for the criteria in this study. It is resulted that the irradiation time is shortened by 87%.

Conclusion: The effectiveness of this method using bolus was confirmed for some of the BNCT studies for head and neck tumors which are carried out at KUR-HWNIF. It is planned to confirm for the other BNCT studies, in order to find the proper condition that the effectiveness of this method can be effectively used.
Conclusions

The implementation of the peripheral neutron dose calculation script in Pinnacle³ TPS has shown as an appropriate tool for peripheral neutron dose calculations. It is able to estimate peripheral neutron doses by terms of patient parameters and thus give an idea of peripheral neutron doses when choosing patient treatment strategy.

References


PS04.083 - Dual Energy X-ray Stereoscopic Image Guidance for Spine SBRT

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Image guidance is a key requirement for stereotactic body radiation therapy (SBRT) of spine to achieve a high accuracy in target positioning. Although cone beam computed tomography (CBCT) maybe used to acquire 3 dimensional volumetric imaging for target positioning, its acquisition is slow and it requires treatment interruption. Therefore, stereoscopic image guidance may be used which offers a faster image acquisition, finer resolution, and lower dose than CBCT. However, since stereoscopic imaging is based on projection imaging, soft tissue overlap on vertebral body may compromise its utility for spine SBRT, especially in large patients. The objective of this work is to investigate the feasibility of dual energy stereoscopic imaging to remove "anatomical noise" and create bone-only images for spine SBRT. An ExacTrac stereoscopic imaging system on a clinical linac was used to image an anthropomorphic Rando phantom with a 2.5 cm sphere (soft-tissue-equivalent) implanted in its lung (Figure 1). Tube voltage for low-energy and high-energy were chosen in the ranges of 40–80 kVp and 90–140 kVp respectively. A corresponding mAs was chosen in 6.3–63 range for each kVp to acquire high quality images without saturating the detectors. Weighting factors for log subtraction were chosen by trial and error. Imaging dose at isocenter from one X-ray tube was also measured for each available kVp using a calibrated dosimeter. Preliminary results showed that the best bone-only image could be obtained using a combination of 80 kVp and 140 kVp energies with a corresponding weighting factor of 3.4 (Figure 2). The corresponding dose
for 80 and 140 kVp were 8.61 and 27.07 microGy/mAs respectively. Our results demonstrate the feasibility of dual energy stereoscopic imaging to create bone-only images that could be applied to spine SBRT. An optimal dose allowance between the low-energy and high-energy images needs to be established.

PS04.084 - Comparison between our EPID-IMRT-QA tool and commercial phantom based QA tools
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Purpose: Different commercial solutions have been developed to take the increasing complexity of IMRT treatment plans into account and to provide a good relation between delivery errors of the calculated plans and the measured parameters. In our clinic we developed an IMRT quality assurance dosimetry tool based on the EPID attached to our LINACs. We compared the efficiency and accuracy of the patient specific plan QA between our EPID QA tool and two phantom-based commercial IMRT QA solutions.

Material and Methods: Elekta Synergy LINACs with 6 MV, 10 MV and 18 MV photons with an Agility MLC were used to perform the measurements. The EPID attached to these LINACs is the iView-GT™ being the standard aSi-EPID with 1024 x 1024 pixels of size 0.4 x 0.4 mm². This corresponds to a pixel size of 0.25 x 0.25 mm² in the plane of the isocenter. For the calculation of the dose distribution we used Pinnacle 9.8. Processing of the EPID measurement signals was done in-house developed software based on MATLAB (MathWorks Inc.). For the calibration of the EPID measurement grey scale values to dose, we use the quotient of the output in water in 5cm depth to the EPID signal, free in air, for quadratic homogeneous fields. For the Gamma Analysis we used Verisoft 6.0 and compared the calculated planar dose distributions to the EPID measurements. Reference values were achieved with the ionization chamber array OCTAVIUS Detector 729 by PTW, which has 27 x 27 ionization chambers with a size of (0.5 cm)³ and a distance center-to-center of 1.0 cm. To test our procedure we also measured exemplary fields with intentionally introduced errors.

The phantom based QA tools were the ArcCheck by SunNuclear and OCTAVIUS 4D by PTW. Phantom QA data were evaluated following our standard clinical protocol.

Results: The plan evaluation of our QA tool showed good agreement with the dose distribution calculated by the planning system and the one measured with the ionization chamber array. Due to the high resolution of the pixel array, the stricter 2%/2mm gamma criterion could be used for comparison of the EPID measurement data and the calculated planar dose distributions. The 2%/2mm gamma evaluation with the reference values achieved with the OCTAVIUS Detector 729 turned out to be not meaningful due to the low resolution of the chamber array. The outcome of the ArcCheck QA showed good accordance with those of the EPID QA with both the 3%/3mm and the 2%/2mm gamma evaluation. The analysis of the OCTAVIUS 4D, restricted to the 3%/3mm criterion also showed comparable results. All systems were able to detect the intentionally introduced errors in dependence of the magnitude of the alterations.

Conclusion: We developed an EPID QA tool suitable for efficient step-and-shoot IMRT plan QA. The comparison with the commercial systems showed good agreement. As we can use the advantage of the high spatial resolution of the EPID, our QA tool provides a benefit particularly for the analysis of highly modulated IMRT plans.

PS04.085 - Dosimetric assessment of a novel metal artifact reduction tool (iMAR)
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Purpose: Metal artifacts in CT images can cause relevant errors in...
Methods: The performance of the iterative Metal Artifact Reduction (iMAR) algorithm developed by Siemens Healthcare is evaluated on a test platform. A calibration phantom constituted of tissue-equivalent plastics is used to estimate the image bias from artifact correction. Patient CT data with metal implants (5 dental fillings, 1 bilateral hip) are reconstructed using the weighted filtered back projection (WFBP) and corrected using the iMAR algorithm. Radiotherapy treatment plans are calculated and compared on corrected and uncorrected images using the collapsed cone convolution (CCC) dose algorithm implemented in RayStation (RaySearch).

Results: Phantom scans show that iMAR reproduces HU for tissue equivalent substitutes in 3.6 cm² circular ROIs within ± 25 HU. The effect of this HU difference on megavoltage photon dose calculation is shown to be within ±1 % dose error. Comparing patient plans from corrected and uncorrected images, dose differences of up to 5 % are discovered in PTV and OARs, depending on the treatment site.

Conclusion: The iMAR algorithm shows good performance in correcting metal artifacts in the context of radiotherapy. The technique reduces dose errors significantly while keeping calculated doses in the surrounding tissues within a clinically acceptable level in comparison to ground truth. Future work could aim at the improvement of benchmark methods for a clinical environment (e.g., the development of a specific test phantom).

PS04.086 - An Image quality and dose comparison between Varian OBI and Elekta XVI CBCT systems.

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Purpose: As image-guided radiotherapy (IGRT) becomes common practice in radiation treatment, its overall quality and performance, such as image quality and amount of dose delivered, need to be assessed. In this study, we investigated the image quality and dose of cone-beam computed tomography (CBCT) of two imaging systems commonly used in radiotherapy: Varian On-Board Imager (OBI) and Elekta X-ray Volumetric Imager (XVI).

Materials and Methods: Our investigation involved two units of Varian OBI and two units of Elekta XVI. For CBCT imaging quality, several quality tests were performed, including high contrast resolution, Hounsfield Unit (HU) accuracy, low contrast sensitivity, and image uniformity. All imaging tests were carried out using a Catphan 500 phantom (model: CTP 504) and current clinical imaging protocols provided with both systems. The reconstructed images were analyzed using Osirix software v.5.8.2. The CBCT dose was estimated using standard CT dose index (CTDI). CTDI was measured by using a head and a body phantom, in which a 3 cm³ ion chamber was inserted. Measurements were taken under several imaging protocols.

Results: Regarding CBCT image quality, OBI revealed better high contrast resolution and HU accuracy when using head and pelvis protocols. CBCT dose measurements demonstrated that the XVI used lower doses for both head and body protocols than OBI did, which explained the observed differences in image quality. For the standard-dose head protocol, for example, OBI (#1) delivered 5.74 mGy, while XVI (#1) used 0.93 mGy dose for the same protocol. In addition, the head protocols in both systems delivered lower doses compared to body protocols to minimize the exposure of superficial organs located at the anterior part of the head to the radiation.

This is because both systems used a half-rotation scan for head and neck protocols (200°). In head and neck protocols of the OBI units, the anterior part of the head received only one-quarter of the maximum dose measured (posterior region), while for the XVI units, the ratio was one-third.

Conclusions: The Varian OBI and Elekta XVI were evaluated by performing image quality and dose measurements for four clinical protocols: head and neck, pelvis, prostate, and thorax. Based on the results, both systems are suitable for performing image-guided radiotherapy on a regular basis.

PS04.087 - An open-source treatment planning system for research in particle therapy: Implementation and dosimetric evaluation

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The number of particle therapy centers substantially increased during recent years, yet it remains a very costly technique in terms of both facility and equipment. Commercial Treatment Planning Systems (TPS) are no exception and are often unaffordable for research groups. We introduce an open-source TPS aimed toward eliminating this economic barrier, and give global momentum to research in the radiotherapy community.

Our TPS is designed for passive scattering proton treatments, and is implemented based as part of the SlicerRt toolkit [1], which is an extension for the 3D Slicer medical image analysis and visualization tool [2]. It supports a large number of image types, including DICOM CT/MR/RT-images and the most widely supported image file formats. The interface was developed as a 3D Slicer Qt loadable module, and a pencil beam dose calculation engine was implemented in the open-source image computation software Plastimatch [3].

The dose calculation engine uses a differential approach for estimating Coulomb scattering along the beamlet pathway. Three different geometric approaches are used for pencil selection and summation. Computation results were compared with Monte Carlo simulations. The dose response of these algorithms show equivalent results to published literature in homogeneous conditions and better results for lateral scattering in heterogeneous media or air-gaps for the 10-250MeV energy range. These satisfying results allow a user to build accurate proton dosimetry of real, clinical cases like prostate or head & neck treatment plans. Regarding the calculation speed, our algorithms are approximately equivalent to commercial TPSs, and can calculate a dose volume for a multi-beams plan in a few minutes.

The majority of the expected, user-friendly tools available in the commercial TPSs are also included in this open-source software: definition of a plan with multiple beams; automatic creation of a collimator fitting the beam aperture to the target shape; automatic construction of a range compensator in Lucite material; energy selection to create a spread out Bragg peak; selection of target proximal and distal limits; and margin calculations. The system also includes the possibility to visualize the Digital Reconstructed Radiograph, set a dose normalization point, or even customize the geometrical description of the beam line for a determined particle therapy center, including selection of the source and collimator positions and the source size.

We put forward our open-source TPS as a concrete solution for
research groups in the particle therapy field and confide that our efforts will contribute to the worldwide application of particle therapy. This software is continually in development and regularly improved with new tools.


**PS04.089 - GMM guided automated Level Set algorithm for PET image segmentation**

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AIM. Positron Emission Tomography (PET) is nowadays one of the main imaging modalities used in oncology field. The accuracy in lesions borders identification has a key role since it may affects diagnosis, treatment planning and consequently patient outcome. Ideally, segmentation algorithm should be accurate and automatic as much as possible, avoiding to obtain user dependent contours. Many efforts have been spent facing the problem in many different ways. Level Set (LS) algorithms are a well established methods for object contouring where an initial function evolves until convergence of a predefined cost function. One of the drawback of this method is the necessity to properly set the values of parameters that weight and balance internal and external forces used to shrink or dilate the estimated boundaries until convergence. The basic idea of the present work is to develop a segmentation algorithm based on LS formulation where the best values for the weighting parameters are iteratively estimated using information from a clustering algorithm based on Gaussian Mixture Model (GMM).

**MATERIALS AND METHODS.** The proposed algorithm (LSGMM) starts with the initialization of the LS function using the segmentation performed after two iterations of the GMM based algorithm. Then the LS function is updated as indicated by the minimization of the Mumford-Shah functional. The LS parameters iteratively updated in the proposed algorithm are the ones weighting the internal and external object homogeneity and the one weighting their balance. Every 10 iterations of LS, weighting parameters are then updated on the basis of equations formulated as Gibbs functionals, using hard or fuzzy classification performed with GMM algorithm. Basically, updating equations use information derived by a clustering method to correctly tune the LS parameters. Finally, as LS method, LSGMM performs the object boundaries identification evaluating the sign of the converged LS function. The proposed method was tested on simulated data divided into three categories: homogeneous and heterogeneous lesions, and lesions with low background contrast and/ or near high uptake object that can be misinterpreted. Comparisons were performed among LSGMM, LS with manually tuned parameters, Black’s and Schaefer’s thresholding methods.

**RESULTS.** Applying LSGMM, segmentations of homogeneous and heterogeneous lesions were comparable to the ones obtained with manually tuned LS, with Dice indexes higher than 0.85 and errors in estimated volumes lower than 2% as mean value. LS parameters could increase or decrease independently in order to converge to the optimal ones. LSGMM was also able to overcome performances of Black’s and Schaefer’s algorithms.

**CONCLUSIONS.** A completely automated LS based algorithm was presented and promising results were shown. Further evaluations will be done in order to assess robustness of the method and its applicability to multimodal data.

**PS04.089 - Impact of the magnitude of MLC radiation leakage in IMRT treatment planning**

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**Purpose:** To assess the impact of the magnitude of the radiation leakage (RL) through the multileaf collimator (MLC) system on dose calculation for intensity modulated radiation therapy (IMRT) treatment planning. Previous works have demonstrated that the inclusion of RL on IMRT treatment planning is mandatory, in order to avoid dosimetric errors in treatment delivery up to 11% relative to the isocenter dose (Jin Sheng Li, Med. Phys. 2010). However, up to date there aren’t studies about the impact of MLC different values of RL that may be originated by wrong measurements or MLC deterioration.

**Material and Methods.** Different values of RL (0.1, 0.5, 1.0, 1.5 and 2%) were used to simulate in the treatment planning system (TPS) wrong measurements and/or MLC deterioration of a m3-mLC (BrainLab, Germany) with a 6 MV photon beam. The RL values were used to create TPS beam profiles, one for each RL value, in the TPS iPlan RT 4.1 (BrainLab, Germany) for dose calculation. A set of 5 IMRT patients were chosen randomly from our centre database, and a RL value of 1% was assumed to be the MLC true RL in order to set a reference beam profile. The 5 IMRT patients were re-optimized and the dose distributions were re-calculated and exported for posterior analysis by using each of the beam profiles (resulting in 4 re-optimizations per IMRT patient). After re-optimization, the monitor units (MU) were fixed and only the dose distribution was re-calculated and exported for each re-optimization by using the reference beam profile (RL=1.0%). The resulting dose distributions were compared by calculating the differences between the calculated dose distribution of the re-optimized and the referenced plans. The differences were normalized to the prescription dose that was set to 2.0 Gy/fraction. On the other hand, the dose volume histograms for each re-optimization were exported and compared by using the following metrics: dose maximum, coverage, homogeneity index and conformity index.

**Results.** The comparison of the dose distribution showed differences up to 4% using the profile with RL=2%. This difference may reflect an overall absolute dose difference of 2.4 Gy for an standard 30 fraction treatment. The spatial location of these differences were found in the normal tissue. The DVH analysis showed differences from 7 to 20% in the maximum dose to organs at risk, differences up to 2% in coverage, 25% in conformity index, and 2% in homogeneity index.

**Conclusions.** The present results suggest that an accurate measurement and/or frequently verification of TL factor is needed, since small differences (up to +/- 1%) in the RL value produce a difference up to 4% for the TPS and the MLC system used in this work. The above result may compromise the allowed uncertainty in radiation therapy of 5%.
PS04.090 - Modelling multi-leaf collimator defocusing and focal spot partial shielding for TomoTherapy and Elekta accelerators using Monte Carlo methods

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Purpose: TomoTherapy and Elekta Synergy/S/Agility accelerators include multi-leaf collimator (MLC) with defocused leaf sides with respect to the beam focal spot to minimize interleaf radiation leakage. We used Monte Carlo simulations and measurements to model MLC defocusing and quantify the impact on the dose distributions.

Materials and Methods: Monte Carlo simulations were performed with a modified version of the BEAMnrc/DOSXYZnrc codes. Measurements were done with films (EBT2), diodes (SFD) and ionization chambers (A1SL). The TomoTherapy MLC model was focused at a point located 2 mm above the target. The Elekta MLC model was rotated by 0.5 degrees around the crossplane axis and translated by 2.2 mm. Fine tuning of parameters were performed using different types of measurements such as transmission, tongue-groove and small off-axis fields.

Results: Figure 1 and Figure 2 show that tomotherapy simulations are modelling well (2%/1mm) small off-axis field and tongue-groove measurements. Figure 3 shows a similar example of tongue-groove measurements for the Elekta Synergy/S accelerator.

Conclusion: Modeling accurately MLC defocusing is important because it can have a significant impact on interleaf leakage (> 1%), field size (>0.5 mm) and off-axis small field output factors (>5%) due to partial focal spot shielding.

Figure 1 MC simulation of TomoTherapy field. The source and the geometry are static and the field contains openings of different sizes (1 leaf, 2 leaves, 3 leaves) at various angled positions. Film measurements (normalized with ionization chamber reading in the largest open section of the field) are shown in black, SFD diode measurements are shown in red and Monte Carlo simulations are shown in yellow. These measurements are used to validate the accuracy of the Monte Carlo simulation.

Figure 2 MC simulation of TomoTherapy tongue-groove measurements. The tongue-groove effect is obtained by summing the dose measured or calculated for two opposing fields, being respectively odd and even leaves opened. Film measurements (normalized with ionization chamber reading in the smallest open section of the field) are shown in black and Monte Carlo simulations are shown in yellow. The blue line and the red line are used to illustrate the impact of the Monte Carlo simulation of sub-mm changes in the MLC geometry parameters.

Figure 3 MC simulation of Elekta Synergy/S tongue-groove measurements. The tongue-groove effect is obtained by summing the dose calculated for a given set of leaf open and leaf closed. Film measurements (normalized with ionization chamber reading in the smallest open section of the field) are shown in black and Monte Carlo simulations are shown in yellow. The blue line and the red line are used to illustrate the impact of the Monte Carlo simulation of sub-mm changes in the MLC geometry parameters.

PS04.091 - Can Image-Guided Intensity Modulated Brachytherapy delivery be better than IMRT and classical brachytherapy methods for cervical cancer: A Dosimetric analysis

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Objective: To evaluate the dosimetric superiority of intensity modulated brachytherapy(IMBT) based on inverse planning simulated annealing optimization method with external beam intensity modulated...
radiotherapy optimization and brachytherapy classical optimization methods in patients of cervical carcinoma.

**Materials and Methods:** Ten patient of cervical cancer who have already undergone interstitial HDR brachytherapy with MUPIT template, were selected for this study. The target volume was drawn and the target volume was in the range of 285.49 cm$^3$ to 83.49 cm$^3$. The planning was performed in PLATO-3D-planning system for HDR In-192 interstitial brachytherapy treatment. The actual treatment was carried out according to the catheter based plan using graphical optimization and considered as “conventional brachy plan” for comparison. The target based plans were made for dose point optimization(DPO), geometric optimization(GO), Inverse planning simulated annealing (IPSA) optimization techniques. The same target and OARs were transferred to Eclipse 3D planning system for external beam intensity modulated radiotherapy (IMRT) planning. The prescription dose was 10 Gy to the target. All plans were evaluated using following dosimetric indices: volume receiving 90%(V$_{90}$), 95%(V$_{95}$), 100%(V$_{100}$), 150%(V$_{150}$) and 200%(V$_{200}$) of prescription dose and coverage index(CI), conformity index(COIN), dose non-uniformity ratio(DNR), homogeneity index (HI) and external volume index (EI) for target. For OARs, dose received by volume of 1 cm$^3$ (D$_{1cc}$), homogeneity ratio (DNR), conformity index (COIN), dose non-uniformity ratio (DNR), homogeneity index (HI) and external volume index (EI) for target. For OARs, dose received by volume of 1 cm$^3$ (D$_{1cc}$), 2 cm$^3$ (D$_{2cc}$), 5 cm$^3$ (D$_{5cc}$) and also volume received by 50% and 75% of prescription dose (V$_{50}$) and (V$_{75}$) were evaluated for both bladder and rectum. The statistical analysis was done using paired t-test and a p-value <0.05 was considered significant.

**Results:** Percentage difference was calculated with respect to conventional brachy plan optimization. The maximum difference in V$_{90}$ was 16.8%, 18.1%, and 33.6% in DPO, GO, and IPSA respectively and it was statistically significant between conventional versus IPSA (p=0.001). Maximum difference in COIN was 58.1% for IPSA (p=0.0001) with conventional plan. The differences in DNR, EI, HI between classical optimizations and inverse optimizations were significant (p<0.0001).Maximum differences for IPSA in D$_{2cc}$ was 30.7% and 33.9% and in V$_{50}$ the difference of 47.8% and 51.8% for both rectum and bladder respectively (p<0.001). In comparison between IMBT versus IMRT, the percentage difference was calculated with respect to brachy plan. The maximum difference in V95 between IMBT and IMRT plans was 20.1% and it was statistically significant (p<0.001) with IMBT. The similar difference in CI-ON was 3.8% and it was not significant. In OAR dose comparison, the maximum differences between IMBT and IMRT in V$_{90}$ and V$_{50}$ were not statistically significant for both bladder and rectum

**Conclusion:** The IPSA resulted in improved dose conformity and homogeneity and reduced dose to OAR compared to classical brachytherapy optimization techniques. It has also been observed that the conventional brachy plan resulted in improved target coverage compared to IMRT technique. But, the target dose conformity was greatly improved with IMRT. As for OAR dose, IMRT technique resulted in reduced dose as compared to conventional brachy plan. The differences between IMBT and IMRT, in terms of target dose conformity and homogeneity and dose to OAR were not statistically significant.

**Conclusion:** The IPSA resulted in improved dose conformity and homogeneity and reduced dose to OAR compared to classical brachytherapy optimization techniques. It has also been observed that the conventional brachy plan resulted in improved target coverage compared to IMRT technique. But, the target dose conformity was greatly improved with IMRT. As for OAR dose, IMRT technique resulted in reduced dose as compared to conventional brachy plan. The differences between IMBT and IMRT, in terms of target dose conformity and homogeneity and dose to OAR were not statistically significant.

**Results:** In the phantom study, the percent of volume differences were found to be 55%, 35%, 74% between FB vs MIP for GTV, OAR-1 and OAR-2 respectively. In the patient study, the percent of volume differences were found to be 38% for GTV and 74%, for the spinal cord between FB vs MIP, respectively. All dosimetric variations between FB vs Avg-iP CT based plans were found to be 10-19.2% for target and OAR for both phantom and patients studies.

**Conclusion:** The volumetric and dosimetric variations between free-breathing and MIP images for both phantom and patient targets and organs-at-risk were significant. The free-breathing CT was underestimated the volumes compared to MIP images. The effect of motion becomes important for accurate dose planning in stereotactic body radiotherapy.

**PS04.092 - Analysis on Volumetric and Dosimetric accuracy of Maximum-Intensity Projections based 4DCT for stereotactic body Radiotherapy**

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**Purpose:** To compare and evaluate volumetric and dosimetric accuracy of 4DCT for stereotactic body radiotherapy between free breathing and maximum-intensity projection (MIP) imaging.

**Method and Materials:** Three lung cancer patients who had undergone the treatment of stereotactic body radiotherapy and QUASAR respiratory motion phantom were used in this study. The Philips 85cm Big-bore brilliance 16-slice CT scanner with bellow-system was used to generate the 4DCT data sets. The planning CT was done in free breathing (FB) conditions for treatment verification purpose. The patient 4DCT was obtained and its amplitude of motion parameters was used to acquire 4DCT data of moving phantom. Each patient had 13 different 4DCT sets. All these images were imported into the 3D-RTP system. Treatment planning was made using ADAC Pinnacle 8.0 system for Synergy-S linear accelerator for both phantom and patients for conformal stereotactic body radiotherapy. The treatment planning was made such as 0%-plan, 10%-plan, 20%-plan 30%-plan 40%-plan 50%-plan 60%-plan 70%-plan 80%-plan, and 90%-plan, AvgiP-plan, MIP-plan and FB-plan for both phantom and patients for comparison.

**Results:** In the phantom study, the percent of volume differences were found to be 55%, 35%, 74% between FB vs MIP for GTV, OAR-1 and OAR-2 respectively. In the patient study, the percent of volume differences were found to be 38% for GTV and 74%, for the spinal cord between FB vs MIP, respectively. All dosimetric variations between FB vs Avg-iP CT based plans were found to be 10-19.2% for target and OAR for both phantom and patients studies.

**Conclusion:** The volumetric and dosimetric variations between free-breathing and MIP images for both phantom and patient targets and organs-at-risk were significant. The free-breathing CT was underestimated the volumes compared to MIP images. The effect of motion becomes important for accurate dose planning in stereotactic body radiotherapy.

**PS04.093 - 2D/3D registration for compensation of patient positioning error in Korea Heavy Ion Medical Accelerator Center**

**Author(s):** Min Joo Kim$^1$, Woong Cho$^2$, Won Gyun Jung$^2$, Tae-Suk Suh$^3$

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This research has proposed to develop the validation tool for compensation of patient positioning error using 2D/3D and 3D/3D image registration. For 2D/3D registration, digitally reconstructed radiography (DRR) and three-dimensional computed tomography (3D CT) image was applied. The ray casting algorithm is the most straightforward method to generate DRR. We adopted the traditional ray casting method which finds intersections of a ray with all objects, voxels of the 3D CT volume in the scene. Similarity between extracted DRR and orthogonal image was measured by using normalized mutual information method. Two orthogonal image was acquired from Cyber-knife system from anterior-posterior (AP) view and right lateral (RL) view. 3D CT and two orthogonal image of an anthropomorphic Alderson-Rando phantom has been acquired in 2D/3D registration. Also, this research could compensate the patient positioning error. Also, this research could be fundamental research step to compensate patient positioning error in first Korea heavy ion medical accelerator treatment center.
**PS04.094 - Cardiac movement in deep inspiration breath-hold for left-breast cancer radiotherapy**

**Author(s):** Seu-Ran Lee1, Min Joo Kim1, Jae-Hong Jung2, Tae-Suk Suh1

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Most of breast cancer patient has suffered from unnecessary radiation exposure to heart, lung. Low radiation dose to the heart could lead to the worsening of pre-existing cardiovascular lesions caused by radiation. The objective of this study was to determine cardiac displacement by comparing the CT data and cardiac radiation exposure levels during Deep Inspiration Breath Hold (DIBH) and free breathing (FB). Treatment planning was performed on the computed tomography (CT) datasets of 10 patients who had received lumpectomy treatments. Heart, lung and both breasts were outlined. The prescribed dose was 50 Gy divided into 28 fractions. Displacement of heart was measured by calculating the distance between center of heart and left breast. Radiation dose to heart, minimum, maximum and mean dose to heart were calculated. Mann-Whitney U test was used for the statistical analysis of each evaluation index, and significance was set at an adjusted value of ≤0.05. The DIBH technique could help to reduce the risk of radiation dose-induced cardiac toxicity because the heart moved as far as 8.98 mm from the left breast with this technique; additionally, the cardiac motion in the LR direction varied between the DIBH CT and FB CT datasets (maximum, 7.9 mm), and the DIBH technique was found to reduce the delivered dose to the heart by a maximum of 3670 cGy, compared with FB. The DIBH technique could be used in an actual treatment room for a few minutes and could effectively reduce the cardiac dose.

**PS04.095 - Dosimetric evaluation according to patient set-up errors using biophysical indices in whole breast irradiation**

**Author(s):** Seu-Ran Lee1, Min Joo Kim1, So-Hyun Park2, Ji-Yeon Park1, Min-Young Lee1, Tae-Suk Suh1

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Purpose: The dose-related effects of patient setup errors on biophysical indices were evaluated for conventional wedge (CW) and field-in-field (FIF) whole breast irradiation techniques.

**Methods:** The treatment plans for 10 patients receiving whole left breast irradiation were retrospectively selected. Radiobiological and physical effects caused by dose variations were evaluated by shifting the isocenters and gantry angles of the treatment plans. Dose-volume histograms of the planning target volume (PTV), heart, and lungs were generated, and conformity index (CI), homogeneity index (HI), tumor control probability (TCP), and normal tissue complication probability (NTCP) were determined.

**Results:** For “isocenter shift plan” with posterior direction, the D_{90} of the PTV decreased by approximately 15% and the TCP of the PTV decreased by approximately 50% for the FIF technique and by 40% for the CW; however, the NTCPs of the lungs and heart increased by about 13% and 1%, respectively, for both techniques. Increasing the gantry angle decreased the TCPs of the PTV by 24.4% (CW) and by 34% (FIF). The NTCPs for the two techniques differed by only 3%. In case of CW, the CIs and HIs were much higher than that of the FIF in all cases. It had a significant difference between two techniques (p<0.01). According to our results, however, the FIF had more sensitive response by set up errors rather than CW in bio-physical aspects.

**Conclusions:** The radiobiological-based analysis can detect significant dosimetric errors then, can provide a practical patient quality assurance method to guide the radiobiological and physical effects.

**PS04.096 - Comparison of proton boron fusion therapy with boron neutron capture therapy**

**Author(s):** Joo-Young Jung, Do-Kun Yoon, Han-Back Shin, Moo-Sub Kim, Tae-Suk Suh

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Proton boron fusion therapy (PBFT) is based on the treatment using characteristic of alpha particle. Because the PBFT is similar to the boron neutron capture therapy (BNCT) technique, the verification of feasibility of PBFT can be possible by the comparison of some performances of the BNCT. The verification and analysis were progressed by the Monte Carlo simulation code. Basically, the virtual water phantom including boron uptake region (tumor region) was simulated for the verification. The proton beam passed through the water phantom. The alpha particles were generated from reaction point between proton and boron particle. The variation of the alpha particle was observed from the percent depth dose (PDD) of proton beam. Also, the dramatic effectiveness of alpha particle by the PBFT was confirmed by the comparison. The utility of PBFT was verified using the simulation. It has sufficient worth of usage of radiation therapy.

**PS04.097 - Verification for prompt gamma ray imaging during proton boron fusion therapy: A Monte Carlo study**

**Author(s):** Han-Back Shin, Joo-Young Jung, Tae-Suk Suh, Do-Kun Yoon, Moo-Sub Kim

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Purpose: The purpose of this study is to verify the three dimensional single photon emission computed tomography (SPECT) image using prompt gamma ray originated from proton boron fusion therapy (PBFT).
Method: The imaging system during PBFT was simulated to acquire the reconstructed image of prompt gamma ray by using Monte Carlo simulation (MCNPX). We acquired the percentage depth dose (PDD) of the proton in the water phantom, energy spectrum of the prompt gamma ray and tomographic image. In order to verify the reconstructed image, the image profile and receiver operation characteristic (ROC) curve were analyzed.

Results: The PDD in the BUR shows higher efficiency than conventional proton therapy on the tumor region. The area under curve (AUC) of ROC values were acquired from results.

Conclusion: We confirmed that the prompt gamma ray image was successfully deducted, and results of quantitative image analysis show good agreement with the original pattern of the BUR.

PS04.099 - Feasibility study of flattening filter free beam for stereotactic ablative radiotherapy of localized prostate cancer patients

Methods: We reconstructed image, the image profile and receiver operation characteristic (ROC) curve were analyzed.

Results: The PDD in the BUR shows higher efficiency than conventional proton therapy on the tumor region. The area under curve (AUC) of ROC values were acquired from results.

Conclusion: We confirmed that the prompt gamma ray image was successfully deducted, and results of quantitative image analysis show good agreement with the original pattern of the BUR.

PS04.099 - The evaluation of radiobiological and physical impacts based on multi-modality images using in-house software

Methods: A software system was developed using MATLAB
PS04.100 - Comparison of Conventional 3D Static Planning and 4D Planning using Dose Warping Technique for Liver SBRT
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Currently, SBRT has been widely used to deliver highly conformal dose to target while sparing normal tissue. So, SBRT need accurate target delineation, dose calculation and motion management techniques such as breath-hold or abdominal compressor. In spite of the benefits about these techniques, there are still deformation and movement which could lead to reduce the probability for tumor control, imprecise prediction of normal tissue complication. This study aims to evaluate the dosimetric difference between four-dimensional planning using dose warping technique (4D dose) and conventional 3D static planning (3D dose) in liver stereotactic body radiotherapy (SBRT). Five patients who had previously treated liver SBRT were included in this study. The average prescription dose and the fraction size was 40 Gy and 8 Gy. Four-dimensional computed tomography (4DCT) images with 10 phases for all patients were acquired on multi–slice CT scanner (Siemens, Somatom definition). Treatment planning and delineation was done on 100% exhala-tion phase image. Target volume was generated according to the clinical protocol. The internal target volume (ITV) was defined as the sum of GTV at end exhala-tion and end inhalation phases, and a PTV was defined by adding 5mm margin to ITV. 3D dose calculation was performed using end-exhalation phase as a reference image. And then, the same planning information were copied to the other phases. 4D dose was accumulated using intensity-based deformable image registration (DIR) algorithm (Horn and Schunck optical flow) in DIRART. The target and normal organs dose were evaluated with the 4D dose and compared with those from 3D dose. The dose difference between 3D dose and 4D dose were analyzed from dose-volume histogram (DVH) and Index of achievement (IOA) which assesses how close the planned dose distribution is to be the planned one. The average difference of Dmean, Dmax, Dmin, EUD, and IOA was 0.6 %, 0.9 %, 1.6 %, 2.1 %, and 1.1 % respectively. In case 2, we could find significant difference in duodenum which located close to PTV. Although the 3D dose calculation considered the moving target coverage, significant differences of various dosimetric parameters between 4D and 3D dose were observed in normal organs. In contrast, there was no significant difference for PTV. 4D dose which can consider dosimetric effect of respiratory motion has a possibility to predict the more accurate delivered dose to target and normal organs and improve treatment accuracy.

PS04.101 - Monte Carlo Design and Simulation of a Grid–type Multi–layer Pixel Collimator for Radiotherapy: Feasibility Study
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Purpose: In order to confirm the possibility of field application of a different type collimator with a multi-leaf collimator (MLC), we constructed a grid-type multi-layer pixel collimator (GTPC) by using a Monte Carlo n-particle simulation (MCNPX).

Methods: In this research, a number of factors related to the performance of the GTPC were evaluated using simulated output data of a basic MLC model. A layer was comprised of a 1024-pixel collimator (5.0 x 5.0 mm2) which could operate individually as a grid-type collimator (32 x 32). A 30-layer collimator was constructed for a specific portal form to pass radiation through the opening and closing of each pixel cover. The radiation attenuation level and the leakage were compared between the GTPC modality simulation and MLC modeling (tungsten, 17.50 g/cm3, 5.0 x 7.0 x 160.0 mm3) currently used for a radiation field. Comparisons of the portal imaging, the lateral dose profile from a virtual water phantom, the dependence of the performance on the increase in the number of layers, the radiation intensity modulation verification, and the geometric error between the GTPC and the MLC were done using the MCNPX simulation data.

Results: From the simulation data, the intensity modulation of the GTPC showed a faster response than the MLC's (29.6%). In addition, the agreement between the doses that should be delivered to the target region was measured as 97.0%, and the GTPC system had an error below 0.01%, which is identical to that of MLC.

Conclusions: A Monte Carlo simulation of the GTPC could be useful for verification of application possibilities. Because the line artifact is caused by the grid frame and the folded cover, a lineal dose transfer type is chosen for the operation of this system. However, the result of GTPC’s performance showed that the methods of effective intensity modulation and the specific geometric beam shaping differed with the MLC modality.

PS04.102 - Feasibility study of patient alignment method using tactile array sensors
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Ideal alignment method based on the external anatomical surface of the patient could consider an entire region of interest. However, optical camera-based systems cannot blindly monitor such areas, which assesses how close the planned dose distribution is to be the planned one. The average difference of Dmean, Dmax, Dmin, EUD, and BED was decrease by 3, 1, 5, and 4% in normal liver. however, in duodenum, it was decrease by 3, 1, 5, and 4% in normal liver. In contrast, there was no significant difference between 3D dose and 4D dose were observed in normal organs. In contrast, there was no significant difference for PTV. 4D dose which can consider dosimetric effect of respiratory motion has a possibility to predict the more accurate delivered dose to target and normal organs and improve treatment accuracy.
PS04.103 - Analysis of motion-induced dose errors according to the tumor motion in helical tomotherapy

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Motion-induced dose errors caused by tumor motion, couch motion, and gantry rotation can be observed in helical tomotherapy. The purpose of this work is to analyze motion-induced dose errors according to the change of the tumor motion amplitude, period, baseline drift and phase shift. Gafchromatic EBT2TM film (Ashland Inc., Covington KY) was used to acquire the static dose to make a total dose distribution. Slightly irregular tumor motion was simulated by 10% variations in the tumor motion parameters of amplitude, period, and baseline. Large irregular tumor motion was simulated by 40% variations. In addition, in order to account for the effects of phase shift on the total dose distribution, the initial phase of a tumor motion when the beam delivery started was divided into end-inspiration, mid-expiration, end-expiration, and mid-inspiration. The total dose distribution was determined by integrating the static dose on the different part of tumor due to tumor motion and couch motion. A position versus time curve was used to analyze the cause of motion-induced dose error. The larger variation of tumor motion parameters, the larger the motion-induced dose error that was generated. The larger variation of tumor motion parameters, the larger difference of total dose distributions according to the initial phase of a tumor motion was observed. Additionally, larger difference of total dose distribution was observed in the baseline drift case than tumor motion amplitude case and period case. These motion-induced dose errors can be reduced by using abdominal compression and respiratory training. This study could help to understand the impacts of tumor motion parameters and the initial phase of a tumor motion on the total dose distribution.

PS04.104 - Drift correction techniques in the tracking of lung tumor motion

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This work compares three methods of tracking lung tumor motion using an optical flow algorithm to analyze portal images. An earlier approach used sequential image pairs (CU) to track the motion. Errors in the position of the tumor were found to accumulate when patient traces were used and two new approaches were introduced. The first method re-calibrates the position of the tumor at the end-of-exhale (EoE) of each breathing cycle. This was done by computing the position directly between the tumor and the previous reference image. The new image at the EoE is then assigned as the new reference frame, a process called reference shifting (RFSF). Between two EoE, sequential tracking was employed. The second approach derives the position of the tumor in each frame by applying the optical flow computation directly between each image and a reference image. However, since tracking is limited to a finite range (i.e. threshold), new reference images were required when the tumor exceeds a set distance from the reference position, a process called threshold shifting (THSF). Direct comparison of the position in subsequent images was made with respect to the new reference image. A 3D tumor prototype was fabricated using 3D printing techniques and seven patient traces were evaluated. Average position errors of -0.01 ± 0.65 mm, -0.10 ± 0.42 mm and -0.14 ± 0.25 were obtained for the CU, RFSF and THSF methods respectively.

PS04.105 - Application and Parametric Studies of a Sliding Window Neural Network for Respiratory Motion Predictions of Lung Cancer Patients

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In real-time adaptive image-guided radiotherapy (IGRT), the beam delivery position is changed to follow the tumor motion. Most systems cannot respond instantaneously, and compensation for system lag is required. Typically, future tumor positions are predicted based on the respiratory motion tracked from an external surrogate. In the current work, a sliding window of time series data taken from the respiratory cycle is input into a neural network to predict a future position. The finite past history of the respiratory position is used to train the model. A nonlinear autoregressive neural network with exogenous inputs was used to simultaneously predict future positions. Patient data from the Respiratory Trace Generator (RTG) [1] was used for the training, validation and testing of the model.

Parametric studies involving the number of input nodes (length of sliding window), number of hidden nodes and prediction horizon were performed. Tradeoffs between under-learning, training rate and over-learning were identified. While training error decreases as the number of hidden nodes increases, the validation error increases beyond 20 nodes. Large errors occur during transitions between inhale and exhale as well as when the prediction horizon increases.

PS04.106 - VMAT delivery through couch tops: an illustration of loss of dose coverage for prostate plans

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Introduction: Complex radiation therapy treatments are designed using computer algorithms which rely on specific dosimetric inputs. Optimization will be continued until all dosimetric criteria are met or otherwise accepted. Such optimization typically takes place on data sets that exclude the treatment couch top, yielding plans that do not reflect reality. We investigated what ignoring the couch top means dosimetrically for five full arc VMAT prostate plans.

Method: Four different couch tops were considered: iBemino evo, Sinned Mastercouch, Varian flatpanel and Varian unipanel with t-bar support. Each of the Varian couch tops was considered with support bars in and out. Plans were selected based on range in target size and planning complexity. The starting point in each case was a previously accepted clinical case planned without a couch top. Couch tops were added in succession while maintaining the original beams. Parameters characterizing the dose distribution were assessed for each combination, including our standard clinical evaluation criteria. Prescription isodose line shifts were measured on 5 slices, at 3 posterior and 1 each lateral and anterior locations.

Results: For a prescribed dose of 78 Gy, the CTV V78Gy decreased from 0.2 – 40%, while the PTV V74.1Gy decreased from 0.6 – 9%. The greatest loss of dose occurred at the 105% dose level within the CTV.

Conclusion: CTV and PTV coverage reductions observed in this
study show that introducing couch information at the planning stage would produce a different plan than without couch information. These differences significantly exceed plan objectives and assessment criteria. This implies that either the current planning goals for these techniques are overly precise, resulting in little patient benefit gain from time invested in fine tuning a plan, or that planning which includes a model of the treatment couch is required to achieve the precision of dose delivery specified by the clinician.

PS04.107 - Edge Detection for Automated Biological Tumor Volume Definition Based on FDG-PET/CT-fused Imaging: An Agar Phantom study

Author(s):

Purpose: Fused positron emission and computed tomography (PET/CT) images have an important role in external beam radiotherapy (RT), especially for target volume delineation. For contouring on PET/CT images, the source-background algorithm is currently the used method, but its sensitivity to partial volume effects may produce inaccuracies when applied on small lesions. The goal of this research was to develop a computational algorithm based on the Canny’s edge detection tool for processing PET/CT images. Materials and Methods: The software was implemented using the data analysis framework ROOT and the Grassroots DiCoM GDCM libraries (CERN, Geneva, Switzerland). First, a pre-processing Gaussian smoothing was applied to these images. Then directional derivatives and gradients were computed on the basis of multivariate analysis framework ROOT and the Grassroots DiCoM GDCM library. Canny’s edge detection tool for processing PET/CT images. Material and preliminary experience:

Dose prescription was 27Gy to in 3 fractions; all plans were equally normalized keeping OARs within dose tolerances. HybridARC plans were created using 1 arc plus 3 (HA3), 5 (HA5) and 8 (HA8) fixed IMRT fields. HybridARC plans used arc aperture optimization and IMRT inverse planning (OAR high modality). Between 60-40% of the prescribed dose was given by the arc. Treatment with dMLC used 15 fixed gantry angle beams. Treatment times, monitor units (MU), conformity index (CI), V50% and V20% was used for plans comparisons.

Results

Assuming dMLC IMRT treatment plans as reference, the treatment time was reduced by -14.6% with HA8, -8.6% with HA5 and -23% with HA3. Increasing arc dose proportion in HA (arc MU > 2000) requires 2 or more arcs which increments treatment time. Using 1000MU/min HA3 and HA5 exhibits beam hold off for fixed IMRT fields which in some cases need to be split in 2 segments. MU varied +4% with HA8, +3.7% with HA5 and -5% with HA3. CI increased +5% with HA8, +23% with HA5 and +37% with H3. V50% increased +5% with HA8, +43% with HA5 and +62% with HA3. V20% increased +13.2% with HA8, +7.6% with HA5 and +1% with HA3. OARs doses were keep within tolerances in all plans. Patient specific QA for all modalities shows more than 90% of the pixel with g<1 with 3%/3mm pass criteria and high dose threshold of 30%.

Conclusion

HybridARC using an SRS beam for spine SBRT with 8 fix IMRT gantry angles shows a treatment time reduction, comparable MU and similar dose conformation to dMLC IMRT. HybridARC with 5 or 3 fix IMRT fields produce undesirable beam hold off, worse dose conformation and increments the total volume with 50% of the prescribed dose.

PS04.108 - real time dynamic prostate brachytherapy dose calculations using permanent i125 implants: technical description and preliminary experience

Author(s):

Low dose rate (LDR) prostate brachytherapy is an accepted treatment option for low risk prostate cancer patients. However, differences in prostate spatial location, volume and gland deformation between the images acquisition and later on during the implant procedure could carry to an incorrect dosimetry. The aim of this work is reporting on our treatment technique based on interactive real-time dynamic intra-operative dose calculation and to determine dosimetry differences.

METHODS: Images from base to apex are obtained using a motorized stepper connected to the ultrasound and planning system. Physician draws the volumes Prostate, Uretra, Rectum, Bladder, and when is necessary a Boost volume. Then, we implant the periferical needles and capture them by the planning system in the true position. We finish the plan with central needles. Once definitive needle positions have been captured, dosimetry is performed intra-operatively and the physician approves the corresponding isodoses on real time. Each array of seeds are corrected in accordance with actual implanted seeds. This allows real-time intraoperative dosimetric analysis, allowing for correction of under-dosed zones during implantation in an interactive dynamic way. In this work we selected 10 plans and we compare the plans with real needles position (RNP) against the same plans without regard to needles position modifications (WRNP).

RESULTS: We began our LDR prostate brachytherapy program on
2012. We have treated 73 patients, all patients were treated with our real time dynamic intra-operative planning system. A median of 185.5Gy-165.5Gy for D90, of 53.6%-54.3% for V150, 97.2%-96.5% for V100 and 0.0% - 1.7% for Luretra V200 and 1.0cc – 1.1cc for Rectum V100. Was calculated for RNP plan and WRNP plan respectively.

CONCLUSION: Real-time intra-operative planning was successfully implemented in our Institution. It avoids the possible implant quality and dose delivery disadvantages by improving the accuracy of seed placement on real time. The main advantage is the urethral protection which is translated in lower rates of acute and chronic GU morbidity

PS04.110 - Design of a simple device for end to end test of IGRT system using ExacTrac
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Introduction
The ExacTrac system (BrainLAB) for image-guidance radiotherapy (IGRT) uses an infrared pre-positioning system and two RX oblique images for patient positioning based on bones or implanted fiducial. The accuracy of this system depends on the quality of the images, image transfer between TAC-TPS-ExacTrac, volume definition, isocenter calibration and mechanical precision of the treatment machine. Quality control of this complex network requires a phantom capable of verifying each of the stages.

The aim of this study is to design and test a simple phantom sufficient to verify end-to-end process of this IGRT using ExacTrac.

MATERIALS and METHODS
A rectangular acrylic phantom of 30 cm long, 30 cm wide and 6 cm high was designed. It has a cylindrical acrylic insert of 3 cm diameter with spherical endings in their borders, one constructed of plastic (PE) with different density and at the opposite border a lead sphere (PbE) of 2mm diameter in the center of the correspond circumference. On the surface of the phantom baseplate with infrared markers are placed for CT. CT images of 2.5mm thickness are acquired with the cylindrical inserted in the PE side. CT images are sent to the TPS (iPlan v4.5.3) where the spherical volume of PE is drawn. Considering this volume as target an anterior field is located into account the breathing movement of the patient. The verification of the accuracy of this system depends on the quality of the images, image transfer between TAC-TPS-ExacTrac, volume definition, isocenter calibration and mechanical precision of the treatment machine.

Results
Density difference between acrylic insert and PE allowed adequate delineation. The coordinate of the treatment field, based on CM of PE, match with the center of the sphere. ExacTrac X-ray images showed an overlap of the radiological isocenter with the PbE projection (error <1mm) in both treatment machines. The radiological displacement of the PbE with the center of the Linac field was less than 1mm for both machines. The duration of the end-to-end test with this device was less than 3 hours.

Conclusions
The designed phantom is economical and practical for End-to-End QA of ExacTrac IGRT system. Its construction is simple, easy positioning and its use allows a quantitative or qualitative correlation between displacement and errors obtained.

PS04.111 - Study on the use of an in-house device to consider the motion effects on absorbed dose determination and measurements using different calculation algorithms in lung SBRT cases
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One of the challenges in radiation therapy consists in the administration of treatments for tumors that are susceptible to modify their position due to the respiratory cycle, as occurs in those located in the pulmonary or abdominal areas. There are different tomography simulation devices available which take into account the movements of the patient anatomy due to respiration cycles, known as 4DCT. The 4DCT scans are used to provide accurate representations of the motion effects, through datasets such as the maximum, minimum and mean projections. These can be useful for determining the contours of lung or liver tumors, which are modified by motion, as well as those of the surrounding organs at risk and healthy tissue. Therefore, the absorbed dose delivery considering these movements is possible. Also, a reduction of the target volume margins reduces the risk of complications due to the surrounding healthy tissue irradiation.

A movable platform was built to simulate one direction movement of an anthropomorphic thorax phantom in order to perform quality assurance (QA) processes for treatment planning using 4DCT. In this work the performance of this device is examined to run some QA tests for lung stereotactic body radiation therapy, taking into account the breathing movement of the patient. The verification which compose the QA process are made in typical treatments of 50 Gy in 5 sessions using different planning systems such as: iPlan RT Dose and Eclipse, using three different algorithms for the calculation of the absorbed dose; Analytical Anisotropic Algorithm, Pencil Beam and Monte Carlo. To measure the absorbed dose a QUASARTM Multi-Purpose Body Phantom thorax is used with in-house manufactured cavities that allow the access of a SemiFlex, MicroLion and PinPoint ionization chambers. In addition, a separate set of inserts was designed to use radiochromic film sheets. The values of the absorbed dose calculated by the three algorithms are compared with the measurements obtained from the actually delivered absorbed dose on the radiation detectors. With the above, the precision of these algorithms can be quantified considering the implicit respiratory movement.
PS04.112 - In-vivo skin dose evaluation for Pd-103 permanent breast radiotherapy implants

Author(s): Ronald E. Beals¹, Elizabeth Watt², Tyler Meyer³, Jose E. Villareal-Barajas⁴
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Permanent breast seed implant (PBSI) using permanent seed LDR breast brachytherapy was pioneered in Toronto with the first procedure completed in 2004. In late 2013, our centre started a PBSI program using Pd-103 seeds. This study presents our preliminary results of the in-vivo skin dose evaluation on a cohort of six PBSI patients. All patients were forward planned using CT images where the physician defined a PTV as a 1 cm expansion of the CTV trimmed to the skin and chest wall. The implant plans were designed to cover at least 90% of the PTV by the prescribed dose of 90 Gy. The planned dose to the skin was limited to a maximum of 81 Gy. Given the limitations of the water based (TG–43) dose calculation algorithm used by the treatment planning system and its potential under-estimation of the dose to the skin, an in-vivo skin dose evaluation was performed using radiochromic dyes film dosimetry (EBT3). The EBT3 films strips used for the skin dose evaluations were positioned in contact with the skin of the patients at the central axis of the implant. The patient films dose integration period varied from 3.25 hours to 47 hours (see Table 1). These films were scanned in order to obtain their associated net optical density (net O.D.). The net O.D. was used to estimate the skin dose using a 100 kV calibration (Figure 1). The validity of the calibration was verified using two Pd-103 point doses from a well controlled EBT3 irradiation experiment. The two highest skin doses measured correlated with observed skin reactions in the corresponding patients. More research is needed to assess the clinical significance of the measured skin doses and their role in the development of an effective metric for the relevant skin dose in PBSI.

<table>
<thead>
<tr>
<th>ID</th>
<th>net O.D.</th>
<th>Exp Time/h</th>
<th>Max. dose/Gy</th>
<th>Max. Total dose/Gy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.398</td>
<td>47</td>
<td>4.720</td>
<td>62.364</td>
</tr>
<tr>
<td>2</td>
<td>0.515</td>
<td>3.27</td>
<td>0.528</td>
<td>68.808</td>
</tr>
<tr>
<td>3</td>
<td>0.623</td>
<td>5.0</td>
<td>0.324</td>
<td>30.373</td>
</tr>
<tr>
<td>4</td>
<td>0.647</td>
<td>3.0</td>
<td>0.122</td>
<td>33.836</td>
</tr>
<tr>
<td>5</td>
<td>0.695</td>
<td>3.25</td>
<td>0.275</td>
<td>33.807</td>
</tr>
<tr>
<td>6</td>
<td>0.640</td>
<td>3.25</td>
<td>0.147</td>
<td>26.706</td>
</tr>
</tbody>
</table>

Table 1. Net optical density obtained by scanning the exposed film (red channel), patient film exposure in hours, absorbed dose to water estimate for the corresponding exposure, and maximum total dose estimate obtained by integration based on the maximum dose in the patient film. The dose uncertainty in the maximum total dose column is derived from the variation (k=2) observed in the net O.D. derivation of the 5 × 5 mm² area used to score the maximum dose in the patient film.

PS04.113 - Dosimetric Variations in Permanent Breast Seed Implant (PBSI) Evaluated at Different Arm Positions using Deformable Image Registration

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Purpose: Permanent Breast Seed Implant (PBSI) is a novel method of treating early-stage breast cancer. It is a one-day, outpatient procedure in which radioactive Pd-103 seeds are surgically implanted in and around the seroma following breast-conserving surgery. The planning for PBSI is done with the patient’s ipsilateral arm raised; however, changes in implant geometry can be expected due to healing and anatomical motion as the patient resumes her daily activities. The purpose of this study is to quantify the effect of arm position on postplan dosimetry.

Methods: Thirteen patients treated at the Tom Baker Cancer Centre in Calgary, Alberta were included in this study. All of these patients underwent two post-implant CT scans on the day of implant. One scan was taken with the patient’s ipsilateral arm raised above the head, recreating the position of the planning scan, while the other was taken with both arms down beside the body in a relaxed position. Postplans on both scans were completed using MIM Symphony™ (MIM Software, Cleveland OH). The pre-implant planning scan was deformably registered to the post-implant scan to deform the seroma contour and other relevant contours to the post-implant scan. An evaluation PTV, with a 0.5 cm margin to the seroma, was generated after deformation. Statistical analysis was performed using a paired, two-tailed t-test, and an alpha value of 0.05 was used for statistical significance.

Results: A summary of the dosimetric parameters for the target volumes and nearby structures for both arm positions is shown in Table 1.

![EBT3 film calibration using a 100 kVp (35x35 mm²) orthovoltage x-ray clinical beam and two verification Pd-103 doses (2.55 and 5.35 Gy). The Pd-103 doses were evaluated based on a measured activity and using the TG-43 formalism with a Monte Carlo model to obtain the dose to water in acrylic (PMMA). The Pd-103 dose estimates derived from the measured net O.D. are within 5% of the expected doses derived using a 100 kVp x-ray beam calibration.](image-url)
Intensity Modulated Radiation Therapy (IMRT) has been used in lung cancer treatment to deliver dose distributions with steep gradients and exquisite target volume conformity. While many benefits of IMRT exist, significant challenges are involved when unpredictable intrafractional movement is combined with the highly optimized nature of IMRT. The National Cancer Institute (NCI) Guidelines for the Use of IMRT state that there is potential for significant dosimetric consequences if the target volume moves while treatment is being administered. Thus, lung IMRT is especially challenging due to breathing motion. Furthermore, tissue density differences at the lung-tumor interface contribute to disagreements between the administered and planned doses. It is believed that inhomogeneities allow for a relatively large amount of the planning target volume (PTV) to be left without coverage and the target will still receive the prescribed dose during treatment. For example, the Radiation Therapy Oncology Group (RTOG) 0617 study requires that 95% of the PTV is to be covered by 93% of the prescription dose during planning. The study assumed this planning goal was sufficient in ensuring coverage during treatment, although it is unclear if this was achieved due to target motion and the dosimetric effects of inhomogeneities.

This study aimed to establish an IMRT lung planning goal that ensures 99% of the internal target volume (ITV) is covered by 95% of the prescribed dose during treatment. Ten previously generated IMRT plans were compiled for analysis. Each plan was renormalized such that 95% of the PTV is covered by increasingly higher doses, ranging from 93 to 97% of the prescription. For each plan, multiple target movements were simulated by shifting the isocentre of the beams within a range previously measured for this patient population and recomputing the dose. Finally, the coverage of the ITV obtained during simulated treatment was established using dose-volume histograms for each planning goal. Advantage of certain planning goals versus others was established by comparing the number of simulated movements causing inadequate coverage of the ITV.

Kruskal-Wallis analysis showed that none of the studied planning goals was significantly different from another based on the number of times the ITV was not covered by 95% of the prescribed dose. In other words, the RTOG 0617 planning goal of 95% of the PTV covered by 93% of the prescription achieves the same result as the goal where 95% of the PTV is covered by 97% of the prescription. The complete data suggested that coverage failure may decrease with increasing coverage but the current study did not show the decrease was significant. We are currently applying the RTOG 0617 planning goal clinically and will repeat this analysis with additional patient data to ensure optimal delivery of lung IMRT at our institution.

### Table 1: Comparison of Dosimetric Parameters for Ipsilateral Arm Up and Down

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Arm Up</th>
<th>Arm Down</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTV [%]</td>
<td>90.7 (70.9–100.0)</td>
<td>93.9 (79.7–100.0)</td>
<td>0.08</td>
</tr>
<tr>
<td>V100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PTV [%]</td>
<td>83.7 (66.6–99.4)</td>
<td>86.0 (68.7–99.1)</td>
<td>0.17</td>
</tr>
<tr>
<td>V90</td>
<td>80.0 (60.8–97.9)</td>
<td>82.6 (65.3–98.0)</td>
<td>0.17</td>
</tr>
<tr>
<td>V100</td>
<td>58.8 (29.9–79.3)</td>
<td>61.2 (35.9–84.5)</td>
<td>0.21</td>
</tr>
<tr>
<td>V150</td>
<td>34.7 (15.9–54.5)</td>
<td>38.7 (18.9–61.5)</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>V200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin [cc]</td>
<td>1.6 (0.0–6.2)</td>
<td>1.7 (0.0–7.8)</td>
<td>0.59</td>
</tr>
<tr>
<td>V80</td>
<td>1.2 (0.0–5.2)</td>
<td>1.3 (0.0–5.4)</td>
<td>0.52</td>
</tr>
<tr>
<td>V90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lung [cc]</td>
<td>1.6 (0.0–5.2)</td>
<td>0.2 (0.0–1.4)</td>
<td>0.01</td>
</tr>
<tr>
<td>V20Gy</td>
<td>0.04 (0.00–0.30)</td>
<td>0.00 (0.00–0.02)</td>
<td>0.30</td>
</tr>
<tr>
<td>V40Gy</td>
<td>0.00</td>
<td>0.00</td>
<td>--</td>
</tr>
<tr>
<td>Heart* [cc]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V20Gy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V40Gy</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Values are mean (range).
*Only left-sided patients were analyzed for these parameters. Discussion and Conclusions: Results on thirteen patients thus far indicate that the implant becomes significantly hotter with the arm down (indicated by the increase in V200); however the increase exhibited when using a 1 cm PTV margin did not reach significance. Lung dose significantly improved in the arm down position. Change in seroma volume between the arm up and arm down scan (mean: -1.1%; range: -18.3% to 7.8%) is an influencing factor in dosimetric differences. Further investigation is necessary to also determine the effect of shape and seroma position. Seroma volume may change over time due to swelling and resolution (healing); future work will involve analysis of dosimetry on eight week post-implant CT scans to ensure that volume changes on the day 0 post-implant scan due to edema is not skewing the dosimetric results.

### PS04.115 - A modified methodology to accurately validate CT number constancy for proton therapy

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A modified methodology to accurately validate CT number constancy for proton therapy

**Purpose**

In proton therapy, the CT number is calibrated to convert proton stopping power ratio (SPR) and the calibration factor is entered into a treatment planning system. Since CT number vs. SPR is a nonlinear curve throughout the range of clinical interest, the current CT number quality assurance (QA) method is not adequate to test CT# accuracy/constancy for the entire human tissue range. We developed a method that will establish the criteria of the CT number variations which provide the desired percentage variation of the baseline values of SPR.
SPR, the corresponding CT number change can be calculated by applying the polynomial equation from each section.

Result

Table 1 illustrates the calculated CT number change as a result of +/-1% changes of SPR for each entry point. These values are used in the annual CT number QA testing to validate that each entry value is consistent with the original calibration.

Conclusion

We have established a simple and quantitative method for CT number annual constancy testing through the scanner’s entire clinical range.

<table>
<thead>
<tr>
<th>CT#</th>
<th>y</th>
<th>x</th>
<th>+1%SP</th>
<th>-1%SP</th>
<th>+/- HU</th>
<th>Measurement inserts HU</th>
<th>Derived QA HU limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1000</td>
<td>0.001</td>
<td>0.00101</td>
<td>0.00099</td>
<td>0.0</td>
<td>-681.2</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>-739</td>
<td>0.258</td>
<td>0.26058</td>
<td>0.25542</td>
<td>5.2</td>
<td>-528.1</td>
<td>13.1</td>
<td></td>
</tr>
<tr>
<td>-38.6</td>
<td>0.975</td>
<td>0.98475</td>
<td>0.96525</td>
<td>18.8</td>
<td>-79.8</td>
<td>25.3</td>
<td></td>
</tr>
<tr>
<td>-7.1</td>
<td>0.999</td>
<td>1.00899</td>
<td>0.98901</td>
<td>19.2</td>
<td>-30.1</td>
<td>26.6</td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td>1</td>
<td>1.01</td>
<td>0.99</td>
<td>14.2</td>
<td>11.2</td>
<td>27.7</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1.001</td>
<td>1.01101</td>
<td>0.99099</td>
<td>14.3</td>
<td>8.8</td>
<td>27.7</td>
<td></td>
</tr>
<tr>
<td>23.9</td>
<td>1.021</td>
<td>1.03121</td>
<td>1.01079</td>
<td>17.3</td>
<td>97.4</td>
<td>30.1</td>
<td></td>
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<tr>
<td>103.3</td>
<td>1.085</td>
<td>1.09585</td>
<td>1.07415</td>
<td>38.2</td>
<td>237.1</td>
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<tr>
<td>282.3</td>
<td>1.154</td>
<td>1.16554</td>
<td>1.14246</td>
<td>82.6</td>
<td>245.4</td>
<td>34.1</td>
<td></td>
</tr>
<tr>
<td>1365.6</td>
<td>1.707</td>
<td>1.72407</td>
<td>1.68993</td>
<td>71.3</td>
<td>1230.8</td>
<td>60.2</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Derived QA HU for each entry point from polynomial equations

PS04.116 - Development of a real-time portable applicator monitoring system for gynecologic intracavitary brachytherapy

Author(s): Christian Bauer, Reinhard Beichel, Yusung Kim, Timothy Waldron, Wenqing Sun, Sudershan Bhatia, Junyi Xia

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Purpose

To develop a real-time applicator position monitoring system (RAPS) for intracavitary brachytherapy.

Materials and Methods

Applicator displacement during brachytherapy can produce suboptimal dosimetric effects, especially in 3D image-guided brachytherapy, which requires high accuracy applicator localization. 2D X-ray imaging devices, such as C-arm, are routinely used for measuring applicator displacement, however, they deliver extra radiation dose to patients and lack the capability of continuous applicator monitoring. The RAPS was developed for continuous applicator position monitoring without any radiation dose. The RAPS consists of two custom-designed tracking targets with infrared reflective markers and a calibrated infrared stereo-camera setup. The RAPS can measure in real-time the applicator movement by computing the relative displacement between the two tracking targets, which are attached to the applicator and the patient. Both 3D printed tracking targets were custom designed for optimal tracking performance and to be easily attached to the Varian Tandem and Ovoid applicator. A phantom study was conducted to compare RAPS’ measurements with known displacements from a high accuracy positioning stage (0.03mm accuracy) in the range of +/-25 mm.

Results

The RAPS achieved 120 frames per second using a laptop with Intel Core 2 dual CPU. At a camera-to-marker distance of 50 cm, the mean difference between RAPS’ measurements and the positioning stage was 0.068 mm with a standard deviation (STD) of 0.044 mm in superior-inferior direction, 0.013 mm with a STD of 0.015 mm in lateral direction, and 0.061 mm with a STD of 0.024 mm in anterior-posterior direction.
Conclusions

This work demonstrates the feasibility of RAPS to detect applicator motion in real-time. An accuracy of 0.1mm was achieved in the phantom study.

PS04.117 - Quality Assurance of the Radiotherapy Workflow Integrating a Dedicated Wide-bore 3T MRI Simulator

Introduction: A MRI scanner dedicated for radiotherapy planning (also known as MRI simulator) was installed and integrated into our clinical workflow in June, 2013 [1]. There are international protocols regarding quality assurance of MRI for diagnostic performance [2], but there is lack of guidelines with regard to its integration in a radiotherapy workflow. The purpose of this study was to establish a QA program for quality control of an MRI-integrated radiotherapy workflow implemented in our centre.

Materials and methods: All scanning was performed on a dedicated wide bore 3.0 Tesla MRI scanner (Siemens Skyra) with radiotherapy accessories including a flat table top with integrated RF coil and external localization lasers for setting up patients at the same position as during treatment. The MRI simulator is integrated into our clinical workflow in following way: patient is first scanned on a Philip 4D CT simulator in the treatment position, and then scanned in this position on the MRI simulator which is in the next room. The CT and MRI image are sent to the treatment planning system (Pinnacle version 9.8). The MRI is initially auto-coregistered with CT images using a mutual information algorithm and then manually adjusted by the radiotherapist (RT) and oncologist. Once the MRI images are registered with CT images, the oncologists delineate the target and organs at risk on MRI images and transfer the contours to CT images. In order to provide a quality assurance of the whole workflow, a cylindrical phantom routinely used for checking laser alignment was employed. The phantom has a base for levelling the phantom and external marks for phantom setup. The QA procedure using phantom was exactly same as the patient workflow. The phantom was scanned using CT head-neck protocol and then setup on MRI by aligning its external marks with localisation lasers and scanned using bore coils and a standard SE sequence (TE=30ms, TR=3410ms). Both CT and MRI images are sent to Pinnacle for co-registration as described previously and the translation and rotation parameters were recorded. This procedure was repeated for a period of eight days.

Results and discussion: The averaged translation parameters in all three directions were less than 1.2mm, whereas the rotation is less than 0.3 degrees. Especially along z direction, on average, there is no rotation and less than 1mm translation along x direction. The standard deviation of translation and rotational parameters are less than 0.45, indicating that the MRI-integrated workflow is consistent and highly reproducible. It is recommended that the QA procedure be performed quarterly or in the event of MRI scanner maintenance and repair.

Conclusion: A phantom-based QA program for checking the consistency of MRI-integrated radiotherapy workflow was implemented in our centre. The QA procedure can be adopted by other centres.


PS04.118 - Evaluation of deformable accumulated parotid doses using different registration algorithms in adaptive head and neck radiotherapy

Introduction: The purpose of this study was to establish a QA program for quality control of an MRI-integrated radiotherapy workflow implemented in our centre.

Materials and methods: All scanning was performed on a dedicated wide bore 3.0 Tesla MRI scanner (Siemens Skyra) with radiotherapy accessories including a flat table top with integrated RF coil and external localization lasers for setting up patients at the same position as during treatment. The MRI simulator is integrated into our clinical workflow in following way: patient is first scanned on a Philip 4D CT simulator in the treatment position, and then scanned in this position on the MRI simulator which is in the next room. The CT and MRI image are sent to the treatment planning system (Pinnacle version 9.8). The MRI is initially auto-coregistered with CT images using a mutual information algorithm and then manually adjusted by the radiotherapist (RT) and oncologist. Once the MRI images are registered with CT images, the oncologists delineate the target and organs at risk on MRI images and transfer the contours to CT images. In order to provide a quality assurance of the whole workflow, a cylindrical phantom routinely used for checking laser alignment was employed. The phantom has a base for levelling the phantom and external marks for phantom setup. The QA procedure using phantom was exactly same as the patient workflow. The phantom was scanned using CT head-neck protocol and then setup on MRI by aligning its external marks with localisation lasers and scanned using bore coils and a standard SE sequence (TE=30ms, TR=3410ms). Both CT and MRI images are sent to Pinnacle for co-registration as described previously and the translation and rotation parameters were recorded. This procedure was repeated for a period of eight days.

Results and discussion: The averaged translation parameters in all three directions were less than 1.2mm, whereas the rotation is less than 0.3 degrees. Especially along z direction, on average, there is no rotation and less than 1mm translation along x direction. The standard deviation of translation and rotational parameters are less than 0.45, indicating that the MRI-integrated workflow is consistent and highly reproducible. It is recommended that the QA procedure be performed quarterly or in the event of MRI scanner maintenance and repair.

Conclusion: A phantom-based QA program for checking the consistency of MRI-integrated radiotherapy workflow was implemented in our centre. The QA procedure can be adopted by other centres.


parotids were quantitatively compared and the uncertainties of the propagated parotid contours were evaluated using Dice similarity index (DSI). **Results:** For 10 patient plans, the mean parotid volume (19.19±10.23 cm³) at the last fraction was significantly smaller than those (29.44±13.32 cm³, p<0.0001) at the first fraction. The planned mean dose of the ipsilateral parotids (32.42±3.13 Gy) was slightly higher than those of the contralateral parotids (31.38±3.19 Gy). The difference between the accumulated mean doses of the ipsilateral parotids in the B-spline, Demons and MIMvista deformation algorithms (36.40±5.78 Gy, 34.08±6.72 Gy and 33.72±2.63 Gy) were statistically significant (B-spline vs Demons, P<0.0001, B-spline vs MIMvista, P=0.002). And The difference between those of the contralateral parotids in the B-spline, Demons and MIMvista deformation algorithms (34.08±4.82 Gy, 32.42±4.80 Gy and 33.92±4.65 Gy) were also significant (B-spline vs Demons, P=0.009, B-spline vs MIMvista, P=0.074). For the DSI analysis, the scores of B-spline, Demons and MIMvista DIRs were 0.90, 0.89 and 0.76. **Conclusion:** Shrinkage of parotid volumes results in the dose increase to the parotid glands in adaptive head and neck radiotherapy. The accumulated doses of parotids show significant difference using the different DIR algorithms between kVCT and MVCT. Therefore, the volume-based criterion (i.e. DSI) as a quantitative evaluation of registration accuracy is essential besides the visual assessment by the treating physician.

**PS04.119 - Optimization of brain metastases radiotherapy with TomoHDA**

**Author(s):** Slav Yartsev

London Regional Cancer Program, London/CANADA

**Introduction.** Simultaneous in-field boost (SIB) approach has been shown advantageous for dose distribution in axial plane in radiation treatment with prescription of 60 Gy to brain metastases, aka gross tumor volume (GTV), and 30 Gy to the rest of the brain in 10 fractions [1]. However, in the case of tomotherapy system with static jaws, a penumbra of the order of fan beam width is present in superior-inferior (SI) direction both for the whole brain (WB) and GTV regions. Recently, the idea of movable jaws by Gladwish et al. [2] has been realized in the commercially available TomoHDA system. This innovation allowed for drastic reduction of the SI penumbra for the WB, but not for the SIB region. We explore a possibility to take full advantage of dynamic jaws on TomoHDA for brain metastases and whole brain radiotherapy.

**Methods.** A challenging case of the GTV close (9 mm) to the right optic nerve was planned using SIB approach with static and dynamic jaws. Also, two non-SIB treatment plans were generated: 1) WB planning target volume was prescribed to 30 Gy in 10 fractions with 5 cm fan beam/dynamic jaws and the GTV was planned to 20 Gy in 10 fractions; 2) another plan with 2.5 cm fan beam/dynamic with planned irradiation of only the GTV with 60 Gy minus the dose to the GTV from the first plan. Planned maximum doses to the optic nerve and chiasm obtained in SIB and two-phase approach were compared.

**Results.**

<table>
<thead>
<tr>
<th>Plans</th>
<th>SIB</th>
<th>SIB</th>
<th>WB only</th>
<th>GTV only</th>
<th>GTV + WB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fields</td>
<td>2.5 cm</td>
<td>2.5 cm</td>
<td>5 cm</td>
<td>2.5 cm</td>
<td>5 cm +2.5 cm</td>
</tr>
<tr>
<td>Jaws</td>
<td>static</td>
<td>dynamic</td>
<td>dynamic</td>
<td>dynamic</td>
<td>dynamic</td>
</tr>
<tr>
<td>WB, Dmax</td>
<td>32 Gy</td>
<td>32.5 Gy</td>
<td>29.4 Gy</td>
<td>3.8 Gy</td>
<td>33.2 Gy</td>
</tr>
<tr>
<td>GTV, Dmax</td>
<td>61.2 Gy</td>
<td>62 Gy</td>
<td>20.1 Gy</td>
<td>39.4 Gy</td>
<td>59.6 Gy</td>
</tr>
<tr>
<td>Chiasm, Dmax</td>
<td>36.9 Gy</td>
<td>39 Gy</td>
<td>25 Gy</td>
<td>7.7 Gy</td>
<td>&lt;32.8 Gy</td>
</tr>
<tr>
<td>ON, Dmax</td>
<td>41.1 Gy</td>
<td>40.7 Gy</td>
<td>23.6 Gy</td>
<td>9.9 Gy</td>
<td>&lt;33.5 Gy</td>
</tr>
<tr>
<td>Beam-on time</td>
<td>8.4 min</td>
<td>8.8 min</td>
<td>3.9 min</td>
<td>3.1 min</td>
<td>7 min</td>
</tr>
</tbody>
</table>

**Conclusions.** The proposed sequential radiotherapy of brain metastases and whole brain on TomoHDA allows for using dynamic jaws benefit in full. It saves beam-on time and provides improved dose distribution in superior-inferior direction compared to simultaneous in-field boost with static beam. This method can be applied for other disease sites.

**References.**


**PS04.120 - A Rapid Learning Approach for the Knowledge Modeling of Radiation Therapy Plan**

**Author(s):** Lulin Yuan1, Yaorong Ge2, Fangfang Yin1, Q Jackie Wu1

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**Purpose:** The purpose of this study is to implement a rapid learning method to train the knowledge models to predict the organ-at-risk (OAR) dose sparing in radiation therapy (RT) based on an array of patient anatomical features. We also aim to establish the evaluation criteria and a solid validation to ensure an accurate and efficient learning process.

**Method and Material:** The knowledge models to predict OAR dose sparing have been shown to be useful tools to guide RT planning. A rapid learning approach is utilized to train the knowledge models in this study. A total of 100 clinical cancer cases in the pelvic region were retrospectively analyzed. Among them, 40 cases are low-to-intermediate risk prostate cases, 40 are high-risk prostate cases with lymph node irradiation, 40 are anorectal cancer cases. Starting from a base model for type I cases, increasing number of cases with more complex planning-target-volume (PTV)-OAR anatomic features (type II and type III) were continuously added into the training case pool. The studentized residual and the leverage values are calculated as evaluation criteria at each step. The studentized residual quantify how much the new case deviates from the previous model. The leverage measures the distance of the new case in the feature space to the distribution of the other cases and it is used to discriminate if a large residue is due to plan quality variation or because the new case is an isolated case in the feature space. Cases in the former category are excluded from model training.

The efficiency and accuracy of the learning method was quantified by the learning curve. It describes the longitudinal improvement of model accuracies with increasing number of training cases. In order
to reduce the effect of cross-sectional data variation to the learning curve, the modeling accuracies were obtained by a repeated random splitting cross validation method. The gEUD in the bladder and rectum are compared between the model predictions and actual values for the validation cases. The Median of the Absolute value of their Differences (MAD) are calculated for the validation cases.

**Results:** The MAD of the predicted OAR gEUD in all three types of cases gradually decreases when increasing number of training cases are added in training. The MAD of the bladder and rectum gEUD in both type II and III validation cases reaches a stable value of 2.1% to 3.5% of prescription dose when 12 type II or type III are added in training in addition to the 30 type I cases, and they are comparable with the MAD value of 2.0% to 3.4% when all cases are used in training in a batch mode.

**Conclusion:** The rapid learning approach is able to learn knowledge models for multiple cancer types in the pelvic region with comparable accuracy to the batch training method and with improved efficiency. This approach will facilitate the implementation the knowledge based radiation therapy planning in clinics.

**PS04.121 - Plan comparison and delivery verification for intra-cranial stereotactic treatments using Varian TrueBeam STx linac**

**Author(s):** Sergei Zavgorodni  
Medical Physics, BC Cancer Agency, Victoria/CANADA

Modern stereotactic brain treatments are getting away from rigid frame based head fixation systems and mostly rely on pre-treatment and intra-treatment imaging for patient setup and motion control. Circular cones are also getting obsolete and being commonly replaced by high definition multileaf collimators (HD MLCs) that allow using advanced treatment techniques producing more conformal dose distributions. With the aim to minimize potential intra-fraction motion treatment planning includes delivery time as one of considerations. Objective of this work was to evaluate different treatment techniques that utilize HD MLCs from the perspective of treatment plan quality, delivery time, and dosimetric accuracy achievable for different target sizes.

Treatment plans were produced using 7-field static conformal, conformal arc, 7-field IMRT, 2-arc VMAT, and 4-arc VMAT techniques with 6 MV and 10MV-FFF beams. In 4-arc VMAT plans two arcs were coplanar and another two were planned for 45 and 315 degree couch angles. The plans were produced and calculated using Eclipse AAA for the anthropomorphic head phantom that had an insert for micro-diamond detector for the dose measurements. The phantom also had a tungsten bead imbedded for beam position verification. The targets were outlined around the detector position as ellipsoids of 5, 8, 10, 15, 25 mm “effective diameter”, and there were one to three targets per a plan. Plans were produced for treating all targets with a single isocentre. The plan quality was evaluated by using dose volume histograms for the target and surrounding artificial shells that allowed simple evaluation of the dose fall-off. Plans were delivered and the dose measured using micro-diamond detector. The setup was guided by CBCT and its accuracy was evaluated by comparing planned and treatment positions of the tungsten bead. If the plan had multiple targets, the dose in only one of them was measured.

VMAT produced the plans comparable to IMRT and superior to conformal techniques. Non-coplanar plans were more conformal, but the difference was deemed not significant. Plans that used 6MV beams were slightly more conformal than those produced by 10MV-FFF. However the latter, being four-fold faster to deliver are still attractive clinical option.

When treated using regular (4DoF) couch the phantom “roll” rotation had to be set accurately as it was not possible to compensate for this rotational misalignment through available couch movements. Remaining positional error could then be as much as 3 mm compared to 0.5mm when roll rotation was set correctly. 6DoF couch was able to accurately compensate translations and rotations of the phantom and position it within 0.5mm of the plan. For all techniques the dose agreement within 2% was found for the targets of 10mm diameter and larger. For smaller targets the measured dose exceed the plan by as much as 11%. IMRT and VMAT plans had similar delivery times when delivered in “automated” mode. Conformal plans were about 50% faster to deliver due to nearly twice less monitor units.

**PS04.122 - A method to convert cone-beam computed tomography (CBCT) image for dose calculation and the phantom evaluation**

**Author(s):** Guangshun Zhang, Shaomin Huang, Dandan Zhang, Xiaowu Deng, Cui Chen  
Radiation Oncology, Sun Yat-Sen University Cancer Center, Guangzhou/CHINA

**Background and Objective:** Cone-beam computed tomography (CBCT) image is widely used for image guided radiation therapy (IGRT) and has the potentiality to support adaptive radiation therapy (ART). However, uncorrected CBCT images can not be used for re-planning dose calculation due to the larger scatters and artifacts in the Hounsfield unit (HU). Co-relationship between Fan-beam computed tomography (FBCT) and CBCT images was established and used to convert the CBCT image for dose calculation in this study. The results was simulated and verified with an anthropomorphic phantom for IMRT treatment plan computation, compared with the original FBCT based plan.

**Method and material:** Using a self-compiled software based on a fitting function, by registering the FBCT and CBCT image sets of an anatomical head simulated phantom, the CBCT images was converted to get an approximately corrected data sets as CBCTcvt for dose calculation. The precision of CBCTcvt-based dose calculation was then tested and validated, by comparing the iso-dose distribution and dose volume histogram (DVH) of planning target volume (PTV) and organs at risk (OARs) with the FBCT-based computation using an IMRT plan. Gamma comparison in different criteria between CBCTcvt- and FBCT-based plans was provided as well.

**Results:** The gamma comparison between CBCTcvt- and FBCT-based dose computations showed that the pass-rates of (1%, 1mm), (2%, 2mm) and (3%, 3mm) criteria were 71.28%, 97.55% and 99.72%. In the two results of the CBCTcvt- and FBCT based plan calculation, the differences in the mean dose, near minimum dose (D98%), near maximum dose (D2%) and V95% of the PTV were 1.02%, 1.58%, 0.78% and 0.06%, separately; the near maximum (D98%) near minimum (D2%) discrepancies of brain stem and spinal cord were 0.43% and 1.61%; deviation in the D50% of the left and right parotids were 0.89% and 0.88, separately. Fig 1 showed the DVH differences for the main structures.
PS04.124 - Phantom-based evaluations of two binning algorithms for four-dimensional CT reconstruction in lung cancer radiation therapy  
**Author(s):** Fuli Zhang, Yd Wang  
Radiation Oncology Department, The Military General Hospital of Beijing PLA, Beijing/CHINA

**Objective:** The purpose of this study was to evaluate the performance of the phase-binning algorithm and amplitude-binning algorithm. **Methods:** Quasar phantom data were used for evaluation. A phantom of known geometry was mounted on a four-dimensional (4D) motion platform programmed with twelve respiratory waves (twelve lung patients trajectories) and scanned with a Philips Brilliance Big bore 16-slice CT simulator. 4DCT images were reconstructed using both phase- and amplitude-binning algorithms. ITV (internal target volume, ITV) volumes of the phase- and amplitude-binned image sets was compared by evaluation of shape and volume distortions. **Results:** The phantom experiments illustrated that, as expected, maximum inhalation occurred at the 0% amplitude and maximum exhalation occurred at the 50% amplitude of the amplitude-binned 4DCT image sets. The amplitude-binned algorithm rendered smaller ITV than the phase-binning algorithm. **Conclusions:** The amplitude-binning algorithm for 4DCT reconstruction may have a potential advantage in reducing the margin and protecting normal lung tissue from unnecessary irradiation.

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**PS04.123 - Thermoluminescent dosimetry of the model BT-125-1 125I interstitial brachytherapy seed**  
**Author(s):** Nan Zhao, Ruijie Yang, Junjie Wang  
Radiation Oncology, Peking University Third Hospital, Beijing/CHINA

**Purpose:** To study the dosimetric parameters of dose rate constant, radial dose functions and anisotropy functions for the model BT-125-1 125I seed with thermoluminescent dosimeters.  

**Materials and Methods:** The preliminary experiment is to study repeatability, linearity of dose response, dose rate effect and energy response of the thermoluminescent dosimeters (TLD). The seed was placed perpendicularly in the center of the PMMA phantom, and 12 TLDs were placed parallel to the source long axis at radial distance of 1 cm with 30° increments, to study the dose rate constant of the model BT-125-1 125I seed; the TLDs were placed at radial distances of 0.5, 0.7, 1.0 to 10.0 cm with a 0.5 cm increment and a 5° step, to study the radial dose functions of the model BT-125-1 125I seed. The seed was placed horizontally in the center of the PMMA phantom, and the TLDs were placed vertically to the longitudinal axis of the seed at radial distances of 0.5, 1, 1.5, 2, 3 to 7 cm with a 1 cm increment, and polar angles in 20° increments at the radial distance of 0.5 cm, while polar angles in 10° increments at the other radial distances, to study the anisotropy functions of the model BT-125-1 125I seed.

**Results:** For the model BT-125-1 125I seed, the maximum deviation of repeatability for TLDs was 4.0%. The TLDs had linear dose response without dose rate effect, but the dose response is energy dependent. The dose rate constant, radial dose functions and anisotropy functions were similar to the model 6711 125I presented in the TG43 U1 report.

**Conclusions:** The thermoluminescent dosimetry presented the dose rate constant, radial dose functions and anisotropy functions of the model BT-125-1 125I seed which were similar to those of model 6711 125I seed presented in the TG43U1 report.
**PS05 - TRACK 05: DOSIMETRY AND RADIATION PROTECTION**

**PS05.005 - Dose analysis for paediatric patients under cardiac catheterization at Hamad General Hospital in Qatar.**

A.E.Aly, H.A. Al-Saloos, H.M. Al Naemi  
Hamad Medical Corporation, Qatar  
**Author(s): Antar Aly**  
Hamad Medical corporation, Doha/QATAR

**Abstract**

The risks associated with radiation exposure are higher in children compared to adults. The use of fluoroscopy in common pediatric examinations such as left and right heart (L&Ra), patent ductus arteriosus (PDA), atrial septal defect (ASD), pericardial tap, patent truncus arteriosus (PTA) are the common procedures for paediatric undergoing cardiac catheterization requires accurate determination of the associated effective dose. In this study the results of an analysis of doses recorded for 198 paediatric patients for the last 2 years 2013 and 2014 carried out on paediatric patients.

**Materials and Methods**

One X-ray fluoroscopy machine from Hamad Medical Corporation (HMC) in Hamad General Hospital in the state of Qatar performing interventional Cardiology procedures used in this study. Database includes patient age, gender, procedure type and fluoroscopy time; Kerma Aria Product (KAP) and Cumulative dose data were recorded for 198 patients. The average paediatric age, weight, and height were 3.03 year, 13.8 kg and 88.4 cm respectively. Peak voltage was 60.8kVp – 80 kVp.

**Results and discussion.**

**Figure 1 and table 1** illustrate the common cardiac catheterization procedures for paediatric patients. The average KAP ± SD of cardiac catheterization was 956.7 ± 1278.23 cGy x cm². The average fluoroscopic time ± SD was 11.83 ± 9.7 minutes for children. The Cumulative Dose Interventional Reference point (CD_IRP) was 113.4± 45.4 mGy. Body weight is an effective indicator of KAP for cardiac catheterization procedures in children as shown in**\textbf{figure 2}. It’s clear in **figure 3** also good correlation between KAP/BW and KAP ( \( R^2 = 0.7 \) ) for the paediatric patients less than or equal 6 years of age.

![figure 1](image1.png)  
**Figure 1:** Common cardiac catheterization procedures during the years 2013 and 2014.

<table>
<thead>
<tr>
<th>Heart disease</th>
<th>No. of patients (n=198)</th>
<th>Mean fluoroscopy time (min.)</th>
<th>Mean KAP/W (cGy/cm² x kg⁻¹)</th>
<th>Mean CD mGy</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD</td>
<td>25</td>
<td>18.5</td>
<td>864.2</td>
<td>88.8</td>
</tr>
<tr>
<td>R&amp; L Heart</td>
<td>100</td>
<td>17.86</td>
<td>925.17</td>
<td>118.1</td>
</tr>
<tr>
<td>PTA</td>
<td>15</td>
<td>11.2</td>
<td>815</td>
<td>113.6</td>
</tr>
<tr>
<td>Balloon</td>
<td>7</td>
<td>8.1</td>
<td>67</td>
<td>73</td>
</tr>
<tr>
<td>PDA</td>
<td>22</td>
<td>4.41</td>
<td>308.8</td>
<td>40.2</td>
</tr>
</tbody>
</table>

**Figure 2:** The relation between KAP/BW, KAP and CD IRP for different cardiac procedures (best fitting \( R^2 \)).

**Table 1:** Mean Kerma area product, Mean fluoroscopy time and Mean CD_IRP for different procedure.

**PS05.006 - In vivo dosimetry implementation with diodes at the National Radiotherapy Center of the Korle-Bu Teaching Hospital, Ghana**

**Author(s): Vivian Della Atuwo-Ampoh¹, Cyril Schandorf², Samuel N.A. Tagoe³, Eric K. Addison⁴**  
¹Medical Physics, School of Nuclear and Allied Health Sciences, University of Ghana Atomic Ghana, Accra/GHANA, ²School Of Nuclear And Allied Sciences, University of Ghana - Atomic Campus, Accra/GHANA, ³National Centre For Radiotherapy And Nuclear Medicine, Korle-Bu Teaching Hospital, Accra/GHANA, ⁴Oncology Directorate, Komfo Anokye Teaching Hospital, Kumasi/GHANA

Protocol for in vivo dosimetry using silicon diodes in radiotherapy department of the Korle-Bu Teaching Hospital is implemented. The diodes were calibrated using IAEA standards (TRS 389); correction factors were determined with solid water phantom and then implemented on patients.

The phantom studies conducted established that the mean deviation (\( \Delta \pm \alpha \% \)) between the measured and expected entrance doses was (0.34 ± 1.8%). Almost all were within ±5% as recommended by international standards.

The sites of measurement included: pelvis (n=60), head & neck (n=13), breast (n=48) and other cases (n=13) with corresponding mean deviations of 1.92± 4.05%, 0.15± 4.0%, 0.12± 4.20% and 1.66± 3.23% respectively.

Results obtained from patient measurements were comparable to works published in the literature. An overall mean deviation of 1.02%±4.1% was observed (n=134). The percentage of measurement (N %) for which the deviation was within the 5% tolerance was 79.85%. About 3.73% of the total deviations were beyond 7%.
However, two actions levels were adopted for this study as 5% and 7% for simple and tangential fields respectively in line with similar studies using diodes in Poland.

The few major deviations that were however recorded can be attributed to sources of errors (wrong beam parameters) such as depth, wedges and the inability to precisely position the dosimeter in blocked and wedged fields.

There is more room for reduction of uncertainties associated with the measurement protocol by carefully limiting or avoiding all the errors.

**PS05.007 - Assessment of radiation dose due to radio frequency emitted from medical high voltage modules**

**Author(s):** Mosa Moradi1, Alireza Kamali Asl1, Mohammad Reza Ay1

1Radiation Medicine, Shahid Beheshti University, Tehran/IRAN, 2Department Of Medical Physics & Biomedical Engineering, Tehran University of Medical Sciences, Tehran/IRAN

Public and occupational exposure of electromagnetic fields due to the growing trend of electronic devices may cause adverse effects on human health. The effects of radiofrequency (RF) radiation absorption on human health can be expressed as high temperature and thermal effects on body tissue. But it also lead to cancer in the body, especially the in head and nervous system. In this study, the dose resulting from the high voltage power supply (HVPS) that has built for the Single Photon Emission Computed Tomography (SPECT) system has been measured. Also, risks arising from the waves, according to a report by International Commission on Non Ionizing Radiation Protection (ICNIRP), to every organ of the body is defined by the beam and electromagnetic radiation from this electronic device on the human was investigated. In this study, the dose of high voltage module in switching mode at different frequencies using a scintillation detector was measured. Results showed that the maximum personal dose over 15 min working of mentioned HVPS don’t exceed from 0.31 µSv/h (With aluminum shield). So, according to other sources of radiation, continuous working time of the system should not be more than 10 hours. Finally, a characteristic curve for secure working with modules at different frequencies been has reported. The RF input signal to the body for maximum penetration depth (δ) and specific electromagnetic energy absorption rate (SAR) of biological tissue can be obtained for each tissue.

**Objective**

This presentation aims to instruct the audience how to calculate skin dose following a fluoroscopically guided procedure automatically by using the data provided in Digital Imaging and Communications in Medicine (DICOM) file headers and a simple Java program.

**Methods**

Using a Java program the audience is instructed in automating skin dose calculations for patients undergoing interventional procedures. This method relies heavily on manufacturer provided information found in the headers of DICOM files. The dcm4che project Java libraries are used in the Java program to interrogate this information from the DICOM files when calculating skin dose. This method is validated using direct measuring techniques to determine entrance skin dose which is then compared to values calculated by the program.

**Results**

The Java program is successfully used to calculate entrance skin dose following fluoroscopically guided procedures. However, there are many limitations that must be taken into considerations should this method be employed clinically. Validation of the program following corrections made for each unit provide accuracy to within 10%.

**Conclusion**

A Java program can be set up to automatically calculate the entrance skin dose from DICOM files following an interventional procedure. If limitations are taken into consideration this method proves accurate to within 10%.

**PS05.009 - Current Status of a-Si EPID Dosimetry: An Application for Dose Verification in Standard Radiotherapy Techniques**

**Author(s):** Omemh Bawazer1, Siva Sarasvandarajah1, Sisira Herath1, Tomas Kron2, Pradip Deb1

1School Of Medical Radiation, RMIT University, Melbourne/AUS-TRALIA, 2Radiation Oncology, Peter MacCallum Cancer Centre, Melbourne/AUS-TRALIA

As radiotherapy becomes more complicated, a required of dose verification is strongly recommended. Electronic portal imaging device (EPID) is a promising detector to use with the dose verification of radiotherapy technique. This is due to its advantages compared to other detectors, such as a high spatial resolution, large imaging area, and real-time acquisition and less setup time. Therefore, the implementation of EPID for dosimetry purpose in clinical practice has currently received a great attention with the increasing the need of dose verification [1, 2]. The purpose of this study is to firstly list the commercially available solutions for EPID dosimetry. Secondly offer the solutions that used to improve the performance accuracy of EPID dosimetry. Thirdly summarize clinical or proposed approaches based on EPID dosimetry for different radiotherapy techniques. The previous publications demonstrated a variety of reliable and accurate dose verification methods used based on EPID for intensity modulated radiotherapy (IMRT) while the dose verification with volumetric modulated arc therapy (VMAT) and stereotactic ablative body radiotherapy (SABR) is still under development [3-5], see Figure 1. However, further efforts are needed to optimize the time required for verification procedure based on EPID. Also, further research is required to study the possibility of replaced pre-treatment verification with in vivo verification. This may have the benefit of reduced workloads in clinical practice.


PS05.011 - Micronuclei assessment of Selenium and Vitamin E radioprotective effects in human lymphocytes

**Author(s):** Vahid Changizi, Aram Rostami

**Introduction:** Critical macromolecules such as DNA are in exposure to damage of free radicals that induced from interaction of ionizing radiation with biological systems. Selenium and vitamin E are natural compounds which are radioprotective substances and could be used as a direct free radical scavenger. The aim of this study was to investigate the in vivo/in vitro radioprotective effect of selenium and vitamin E against genotoxicity induced by 6MV x-ray irradiation in human cultured blood lymphocytes.

**Methods:** Five volunteers received selenium and vitamin E. Their peripheral blood samples were collected before and 1, 2 and 3 hours after taking selenium and vitamin E. The samples were exposed to 2Gy of 6MV x-ray, and then were cultured with mutagenic stimulation to determine the chromosomal aberration with micronucleus assay on cytokinesis-blocked binucleated cells.

**Result:** The lymphocytes in the blood samples collected at 1 hr after ingestion selenium and vitamin E, exposed in vitro to x-rays exhibited a significant decrease in the incidence of micronuclei, compared with control group at 0 hr. The maximum protection and decrease in the frequency of micronuclei (50%) was observed at 1 hr after administration of selenium and vitamin E.

**Conclusion:** Selenium and vitamin E could be as radioprotector substances and may reduce genetic damage caused by x-ray irradiation.

**Acknowledgements:** The EMRP is jointly funded by the participating countries within EURAMET and the European Union.

**References**


**PS05.012 - The Organ and Skin Dose Distribution in Total Body Irradiation**

**Author(s):** Jeongmin Yoon, Jungil Lee, Ho Lee, Samiu Cho, Eungman Lee, Woohnoon Choi

**Radiation Oncology, Yonsei University Health System, Seoul/KOREA**

**Purpose:**

To achieve uniform dose distribution is the most important in total body irradiation. The aim of this work is to verify the organ dose distribution and skin dose distribution using OSLD within ±10% of the prescribed dose.

**Materials and Methods:**

An Adult male phantom (CIRS, Model 701, Φ 14mm hole placement for nanoDot) was irradiated bilateral total body technique. We placed optically stimulated luminescence detectors (OSLDs) inside the adult male phantom to measure the dose at brain, neck, lung, abdomen, pelvis and thigh. At the same time we placed OSLDs on adult male phantom to obtain skin dose during bilateral irradiation. The phantom was set at 410cm of source-axis distance (SAD) and irradiated with field size 164 × 164 cm² (40 x 40cm² at SAD 100cm) which covered the entire phantom with 10MV x-ray (Agility, Elekta Ltd, Crawley, UK). The prescription dose is 150cGy per fraction. We used aluminum compensators to adjust the thickness of tissue deficit easily.

**Results:**

From the OSLDs measurements, we obtained inside dose of phantom at the various anatomical regions. The differences from the prescription dose were shown: 0.8% (brain), 8.9% (neck), -2.64% (lung), +6% (abdomen), 0.78% (pelvis), -1.13% (thigh). We also checked the skin dose at the same organ plate positions: -8.5% (brain), -2.1% (neck), -0.9% (lung), 0.4% (abdomen), -4.3% (pelvis), 0% (thigh). All of the measured points showed within ±10% of the prescribed dose. As the results, we could achieve the homogeneous dose distribution of organ and skin during total body irradiation.

**Conclusions:**

The OSLDs results showed not only the organ homogeneous dose distribution but also skin uniform dose distribution during total body irradiation.

**Key words:**

Total body irradiation, Organ and skin dosimetry, OSLD, Adult male phantom

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**Conclusion:**

The Stanford technique was used. The distance calculated from the source to the patient was 3.90m.

**Materials:**

Varian Clinac iX linear accelerator, patient positioning platform, acrylic scattering screen (10mm thickness), IBA I’mRt phantom, PTW UNIDOS E electrometer, plane parallel ionization chamber PTW ROOS, PTW RW3 solid water phantom, GAFCHROMIC EBT3, EPSON PERFECTION V700.

**Methods:**

When using the Stanford technique, it’s necessary to have a region of about 1.80m, depending on the patient’s height, in which the field flatness is guaranteed to be below ±10% of variation. Because of the adaptors provided by the manufacturer, the field size was 36x36cm for the 9MeV and 34x34cm for the 6MeV beam. Since a single irradiation field does not provide the desired flatness. It is indispensable to use two complementary fields that contribute 50% each and assure the desired flatness. The angle needed is calculated finding the 50% of a single irradiation field. The dose profile was measured using the gantry angles found, and it was below ±10% of variation for both energies.

Using the RW3 at treatment distance, the ionization chamber, the ionization-depth curve was found, from where the dose output was calculated.

Six different patient positions are used to complete a total irradiation, using three each day. These positions were simulated on the IBA phantom to obtain the dose distribution on a plane.

**Results:**

<table>
<thead>
<tr>
<th>Measure</th>
<th>6 MeV</th>
<th>9 MeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>R100</td>
<td>3 mm</td>
<td>9 mm</td>
</tr>
<tr>
<td>R90</td>
<td>6 mm</td>
<td>14 mm</td>
</tr>
<tr>
<td>R80</td>
<td>8 mm</td>
<td>17 mm</td>
</tr>
<tr>
<td>R50</td>
<td>11 mm</td>
<td>22 mm</td>
</tr>
<tr>
<td>R10</td>
<td>15 mm</td>
<td>25 mm</td>
</tr>
<tr>
<td>Output</td>
<td>0.0635 cGy/MU</td>
<td>0.3911 cGy/MU</td>
</tr>
<tr>
<td>Gantry Angle</td>
<td>17.5°</td>
<td>15°</td>
</tr>
<tr>
<td>Treatment Time</td>
<td>3.5 min</td>
<td>48 min</td>
</tr>
</tbody>
</table>

**Conclusion:**

The best suited energy for the case is 6 MeV although the output is much smaller, translating to a longer treatment time.

**References:**

- AAPM Report 23; Total skin electron therapy: Technique and dosimetry.
- M.E.R Poli; Dose Measurements in the Treatment of Mycosis Fun-goides with Total Skin Irradiation using a 4MeV Electron Beam
- S. Lloyd Morris; Results of a 5-Week Schedule of Modern Total Skin Electron Beam Radiation Therapy
- Eric P. Reynard; Rotational total skin electron irradiation with a linear accelerator
PS05.014 - Analysis of Informal Commerce Sunglasses using Spectroscopy
Author(s): Juan Alberto L. Cruz, Tertuliano T. Neto, Ernando S. Ferreira
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Despite a growing of literature on the adverse biological effects of ultraviolet radiation on eyes and skin, a considerable number of persons follow buy sunglasses in informal commerce establishments, for photoprotection of the eye exposure at the ultraviolet radiation in sunlight. The main goal of this work was to perform experiments to verify if the sunglasses lenses with their filters types provide or not protection against ultraviolet radiation (280 – 380nm), in agreement with the specification of the European British Standard norm EN1836:2005, EN 1836. The experimental setup is basically composed by radiation sources (60 W white light and mercury lamps), which passes through the sunglasses lenses, and transmitted electromagnetic radiation is collected and guided by a optic fibre of 1 mm of diameter and 1 m of length connected to a spectrometer USB4000 from Ocean Optics. Then the spectrometer is coupled to a computer through which the measurements are controlled and analyzed using the Spectra Suite software. The spectrometer were configured to performed, transmission spectroscopy, to evalute the lenses filtering power to ultraviolet radiation of 21 sunglasses pairs (42 lenses) commercialized in informal establishments of Feira de Santa city, in Bahia, Brazil. The results from the transmittance experiments in the visible, all lenses of the sunglasses were classified in categories according to requirements of the Standard norm mentioned above. From the analyze of the results obtained in the transmittance experiments with the UV radiation, 04 sunglasses of 21 (19,04%) were considered no conforms because they allow the passage of ultraviolet radiation between 280 and 380 nm, and could produce adverse biological effects on eyes in accordance with the standards.

PS05.015 - Dosimetric Evaluation Of Lung Dose Using Indigenously Developed Respiratory motion phantom
Author(s): G Dheva Shantha Kumari1, Shanmugam Senthilkumar2 1P.g. Dept. Of Physics, Fathima College, Madurai/INDIA, 2Radiotherapy, Govt. Rajaji Hospital & Madurai Medical College, Madurai/INDIA

Introduction
Respiration induced organ motion is one of the major uncertainties in lung cancer radiotherapy, which may cause clinically significant targeting errors and greatly degrade the effectiveness of conformal radiotherapy. Motion of the tumor due to respiration during the radiation treatment process is difficult to manage. Without managing the respiratory motion, the critical organs may receive high radiation dose with decreasing target dose. Intrafraction motion is an issue that is becoming increasingly important in the era of IMRT. Intrafraction motion can be caused by the respiratory, skeletal, muscular, cardiac and gastrointestinal systems. The main aim of the present study was to evaluate the lung dose in the presence of respiratory movement and absence of movement in lung and also compare the dosimetric difference using indigenously developed Respiratory Gating Platform.

Material and Methods
Respiratory motion platform (RPM) was designed indigenously and constructed for testing the targeting accuracy of the lung tumor in respiratory condition. It consists of acrylic Chest Wall Platform, 2 DC motors, 4 IR sensors, speed controller circuit, 2 LEDs and 2 moving rods. The essential component of the device is a movable platform mounted to a base using precision linear bearings. The base and platform are made of clear, 15mm thick polycarbonate plastic. The platform is driven along a linear trajectory using a motor controller that drives a stepper motor attached to the Bi-slide assembly. The targeting accuracy of the respiratory tracking system was evaluated with varied amplitude of skin motion, respiratory rate and tumor distance. The device was designed to be able to simulate the gross anatomical anterior posterior motion attributable to respiration-induced motion of the lung. Depending on the particular application, an appropriate phantom would be placed on the platform. Speed of motion is controlled by Control knob. This parameter controls the period, or how fast one breath cycle in seconds takes place. This value can be adjusted in 1/2 second intervals between 2 and 6 seconds.

Results:
The RMP was used to measure the 20 lung tumor patients with treatment planning system (TPS) calculated dose in both the respiratory and non respiratory condition. We have found 3% dose difference between the TPS calculated dose and measured value with the help of RMP in respiratory and non respiratory condition. So, for lung cancer radiotherapy treatment, respiratory motion has to be taken for better dose delivery to the lung tumor.

PS05.016 - Activation of Medical Linear Accelerators
Author(s): Adam C. Dodd
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Purpose: Radioactivity is induced in medical linear accelerators (linacs) operating at high energies for extended period of time through photoneutron reactions and subsequent neutron capture. The disposal of linacs is a potential health hazard especially for workers engaged in recycling the tungsten parts. New gamma spectroscopy data and recent experimental data on neutron production in combination with published Monte Carlo results have enabled a general analysis of the longer lived radioactivity induced in linacs.

Methods: A mechanically cooled high purity germanium detector placed at isocentre was used to identify the gamma emitting isotopes for a Truebeam STX. Self absorption correction factors are derived from the data by a differential absorption analysis. Neutron production data in combination with Monte Carlo results are used to determine the activities of pure beta and electron capture radioisotopes.

Results: The principal activities with half-lives longer than 1 day are W-181, W-185, Co-57, Co-60 & Mn-54. Results are presented for Elekta, Siemens and Varian models as a function of beam energy, workload and operating lifetime. The length of time activated components from a decommissioned linac should be kept before they can safely be disposed of is presented for Elekta, Siemens and Varian models.

PS05.017 - Assessment of Patient Dose in Selected Non-Cardiac Interventional Fluoroscopy Procedures Using OSL Dosimeters
Author(s): Isabel A. Elona
Center For Device Regulation, Radiation Health, And Research, Department of Health - FDA, Manila/Philippines

In recent years, interventional procedures have composed a major part in diagnostic radiology and increasingly replaced many surgical procedures. Despite its advantages, the utilization of ionizing radiation for diagnosis delivers radiation doses which present risk to the patient. The fundamental principles of radiation protection call for exposures to patients that are As Low as Reasonably Achievable (ALARA). The purpose of this study was to assess the level of radiation from selected non-cardiac interventional fluoroscopy procedures...
dures at the University of Santo Tomas Hospital, Cardiac Catheterization Laboratory. Radiation dose measurements, using Optically Stimulated Luminescence Dosimeters (OSLD) were performed on 4 patients on femoral angiogram and hepatic embolization. The results showed that interventional procedure such as embolization of the liver may exceed the threshold value for deterministic effects.

**PS05.018 - Measurement of Photon and Neutron Dose Distribution in Cyclotron Bunker During F18 and N13 Production**

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**Introduction:** Self-shield hospital cyclotrons have been received a considerable attention due to have compact size and no necessity for concrete bunker. It is well known that during the bombardment of target in cyclotrons, neutron and gamma flux are produced. However, the activation caused by neutron interaction has considerable radiological hazard in cyclotron components. For safety purpose, measuring of neutron and photon dose rate in the area close to the shield are mandatory. In this investigation we measured the neutron and photon dose rate during 18F and 13N productions in different distance from radiation shield of GE PET Trace 700 the self shield cyclotron that recently installed in Masih Daneshvar hospital.

**Material and methods:** Dose rate measurement were done by neutron dosimeter (LB 6411) and Geiger Mueller dosimeter (BNS-92) during the operation of the cyclotron using different target current at various distance (from 0.5 to 2.5 meter) of self-shield cyclotron in step of 0.5 meter around the cyclotron. All measurements were done at the floor level and also the height of one meter (target position).

**Results:** With increasing target current from 30 to 35μA at the distance of 0.5 meter at the gap between left and right doors, the gamma dose rate varies from 8.9 to 10.7 μSv/h and decreasing neutron dose rate were obtained from 10 to 5.2 μSv/h with increasing distance from 0.5 to 2.5 meter at the height of one meter, during the F-18 production. Whereas the gamma dose rate increases from 2.86 to 8.6 μSv/h at the distance of 0.5 meter from cyclotron during N-13 production with increasing of operation current from 30 to 35μA at 2.5 meter far from cyclotron at the interface of left and right doors this quantity reduced to 2 μSv/h at 35μA target current.

**Conclusion:** the low level of neutron and gamma dose rate outside the self-shield of cyclotron indicated that the polyethylene and concrete component used in GE PET Trace 700 cyclotron can produce nearly safe condition for entire the cyclotron bunker.

**PS05.019 - Energy response of the GAFCHROMIC EBT3 in diagnosis range**

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**Introduction:** For in vivo dosimetry measurements in diagnosis range (over 100 keV), the Gafchromic films, the influence of energy dependence in the diagnosis energy range (less than 100 keV) is larger in the high energy range (over 100 keV). Based on this characteristic, adaptation of the EBT3 dosimetry in the diagnosis range was investigated. The energy response of the EBT3 in the diagnosis range at 30, 40, 50, 60 keV was measured using the density-absorbed dose calibration curve of the absorbed dose versus film density for the EBT3. Various data (degree of leaning, coefficient of determination) of each effective energy were compared. The density - absorbed dose calibration curves were linearly correlated in each of the effective energies. There was an energy dependent error of approximately 0.2 % from 30 to 60 keV (Fig. 1). As a result, it can be seen that the EBT3 is available in the diagnosis energy range. However, the influence of the non-uniformity error caused by the repeatability of the scan method must be considered because EBT3 distortion has a serious influence on measurement precision.

**Materials and methods:** Absorbed dose measurement were done by neutron dosimeter (LB 6411) and Geiger Mueller dosimeter (BNS-92) during the operation of the cyclotron using different target current at various distance (from 0.5 to 2.5 meter) of self-shield cyclotron in step of 0.5 meter around the cyclotron. All measurements were done at the floor level and also the height of one meter (target position).

**Results:** With increasing target current from 30 to 35μA at the distance of 0.5 meter at the gap between left and right doors, the gamma dose rate varies from 8.9 to 10.7 μSv/h and decreasing neutron dose rate were obtained from 10 to 5.2 μSv/h with increasing distance from 0.5 to 2.5 meter at the height of one meter, during the F-18 production. Whereas the gamma dose rate increases from 2.86 to 8.6 μSv/h at the distance of 0.5 meter from cyclotron during N-13 production with increasing of operation current from 30 to 35μA at 2.5 meter far from cyclotron at the interface of left and right doors this quantity reduced to 2 μSv/h at 35μA target current.

**Conclusion:** the low level of neutron and gamma dose rate outside the self-shield of cyclotron indicated that the polyethylene and concrete component used in GE PET Trace 700 cyclotron can produce nearly safe condition for entire the cyclotron bunker.

**PS05.020 - Estimation of In Vivo Dosimetry Accuracy with Dose-Volume Histogram**

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In vivo dosimetry is widely used for verification of the absolute dose received by patient during radiation treatment delivery. The difference between measured dose and calculated at the same point with treatment planning system (TPS) often exceed 5% and depends on patient’s setup variation, organ movement and dose gradient in the point of measurement. The purpose of this study is the estimation of uncertainties and dose accuracy measured with small dosimeters like TLD, OSLD or MOSFET during radiation treatment delivery.

Our novel method for dosimetry measurements takes into consideration distance–to–agreement between measured and calculated points. However, instead of gamma index used as QA criteria in IMRT we apply a dose–volume histogram (DVH) for the area of assumed infra- and inter-fraction movement of measurement point. This area called a region of measurement (ROM) includes all most probable measurement points and can be contoured with TPS tools. Our novel method for dosimetry measurements takes into consideration distance–to–agreement between measured and calculated points. However, instead of gamma index used as QA criteria in IMRT we apply a dose–volume histogram (DVH) for the area of assumed infra- and inter-fraction movement of measurement point. This area called a region of measurement (ROM) includes all most probable measurement points and can be contoured with TPS tools. Our novel method for dosimetry measurements takes into consideration distance–to–agreement between measured and calculated points. However, instead of gamma index used as QA criteria in IMRT we apply a dose–volume histogram (DVH) for the area of assumed infra- and inter-fraction movement of measurement point. This area called a region of measurement (ROM) includes all most probable measurement points and can be contoured with TPS tools.
pometric phantom with Philips Brilliance Big Bore CT simulator and established measurement points in three regions: head & neck, chest, and pelvis. Then 3D conformal treatment plans for head and lung areas and IMRT plans for prostate were created. The prescribed dose for targets was 200 cGy per fraction.

The radiation dose was measured in given points using OSLD and MOSFET dosimeters. Analyzing the DVH we defined the acceptable dose interval from D80 to D20. These intervals (and measured doses) were 184.6 – 210.4 (measured 191.1) cGy for the head and neck plan, 83.7 – 92.7 (87.1) cGy for lung, 73.6 – 89.3 (74.3) cGy for prostate IMRT and 62.0 – 86.4 (64.0) cGy for prostate rapid arc plan. The length of dose intervals depended on the treatment site, location of measurement point, size of ROM, and type of treatment plan. In all studies the measured doses fell into the given acceptance interval, thereby validating the novel method as a way to perform real-time dosimetry.

The proposed method allows estimating the accuracy of delivered dose taking into account the displacement of the measurement point. It applies flexible and justified acceptance criteria. It is possible to define the limits of dose deviation during a treatment planning process. The influence of distance and direction of the measurement point displacement as well as ROM heterogeneity on dosimetric accuracy can be quantitatively analyzed.

PS05.021 - Evaluation of the dosimetric properties of water equivalent microDiamond detector in high energy photon beam.

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The aim of this study was to evaluate the characteristic of a water equivalent synthetic diamond detector (PTW 60019 microDiamond, Germany) for the small field dosimetry in high energy photon beam. We have obtained data in cyberknife 6 MV photon beams of six different collimator size (from 5mm to 30 mm). Data were included dose linearity, dose rate dependence, output factors (OF), percent depth doses (PDD) and off center ratio (OCR). The results were compared to those of pinpoint ionization chamber, Old diamond detector, microLion liquid ionization chamber and diode detector. The dose linearity results for the microDiamond detector showed good linearly proportional to dose. The microDiamond detector showed little dose rate dependency throughout the range of 100–600 MU/min, while microLion liquid ionization chamber showed a significant discrepancy of approximately 5.8%. The OF measured with microDiamond detector agreed within 3.8% with those measured with diode. PDD curves measured with silicon diode and diamond detector agreed well for all the field sizes. In particular, slightly sharper penumbras are obtained by the microdiamond detector, indicating a good spatial resolution. The results obtained confirm that the new PTW 60019 microDiamond detector is suitable candidate for application in small radiation field dosimetry. In future, we are evaluating using the Monte Carlo method in high energy photon beam.

PS05.022 - From simple to advanced dosimetry audits in radiotherapy: IAEA coordinated research

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A series of four coordinated research projects (CRPs) were conducted by the IAEA in 1995-2015 focusing on development of national quality audit programmes for radiotherapy dosimetry in low and middle income countries. The first CRP started with remote audits of beam output in reference conditions using thermoluminescent dosimetry (TLD). The audit programme was then extended through the second CRP to include dose audits in non-reference conditions for high energy photon and electron beams. The third CRP, concluded in 2012, has expanded the dosimetry audit tools to more complex techniques used for cancer treatment. New methodology has been developed and tested for dose audits of irregular fields shaped with multileaf collimators (MLC), dose in the presence of heterogeneities and 2D profiles of small photon MLC shaped fields. This audit programme was based on TLDs and radiochromic films and used specially designed phantoms. The current CRP, initiated in 2013, focusses on dosimetry audits for more advanced technology in radiotherapy dose delivery. Auditing methodology has been developed for remote verification of calculation of small beam output factors by treatment planning systems (TPS), film audit of MLC positional performance for intensity modulated radiotherapy (IMRT), film audit of single clinical IMRT field dose delivery and ‘end-to-end’ dosimetry audit (imaging, planning, dose delivery) for multiple field IMRT techniques using TLDs and radiochromic films. This approach of gradually increasing the audit programme complexity was adopted to learn from experience of previous audit steps and to apply consistently the methods for development, testing and analysis of results for subsequent audit steps.

The IAEA Dosimetry Laboratory has participated in the experimental part of the CRPs, developed new phantoms and conducted multi-centre pilot studies to test the newly developed methodologies. Following such studies, the CRP participants adopt the methodology and organize trial audit runs with local radiotherapy centres in their countries. In addition, the IAEA contributes to strengthening QA of national audit networks by exchanging dosimeters with national dosimetry laboratories. Through the link with the IAEA Dosimetry Laboratory, the national networks closely cooperate at the consecutive stages of developing the dosimetry audit methodology locally and by carrying out cross-measurements. In this way the national audit systems are interlinked to ensure that international and national radiotherapy dosimetry audit networks are working to the consistent levels and standards.

Overall, the IAEA has supported the establishment of several national audit groups for radiotherapy dosimetry and assisted in the development of methodology for a range of dosimetry audit levels, from basic to advanced. The scope of the dosimetry parameters included in subsequent audits corresponds to the evolving complexity of radiotherapy as more advanced technologies are becoming increasingly used for cancer treatment across the world.

PS05.023 - Noise reduction of radiochromic film: median filter processing of subtraction image

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Pre-ultraviolet rays exposure is a useful method to reduce non-uniformity error of radiochromic films. However, dust and scratch noises such as spike noise disturb precise measurement. To reduce these noises, median filter processing is applied for pre-subtraction and subtraction images.

To reduce non-uniformity error of the thickness unevenness of Gafchromic EBT film, ultraviolet rays were exposed to correct data. There were three kinds of images obtained: first ultraviolet exposure image, second ultraviolet exposure image and the subtraction image of both. Median filer processing was performed on all these images. Eleven kinds of median filter radius factors (0.0 to 5.0) were applied using image analysis software. Data and graphs were then estimated.

The maximum pixels value of dust was 229 on the second ultraviolet exposure image film. After median filter pre-processing, the pixel value of the noises were similar to the minimum value. A 2.0-radius median filer is a useful factor for processing.

Noise reduction that affected data of estimated images may be applied to measure radiation doses on a variety of radiochromic films. Ultraviolet exposure and subtraction method with median filter processing enable precise measurement and high spatial resolution dose distribution.

PS05.024 - Proposed Guidelines for Image Quality in Chest PA X-Ray Examinations in Bangladesh

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Abstract— The common practice for chest PA examinations in Bangladesh employ low kV imaging. This practice involves low-contrast images and requires much higher radiation doses than those associated with higher beam energy. Thus, we propose a model relating the change of Entrance Surface Dose (ESD) in response to changes in beam energy, in accordance with European standards for diagnostic radiographic chest imaging to find the optimal ESD corresponding to values of kVp used in Bangladeshi hospitals.

Results show that in order to maintain the standards of Quality for Diagnostic Radiographic Image every 10kVp increase in beam energy must be followed by a decrease of 8/6 in ESD that corresponds to a reduction of 15% in the equivalent dose. Hence, the range of optimal ESD accounting for the kVps practiced for chest PA examinations is 5.6-10 mGy, which represents a factor of 35 above the recommended ESD.

Finally we investigate the effect of Body Mass Index (BMI) on optimal ESD for overweighted Bangladeshi patients. We find that, for each additional 1kg, the ESD must increase 18% in order to maintain standards for chest PA x-ray image.

PS05.025 - Evaluation of inhomogeneity correction using monte carlo simulation in stereotactic body radiation therapy (SBRT)

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Stereotactic Body Radiation Therapy (SBRT) requires high accuracy in order to protect surrounding normal tissue and destroy the tumor. The dosimetric behavior of the small beams used in SBRT in the presence of low-density inhomogeneities is critical for accurate dose optimization. In inhomogeneity materials for the lung, dose correction is not applied with the values calculated by applying the difference in calculation of the difference we told that more than 30% are reported. Significant differences in dose calculation were made to compensate for heterogeneous material. However, the evaluation of dose calculation in molding the slope has not been accomplished. Integrated high-dose molding of slopes for dose calculation accuracy is critical. In this study, molding equipment for SBRT was acquired, including heterogeneous material, to evaluate the accuracy of dose calculation. The accuracy of treatment planning and measurement data, which applied the inhomogeneity correction factor made comparison with result of monte carlo simulation. To measure and evaluation the effects of heterogeneous medium, a inhomogeneity correction phantom is required. Inhomogeneity Correction Phantom (ICP) is able to insert the inhomogeneity materials, which have 12 types in each different electron density. Also it is able to adapt the EBT film and 0.125 cc ion chamber for measurement of dose distribution and point dose. In comparison with monte carlo simulation, the average difference applied the inhomogeneity correction factor was 1.63% and 10.05% in each plan and film measurement data, respectively. In addition, the average difference in dose distribution was 10.09% for each measurement film. The average difference of point dose was 0.43% and 2.09% in each plan and measurement data, respectively. In conclusion, if the inhomogeneity correction factor was not applied in small field, a greater difference in measurement data was observed. In SBRT using small field, it needs to precisely identify the correct inhomogeneity correction factor.

PS05.026 - Dosimetric effect of low dose 4D CT by a commercial iterative reconstruction on dose calculation in radiation treatment planning: A phantom study

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We investigated the HU and dose difference due to the use of CT images acquired with the reduced imaging dose by using a commercial iterative reconstruction technique (iDose, Philips). The phantom with various density materials from 0.2 g/cc to 1.53 g/cc was scanned by the Philips Big Bore CT, using two energies (90 and 120 kV) and four currents (50, 100, 200 and 400 mAs). The CT images were reconstructed with and without iDose with level 5. As the density is higher, the use of iDose increased the mean HU that the maximum change of mean HU was 109 HU in 1.53 g/cc bone core material at 90 kV. At the same energy, the HU with reducing mAs showed a difference less than 27 HU. The 4D CT of lung phantom (CIRS) was scanned with two different exposures of 598 mAs without iDose and 163 mAs with iDose. We performed 2D and VMAT spine planning and 3D CRT and VMAT lung planning based on the 50% phase of CT with and without iDose reconstruction. The difference of mean dose was within 1% in all plans. Therefore, this dose reduction technique in big bore CT is applicable to the radiotherapy
treatment planning. If the high density material is included, it should be used with a caution for the dose calculation in the treatment planning because the HU difference due to the iDose is greater as the density is higher.

**PS05.027 - An Evaluation of the Use Factor for CyberKnife using Clinical Data**

**Author(s):** Yu Ra Cho1, Dong Han Lee2, Yong Min Lee3, Mun Kyu Park1, Han Yeong Lee2, Ung Kyu Chang1

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In order to reduce the regulation limit of integral dose of CyberKnife to below 10%, presently the international guideline standard of the CyberKnife use factor is 0.05(%), which is very small compared to 5~40(%) of conventional radiation therapy, and this shows that the shielding standard of CyberKnife is very strict. In this study, based on the clinical data of patients who had received CyberKnife treatment, tried to examine the adequacy of the existing shielding guideline. 60 patients among approx. 220 who had received CyberKnife (ver. 9.5, Accuray, Sunnyvale, USA) treatment from February 2013 to May 2014 were selected and for intracranial and body, two groups of 30 patients were classified into skull tracking and spine tracking mode. After extracting the specific trajectory of the robot on the beam data of each patient, the direction of the beam towards the shielding wall by using the origin (ver. 9.1, OriginLab, USA) program was reproduced in three dimensions. And many beams examined in each direction were set as one zone, and then MU of formed beams was analyzed. And in order to estimate shielding workload and IMRT factor, prescription dose and total MU were analyzed at the same time. Intracranial patients received an average of 1.9 fractions with 12 Gy per fraction prescribed at the 80.2% isodose line, using 147.2 beams and 1,8163 MU. Body patients received an average of 3.63 fractions with 9.5 Gy per fraction prescribed at the 77.6% isodose line, using 166.6 beams and 4,7942 MU. The most used collimator size was 7.5–35 mm, and fixed and Iris collimators of 1–4 types of size were used. In intracranial and body treatments, 82% of the total beams were distributed being directed towards the floor, and there were few beams directed towards the ceiling. And 18% of the beams were directed towards the surrounding walls and for body no beams were directed to the right side wall from the position of couch. It could be confirmed that more beams were spread on the walls in intracranial than body, and as a result of analyzing MU of each beam, it could be observed that more 'hot zone' were produced in intracranial than body. Because use factor and IMRT factor recommended by the CyberKnife shielding guideline are small and large respectively, more barriers are required for shielding of CyberKnife treatment rooms, which leads to spatial in-efficiency and cost increase in hospitals. Thus, if the use factor analyzed in this study based on the clinical data is considered in designing treatment rooms, more reasonable treatment room designing may be possible.

**PS05.028 - Lung Dose Estimation for a Total Body Computed Tomography Protocol**

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**Introduction:** Computed Tomography (CT) procedures are important diagnostic tools. It is estimated that CT accounts for over 13% of all diagnostic examinations, contributing for approximately 30% of the collective dose in the United States. In Germany, CT represents 7% of total X-Ray examinations, with contribution of 60% for collective effective dose. This work studies a methodology to estimate lung doses on an adult anthropomorphic phantom (The Phantom Laboratory, Salem, USA), undergoing total body CT using Lithium-Fluorite (LiF) thermoluminescent dosimeters (TLD).

**Methods:** LiF TLDs were introduced inside the holes of the phantom, in nine slices, correspondent to lung position (Figure 1). Fourteen groups of five dosimeters were allocated in dosimeter-holders designed for this purpose. The phantom was irradiated in a PET/CT scanner (Discovery PET/CT 690, GE Healthcare). After performing double scan projection radiographs (SPR) (anteroposterior and lateral), the phantom was irradiated using a total-body protocol. TLD data were read by TL/OSL reader Rise (DTU Nutech, Inc., Roskilde, Denmark) and these results converted to “counts” by a routine implemented with the Software Origin 8.5.1 (OriginLab Co., MA, USA). These counts were corrected to a calibration curve, for radiation quality RQT 9. Mean absorbed dose, D, for the lung were calculated using equation (1)

$$D=\sum_{i}f_iD_i$$

where $f_i$ is the fraction of the total lung mass in phantom slice $D$. and is the average dose to the organ in slice.

![Figure 1- Adult anthropomorphic phantom positioned inside the gantry (above); positions of the dosimeter-holders (in green) inside slice 15 (below).](image)

**Results and Discussion:** The lung dose value obtained was (44.4 ± 1.5) mGy, with 0.148 mGy.mAs−1 This value is considered reasonable when compared to similar studies. The doses due to both SPR are accounted in this estimation, which could explain this larger absorbed dose values.

**Conclusions:** This work shows a methodology to estimate lung doses to adult anthropomorphic phantom due to CT exams. The methodology will be extended to other organs of interest and other protocols in the course of time, and also adapted to a pediatric anthropomorphic phantoms.
PS05.029 - Verification of axial dose distributions with radiochromic films for a translational Total Body Irradiation technique

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Purpose:
Radiochromic films were used to validate dosimetrically a translational Total Body Irradiation (TBI) technique. The main objective was to analyze the homogeneity of the dose distribution in the axial plane for the thoracic and pelvic regions. Additionally, the surface dose was studied for two different positions of the PMMA beam spoiler.

Methods and materials:
Two phantoms were used: CIRS Thorax (Model 0002LFC, Computed Imaging Reference Systems Inc. Norfolk, VA) and CIRS Pelvis (Model 002PRA). They were irradiated according to a translational TBI technique [1] in supine and prone positions, and with a 1 cm PMMA spoiler situated 15 cm and 125 cm above the phantom surface. For each irradiation, two 8 in. x 10 in. EBT3 Gafchromic films (Ashland Inc., Wayne, NJ) were used to measure the dose distribution in the phantom. Doses were calculated using Radiochromic.com v1.7 (http://radiochromic.com) [2].

Results:
The homogeneity index (HI), calculated as D5/D95, was 1.16 and 1.23 for the pelvis and thorax phantom, respectively. This was mainly due to the shape of the phantoms, which become thinner in the lateral direction, producing doses up to 20% higher in the laterals than in the midline. Considering only a segment of the dose plane of 6 cm around the midline (3 cm on each side), the HI was 1.03 and 1.07 for the pelvis and thorax phantom, respectively, exhibiting higher dose homogeneity in the anteroposterior axis. When the spoiler was situated 15 cm above the phantom surface, the skin dose in the midline was 94% of Dmax. When it was 125 cm above the phantom, the same isodose was achieved at a depth of 6 mm.

Conclusions:
It was concluded that a 1 cm thick PMMA beam spoiler, situated 15 cm above the phantom, raises the surface dose to an acceptable level. Near the midline, this TBI technique delivers a dose homogeneity in the anteroposterior axis well within the common limits of +/- 10% relative to the prescription dose. For thinner regions, higher doses up to 25% relative to the prescription dose were considered admissible with the present technique.

References:

Purpose/objective:
The higher survival rate of radiotherapy patients entails a growing concern on late effects associated to peripheral doses. The purpose of this work is to evaluate experimentally the peripheral dose outside applicators at the patient level, in different high-energy electron beams used in external-beam-radiotherapy.

Methods and materials:
Commissioning was performed for 6, 9, 12 and 18 MeV electron beams on three different linear accelerators equipped with three different types of applicators. For each beam energy, measurements were performed, in a water phantom, at different depths, with applicator sizes varying from 6 x 6 cm² to 20 x 20 cm², for off-axis distances from 5 cm to 65 cm outward. Thermoluminescent dosimeters (TLD-700) powder measurements were compared to EBT3 films measurements and plane-parallel ionization chamber NACP measurements. Measurements at 10 cm without applicator were made and were compared to the same measurements with applicator.

Results:
Whatever the field size and energy beam, a peak dose spot appeared about at 12.5 cm from the field edge for the Siemens applicators. For Siemens Primus with an applicator size of 10 x 10 cm², this peak reaches 2.3%, 1%, 0.9% and 1.3% of the maximum central axis dose (Dmax) for 6, 9, 12 and 18 MeV electron beams, respectively, doubled for 6 x 6 cm² field size. For Siemens Oncor, with the above applicator size, this peak dose reaches 0.8%, 1%, 1.4% and 1.5% of Dmax for 6, 9, 12 and 14 MeV, respectively, increased when applicator size increased. In contrast for Varian 2300C/D, the doses at 12.5 cm from field edge are 0.3%, 0.5%, 0.6% and 1.1% of Dmax for 6, 9, 12 and 18 MeV, respectively, increased with increasing of applicator size. No peak dose spot is evidenced for Varian applicator. Measurements made at 10 cm depth showed that, depending on beam energy, applicator size, collimator size, and out-of-field distance, the peripheral dose represents 0.01% to 1% of Dmax. Peripheral dose, for the measurements made at 10 cm depth without applicator, was of 55% less than peripheral dose for the same measurements with applicator.

Conclusion:
In certain circumstances the peripheral doses from electron beams may be comparable to values reported for photon beams. Our results should be considered in the optimization of treatment planning and also in studies exploring RT long term effects.

PS05.031 - Dosimetric study for a set iodine-125 seeds using radiochromic films in solid water plates

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Purpose:
The set of iodine-125 seeds is frequently used in cancer treatment. A set of four iodine-125 seeds, model 6711 produced by Amersham Health, were used in this work. These seeds are ranked among the top choices when it comes to the treatment of prostate cancer. These sources emit X and gamma photons with an average energy of 28 keV and a half-life of 59.4 days. The dosimetric characteristics for a seed were obtained taking into account the recommendations of TG-43 protocol, developed by the AAPM (American Association of Physicists in Medicine). To realize the experiment three plates of Standard Grade Solid Water, model 457 Gammex were used. One solid water plate was machined for accommodate the seed set and radiochromic films were used on the machined plate and under...
An experiment was carried out at the BL28B2 beamline of SPring-8. A 25-mm-wide microbeam of x-rays was scanned at 6-mm intervals in the chamber. Figure 1(b) shows the resulting energy deposition curves compared with results at a 1-mm depth in the PMMA phantom measured using a GafChromic film [1] at a probably slightly different alignment condition.


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**PS05.032 - Evaluation of bismuth shielding use in cervical spine CT scans**

**Author(s):** Arnaldo P. Mourao Filho, Carolina Aleme Nehos, Centro Federal de Educação Tecnológica de Minas Gerais, Belo Horizonte/BRAZIL

Computed tomography (CT) is one of the imaging techniques most commonly used for invasive assessments of internal structures of the human body. However, the radiation exposure of patients can cause damages to their health. This study aims to evaluate changes in image quality in scans of the cervical spine CT, when using bismuth shielding to reduce the radiation dose deposited in the thyroid. In a multislice GE Bright Speed CT scanner with 32 channels were done two scans of the neck region, in order to generate diagnostic images of the cervical spine of an Alderson Rando male phantom. The scans were performed with the standard hospital protocol for cervical spine evaluation. The first scan using the thyroid bismuth shielding on the front neck region, and the second without it. Punctual radiation doses in organs (thyroid, breasts, lenses and spinal cord) was recorded using thermoluminescent dosimeters and the image quality control parameters were observed using the image J software. The use of sium shielding resulted in a reduction of 26% in the thyroid dose, while generated a small degradation in the axial images obtained, mainly in the frontal structures, closer to the surface where was the bismuth shielding. Thus, the use of bismuth shielding improved the diagnostic process allowing for dose reduction without compromising the diagnostic quality imaging of the skeletal structures of the neck.

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**PS05.033 - Scanning irradiation of microbeam x-rays in ionization chambers as micro-scale dose analysis tool**

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¹Light Source And Optics Division, Japan Synchrotron Radiation Research Institute, Hyogo/JAPAN, ²Research And Utilization Division, Japan Synchrotron Radiation Research Institute, Hyogo/JAPAN

Microbeam x-rays have been used extensively in various applications, with further applications in the medical field being highly anticipated. For the realization of clinical applications, high spatial-resolution dosimetry is necessary. GafChromatic films HD-810 have long been used for microbeam dose distribution; if another dosimeter is available, the use of these films for this purpose will be fully examined.

Ionization chambers are widely used as absolute dosimeters. The sensitive volume is surrounded by resin, so that the step-by-step scanning microbeam irradiation near the sensitive volume/resin interface was expected to enable the measurement of micro-scale dose distribution in the resin. Figure 1(a) shows the energy deposition in the sensitive volume of the Advanced Markus chamber calculated using a Monte Carlo (MC) code as a function of the incident microbeam position on the side of the chamber along the direction of electric force. Around the edge of the PMMA electrode, the right shoulder curves were almost in agreement with the dose distribution in the PMMA phantom calculated using the MC code [1].
PS05.034 - Dosimetric verification of the scatter integration algorithm of MIRS treatment planning system for photon dose calculations

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Background and purpose: Dosimetric quality control methods by IAEA for treatment planning systems, were tested for scatter integration algorithm. The purpose of this study was to find out the extent of the deviation between planned and delivered dose in different fields and photon energies in homogeneous and heterogeneous media.

Materials and methods: The methodology was based on a semi-automated tomography (CT) images of mentioned phantom with 2mm slice thickness were transferred to the examined TPS (MIRS treatment planning system) and seven different plans according to IAEA task report (TEC-DOC 1583) were designed. Experimental measurements by a farmer type chamber 0.6cc (PTW 30010 ion chamber) at 13 points carried out at 6, 10 and 18 nominal photon energies.

Results: A total of 21 clinical test case datasets for different energies were produced. In most of cases in homogeneous media, the results were in agreement with predefined criteria. The amount of variations in heterogeneous area increases with the beam energy and decreases with the depth increasing.

Conclusion: Large deviations exist in wedge fields and heterogeneities especially in lung. In homogeneous media and using open fields the scatter integration algorithm results are reliable.

PS05.035 - Characterisation of EPSONV700 flatbed scanner for EBT3 Gafchromic film dosimetry.

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Purpose: When a flatbed type scanner, not specifically made for radiotherapy dosimetry, is used to acquire Gafchromic film dosimetry data, error can occur in the measured pixel value. These errors result from the position dependent response of the scanner, the variation in thickness of the active layer in Gaf film which occurs during the manufacturing process, rotation of the film dosimeters and the scattered photons entering the film dosimeter scanning area. The purpose of this work is to determine the magnitude of these errors and propose methods to correct for these errors.

Methods and Materials: To determine the positional dependent response of the flatbed scanner two types of tests were carried out. In the first test one whole unirradiated film was scanned. Average pixel value measured with the region of interest (ROI) covering whole film. Orthogonal profiles at five locations, covering the whole film were performed and average pixel value for each location was calculated. In the second test, the scanning area was divided into 12 equally spaced regions. A 2 cm² piece of unirradiated film was placed in each position and scans were performed for each location. To determine the effect of film rotation, one 2 cm² piece of film was irradiated to 1Gy dose. Scans were performed with the film at 0°, 22.5°, 45°, 67.5° and 90° rotations and changes in the average pixel value and standard deviation was compared. The scanner was operated with SilverFast (LaserSoft Imaging) software, in transparency mode, with colour correction disabled. To reduce noise due to random fluctuations of the light signal, 3 scans were performed as a 48 bit non compressed TIF images. The centre 1 cm² region of each square was averaged to obtain the response (pixel value) corresponding to the delivered dose, using ImageJ software.

Results: The average pixel value for the whole film was 42093 ± 263 (0.6%) and for the 12 equally spaced areas of the scanned film, average pixel value was 42092 ± 275 (0.7%). For the 12 positions on the scanning area, the variation in the pixel value was 0.7% (41642 ± 297). The variation in pixel value for the five orthogonal profile measurements different locations was close to ± 0.5% except for the left vertical region of the film. The variation in pixel value with film rotation ranged from -1% at 22.5° to -5% at 90° rotation, with respect to 0° rotation.

Conclusion: The ESPON V700 is a suitable scanner for EBT3 Gafchromic film dosimetry. The variation in pixel value of EBT3 film scanned using EPSONV700 scanner is negligible except in the extreme left and top of the scanned area. Placing the film dosimeters in the central part of the scanning area and using a template with cut outs for placing film dosimeters orthogonally will further reduce the errors due to film detector non-uniformity, scanner rotation, rotation of film dosimeter and the scattered light photons.

PS05.036 - Nanodosimetric parameters obtained using the Monte Carlo codes PARTRAC, PTra and Geant4-DNA: a comparison study

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The nanoscopic pattern of ionisation radiation, called track structure, is a crucial tool for estimating nanodosimetric quantities that are not directly measurable in biological tissues. This work compares nanodosimetric parameters of track structure (NPTS) obtained with the Monte Carlo track structure codes PARTRAC [1], PTra [2] and Geant4-DNA [3].

In order to calculate the NPTS, two simplified target geometries were used: a liquid-water cylinder of 2.3 nm diameter and 3.4 nm length, representing a 10-base-pair DNA segment; and a liquid-water cylinder of 2.3 nm diameter and 3.4 nm length, representing a nucleosome. For the comparison study of the three codes the following particle type and energies were used: electrons ranging from 20 eV to 1000 eV, protons with energies between 3 MeV and 10 MeV; and alpha particles with incident energies of 8 MeV, 10 MeV and 20 MeV. The radiation field was simulated as a monoenergetic pencil beam incident on the surface of the liquid water cylinders at half their height. The ion beam energies were matched to those used for cell irradiations performed at the PTB ion microbeam facility as part of the BioQuaRT project [4].

In nanodosimetry, the physical features of charged particles passing or penetrating a given target volume at a given distance are described by the probability distribution of the number of ionisations occurring within the volume. This probability distribution, which characterises the radiation quality Q associated with the particle track, also depends on the geometry and orientation of the target volume. This work compares the probability distributions and their statistical moments, such as the mean ionisation cluster size $M(Q)$, obtained for all three codes. In general, the results show a good agreement between the codes for all particle types and energies, except for electrons below 150 eV, where results obtained with PTra deviate from those obtained with PARTRAC and Geant4-DNA.
This work has been funded by the EMRP Researcher Excellence Grant SIB06-REG3. The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

References


PS05.038 - A method to reduce the patient’s eye lens dose during cerebral angiography procedures

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**Purpose:** To propose a radiation protector layer to reduce the radiation dose to the patient’s eye lens during cerebral angiography procedures.

**Materials and methods:** The radiation protector layer was fabricated using VytaFlex 40 polyurethane rubber, with thickness and CT number of 1.8 cm and 89.0 HU, respectively.

The radiation dose received at the left eye and left eyelid for an aneurysm procedure were measured using an adult female anthropomorphic phantom and Gafchromatic XR-RV3 film [Fig. 1]. The procedure was repeated with and without using the protector layer and effects of this layer on the fluoroscopic image and Automatic Brightness Control (ABC) exposure parameters were studied.

**Result:** The protective layer reduced the dose to the left eyelid by 31% and to the left eye lens by 16.7%. The protector layer is radiolucent under DSA, but it can be seen in fluoroscopic images [Figure 1(b & c)]. However, the protector does not affect the ABC exposure parameters and does not perturb and interfere with the treatment procedure.

**Conclusion:** The eye lens protector layer reduces the patient’s eye lens dose during cerebral angiography procedure by attenuating the primary x-ray beam from the lateral tube.

Figure 2 shows the effect of the radiation protector layer on dose level at left eyelid position, (a) without and (b) with protector, and dose distribution over the patient’s head, (c) without and (d) with protector, during an randomly selected aneurysm procedure.

**Figure 2**

**Figure 1a)** The positions of the protector layer and radiochromic film, 1: underneath the protector layer and 2: sandwiched between the phantom’s slabs. Effect of protector layer on fluoroscopic image from (b) frontal and (c) lateral tube
PS05.039 - Angular dependence of absorption spectrum of Gafchromic EBT2 film
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It is important to study absorption spectrum in film dosimetry because the spectral absorbance of the film relates to the film’s total absorption dose. We investigated the absorption spectra of Gafchromic EBT2 film with various rotational angles in a visible wavelength band. The film was irradiated with 6 MV photon beams and a total dose of 300 cGy. Absorption spectra were taken under different rotational angles after 24 h irradiation and we fitted the spectra using Lorentzian functions. There were two dominant absorption peaks at approximately 586 nm (green) and 634 nm (red). The measured spectrum was decomposed at 542 nm, 558 nm, 578 nm, 586 nm, 626 nm, 634 nm, and 641 nm. The maximum total area of the red band absorption spectrum was at 45° (225°) and the minimum at 90° (270°). As the angle of rotation changed, the intensity and integrated area of the blue and green peaks also changed with 180° period, with minima at 90° and 270°, and maxima at 0° and 180°, although the overall absorbance is very low. The spectral peak wavelengths remained constant within ±1.2 nm for all angles. There was no hysteresis of absorption spectrum of the film; spectra taken at 0° and 360° were substantially the same and showed similar behavior for all rotational angles. The change of absorbance with rotational angle of the film affected the dosimetric properties, resulting in rotational variations of film dosimetry in each red-green-blue channel.

PS05.040 - Patient dose audit in mammography
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This study presents the results of a patient dose audit performed in the period Dec 2013 to Feb 2014 on a full field digital mammography unit GE Senographe DS, to: evaluate conformance with the European diagnostic reference levels (DRLs); provide the physician with an estimate of the effective doses involved in bilateral mammography examinations; and, evaluate if displayed dose indicators (Entrance skin exposure (ESE) and average glandular dose (AGD)) can give direct information, relevant for patient dose assessment. According with the Portuguese legislation for medical radiological exposures [Decree-law n° 180/2002] we applied the diagnostic reference level concept in mammography examinations, estimating the average entrance surface dose (ESD) for a sample of 10 standard breasts, and compared it with the European DRL - ESD of the 3rd quartile of a broad dose survey distribution. To assess the patient radiation doses involved we estimated the average dose to the glandular tissue within breast (AGD) since it is the glandular tissue that is believed to be the most sensitive to radiation induced carcinogenesis, and optionally converted it into effective dose for comparison with other diagnostic radiology exams. Half-value layer (HVL) and radiation output data obtained from quality control (according with EFOMP Mamo Protocol 2014) were used for the entrance surface dose (ESD) and average glandular dose (AGD) assessments using the appropriate conversion factors [IAEA (2007), Dance (2000), Dance (2009)]. AGD and effective doses for bilateral mammography were obtained for a range of breast thickness intervals using Dance tables and ICRP 103 breast tissue weighting factor 0.12. The percentage of glandularity was determined using the qualitative method described by Byng (1994). The results were: ESD = 5.8 mGy for cranio-caudal (CC) and ESD = 6.1 mGy for medio lateral oblique (MLO) projections. These results are considerably below the European DRL’s (10 mGy). Average effective doses for a bilateral mammography for each compressed breast thickness interval results were: E = 0.28 mSv for small breasts (34.5±4.5mm); For medium breasts we considered 3 compressed thickness intervals E = 0.35 mSv (44.5±4.5mm); E = 0.33 mSv (54.5±4.5mm); E = 0.45 mSv (64.5±4.5mm); E = 0.61 mSv for large breasts (74.5±4.5mm) and E = 0.69 mSv for very large breasts (84.5±4.5mm). In general, larger compressed breast thickness is associated with a higher AGD and patient effective dose. No correlation was found between AGD shown on the GE Senographe DS display and calculated AGD, but high correlation was found between the displayed entrance skin exposure (ESE) and entrance skin air kerma (ESAK) measurements the average conversion coefficient with 2σ confidence level being (1.01 ±0.05).This results suggests we can use displayed ESE for dose assessments. The annual system conversion factor (CF) measurement (factor used by the system to convert brightness to dose for all AOP-related calculations) and HVL measurement (measures HVL and Output) are essential for dose optimization and patient dose calculations with Senographe DS.

PS05.041 - Experience in implementing a dosimetric registry in an oncological facility of a developing country
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Diagnostic Radiology and Nuclear Medicine studies are an effective tool especially in an oncology facilities where are needed for the diagnostic and also to known the treatment response.

Radiation and radiation dose reduction are at the top of the list of controversial topics in medical imaging today. The risks associated with the use of ionizing radiation in diagnostic imaging include cancer, burns and other injuries.

Is known that the main contribution to cumulative dose is for CT scans (49%), but represents a minus percentage (16%) by type of procedures. However in an Oncology Hospital of Mexico the CT’s scans and PET-CT represent more than 30% of the total studies. In this country currently there aren’t a national policy of registry or collection of dosimetric data.

We have identified several patients with more than 20 CT scans in 24 months or patients with several PET-CT in a small time. That is why in 2014 began the implementation of a registry dose for dosimetric data collection. Unfortunately even when all the radiological equipment are digital direct, some of them had not installed the ionization chamber. When was required data information to the service providers, they didn’t know the topic.

A CT scanner was installed in 2011 and was not acquired the license DICOM RDSR. But a second CT was acquired in 2014 and the provider didn’t know the license required. Also the PACS system has not the ability to receive DICOM RDSR and there are no plans to integrate or upgrade for registry dose data.

To choose the system to collect the dose data we did some market research and found that one of the commercial systems offered great logging capabilities of different modalities. However, this system is not available for the reference country.

That was why we decided to implement the Radiance system, which allowed us to start the dosimetry data collection of 4 CTs, finding information that allowed us to start internal political request for radiological studies.
PS05.042 - Effects of irradiation with low and high doses using in vivo rats: analysis of trace elements in blood using SR-TXRF

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Both natural and man-made sources of ionizing radiation contribute to human exposure and consequently pose a possible risk to human health. While natural background radiation is unavoidable, the increased medical use of radiation, e.g. X-ray and CT scans for diagnosis, inevitably increases the public’s health risk concerns over exposure of low doses of ionizing radiation. The effect of low-dose radiation on cells and tissues is a public health concern, because the human population is exposed to low-dose ionizing radiation coming from a variety of sources, such as cosmic rays, soil radioactivity, environmental contaminations, and various medical procedures. And the effect of high dose radiation can cause more severe damage, by radiotherapy treatment or nuclear accidents such as Chernobyl in 1986 and the Fukushima Daiichi Nuclear Power Plant in 2011. Exposure to ionizing radiation may cause various types of cell damage, and the type of damage is different from low to high doses of radiation. Although the damaging health effects of exposure to high doses of radiation are well documented, more work needs to be done to establish a biologic signature for exposure to low dose. Previous studies have shown that exposure to low radiation dose reduces cell killing compared with a single dose of high radiation dose. There is great interest in the identification of biological markers for exposure to ionizing radiation for the detection of people exposed to low or high radiation dose, which could be in risk to develop late side effects of this exposition. To our knowledge, until now there is no such a convenient biomarker. Our purpose is to use an animal model, with Wistar rats, to analyze the peripheral blood activity, environmental contaminations, and various medical procedures. The obtained results help to identify the differences in the elements concentrations among the analyzed groups, and it can be associated with the received radiation doses. These results are be important with the proposed improved setup here detailed, comparing the results between three groups (control, LD and HD). The study protocol was approved by the local ethical council (No. CEUA/010/2012). The aim is to quantify the trace elements contained in the blood, and compare the results between three groups (control, LD and HD). The obtained results will help to identify the differences in the elements concentrations among the analyzed groups, and it can be associated with the received radiation doses.

Conclusions

Our experiences showed both, the substantial necessity of using extended cables and the impossibility of measuring in anthropomorphic phantom points without cable irradiation. Measurements are now possible with the proposed improved setup here detailed, taking special care on cables and connections quality. Cable extension has a negligible contribution. Cable irradiation could reach a 2.4 m (5.4 m for the reference detector [1]) cable was extended with 300 MU measurements. This work shows some difficulties when adapting TNRD detectors to radiotherapy environments, mainly due to the fact that it has shown structural limitations. Two problems have been studied: (1) the influence of cable lengthening, necessary to be operative in a radiotherapy environment and (2) cable irradiation during the measurements. As we are measuring very small signals, we have to take into account not only these two facts but also the quality of the materials and connectors used.

Material and Method

Original cable length of TNRD detectors was 0.8 m but an extension to a 2.4 m (5.4 m for the reference detector [1]) cable was done to establish a biologic signature for exposure to low dose. Previous studies have shown that exposure to low radiation dose reduces cell killing compared with a single dose of high radiation dose. There is great interest in the identification of biological markers for exposure to ionizing radiation for the detection of people exposed to low or high radiation dose, which could be in risk to develop late side effects of this exposition. To our knowledge, until now there is no such a convenient biomarker. Our purpose is to use an animal model, with Wistar rats, to analyze the peripheral blood activity, environmental contaminations, and various medical procedures. The obtained results help to identify the differences in the elements concentrations among the analyzed groups, and it can be associated with the received radiation doses. These results are be important with the proposed improved setup here detailed, comparing the results between three groups (control, LD and HD). The study protocol was approved by the local ethical council (No. CEUA/010/2012). The aim is to quantify the trace elements contained in the blood, and compare the results between three groups (control, LD and HD). The obtained results will help to identify the differences in the elements concentrations among the analyzed groups, and it can be associated with the received radiation doses.

PS05.043 - Effects of cable extension and photon irradiation on TNRD neutron detector in radiotherapy

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Introduction

A new thermal neutron detector (TNRD), developed for nuclear research, has shown to be effective for clinical use in peripheral neutron dose estimation, either in patient and ‘in-phantom’ measurements [1]. This work shows some difficulties when adapting TNRD detectors to radiotherapy environments, mainly due to the fact that it has shown structural limitations. Two problems have been studied: (1) the influence of cable lengthening, necessary to be operative in a radiotherapy environment and (2) cable irradiation during the measurements. As we are measuring very small signals, we have to take into account not only these two facts but also the quality of the materials and connectors used.

Results

Mean loss of signal of (-0.09±0.08)% per meter of cable, has been obtained for the six detectors when measuring with extension cables with respect to the original setup. A good linearity response was observed for the six detectors when measuring with extension cables with respect to the original setup. A good linearity response, having special care in the implementation and quality of the components and its linearity response, were evaluated under a 10x10 cm² squared field in 15 MV (SSD=100 cm). The influence of the unavoidable cable irradiation [2], was evaluated by series of 300 MU measurements in 4 consecutive fields, with and without cable irradiation (ranging from 10 to 65.6 cm of cable irradiated).

All the measurements were performed in a 15 MV Siemens Primus linac, with detectors inserted in the middle of 8 cm of polyethylene.

Table shows TNRD signal in 15 MV, difference in readings between irradiation and no-irradiation of the cable, and the percentage that represents this difference with respect to total values.

<table>
<thead>
<tr>
<th>Field size (cm²)</th>
<th>Total signal (V s)</th>
<th>Irradiation-Non Irradiation (V s)</th>
<th>Relative Deviation (%)</th>
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<tbody>
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<td>10x10</td>
<td>74.17</td>
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<td>-0.83</td>
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</table>

Conclusions

Our experiences showed both, the substantial necessity of using extended cables and the impossibility of measuring in anthropomorphic phantom points without cable irradiation. Measurements are now possible with the proposed improved setup here detailed, taking special care on cables and connections quality. Cable extension has a negligible contribution. Cable irradiation could reach a 2.4 m (5.4 m for the reference detector [1]) cable was extended with 300 MU measurements. This work shows some difficulties when adapting TNRD detectors to radiotherapy environments, mainly due to the fact that it has shown structural limitations. Two problems have been studied: (1) the influence of cable lengthening, necessary to be operative in a radiotherapy environment and (2) cable irradiation during the measurements. As we are measuring very small signals, we have to take into account not only these two facts but also the quality of the materials and connectors used.

References

PS05.044 - Thermoluminescence dosimetry (TLD) for in vivo dosimetry in radiation therapy with high single doses

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**Purpose:** The aim of this work was to find an extrapolation model to describe the non-linearity of thermoluminescence (TL) dosimeters and to measure single high absolute doses in vivo in rat tissue as accurately as possible.

**Materials and Methods:** For dose-to-water calibrated TL phosphors (rod shaped LiF detectors), the supralinearity of high doses up to 70 Gy was determined using a self-developed calibration phantom. Dose values between 0.1 and 70 Gy were measured incrementally and the measurements were repeated three times. Supralinear behavior of TL phosphors generally follows the correlation $D_{irr} = f(D_{meas})$, whereas $D_{irr}$ is the measured TL output and $D_{meas}$ is the irradiated dose. The mathematical model is then used to perform a first trial of in vivo dosimetry in animals with TL Detectors. For this trial, male rats were transplanted with a syngeneic prostate tumor (Dunning R3327-Hi) at the right hind limb. The TL Detectors were embedded in a commercially available shrink-on tube to avoid surface contamination of the detectors with substances of any kind e.g. dust, blood. Four detectors were placed via 3 mm long incisions subcutaneously around the tumor volume (Fig. 1b) of six male rats. Dose levels of 30, 50 and 70 Gy were chosen referring to former dose-response experiments with this tumor model.

**Results:** The resulting progression of supralinearity needed to be split in three regions regarding to the TL output. Following sections were specified: 1) linear relation for $D_{irr} = 0...2$ Gy; 2) square root fit for $D_{irr} = 2...55$ Gy and 3) cubic polynomial fit function for $D_{irr} = 55...70$ Gy (Fig. 1a). The resulting models fit the measured data points with an average error of ± 2.6 %. Measured values in the rats for irradiations with 30 (50 and 70 Gy) were determined between 29.5 and 32.5 Gy (50.1 and 53.1 Gy / 69.8 and 73.5 Gy, respectively). It was even possible to define dose gradients at the field edge due to the position of the TL detector according to the position of the tumor volume.

**Conclusion:** The trial was a novel method of in vivo dose measurement and produced convincing results with very high accuracy. Thus, the experiments of this study are an important step for in vivo dosimetry. As a future project, the phosphors might be implanted already at an early stage of tumor growth in order to achieve more representative dose values in the center of the tumor volume.

PS05.045 - Study of the response of ionization chambers in photon beams for off-axis point dose

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Numerous challenges associated with small-field dosimetry compared with standard dosimetry, primarily because of the different irradiation conditions than that of the standard case. These challenges include concerns regarding reliability in the fields of small-field stereotactic radiotherapy and radiosurgery with respect to radiation detection. Furthermore, the use of intensity modulated radiotherapy (IMRT) has increased for the treatment of difficulty situated carcinomas. Therefore, while employing IMRT, measurements should include small fields as well as off-axis measurements. In this study, we investigated the response of small-volume ionization chambers and Farmer-type chambers for dose profile measurements at different measurement depths. We found that the response of the ionization chamber decreased at maximum dose depth when moving from the central axis to the 15 cm off-axis position. Until now, only a 0.1 cm³-volume ionization chamber has been investigated. The Farmer-type ionization chamber investigated herein behaved similarly to the small-volume ionization chamber. The response of Farmer-type ionization chamber decreased by 3.1% and 3.5% for the 4 and 14 MV beams, respectively. Furthermore, the response both Farmer-type ionization chamber and small-volume ionization chamber increased with decreasing nominal photon energy. This under response could be the result of the variation of the wall correction factor.

PS05.046 - Analysis of gamma evaluation according to low-dose threshold on VMAT QA

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The American Association of Physicists in Medicine task group-119 (TG-119) recommends applying 10% of the low-dose threshold for gamma evaluation to restrict low-dose region. However, TG-119 didn’t present clinical data to quantitatively demonstrate the impact of the low-dose threshold on the gamma index. Therefore, we performed a gamma evaluation with various low-dose thresholds in the range of 0% to 15% according to both global and local normalization and different acceptance criteria (3%/3 mm, 2%/2 mm, and 1%/1 mm). A total of 30 treatment plans—10 head and neck (H&N), 10 brain, and 10 prostate cancer cases—were selected from the Varian Eclipse treatment planning system (TPS) retrospectively. For the gamma evaluation, a calculated portal image was acquired through a verification plan process in the Eclipse TPS, and a measured portal image was obtained using an electronic portal imaging device. Then, the gamma evaluation was performed using Portal Dosimetry software. As a result, for the global normalization, the gamma passing rate (%) decreased as the low-dose threshold increased, and all cases of low-dose thresholds exhibited an acceptable %GP above 95% for both the 3%/3 mm and 2%/2 mm criteria. On the other hand, for local normalization, the %GP with 10% of low dose threshold increased by 18.64% and 17.45% compared with
the 0% of low dose threshold in brain case for 1%/1 mm and 2%/2 mm criteria, respectively. Even in 3%/3 mm acceptance criteria, the %GP increased by up to 9.22%. In conclusion, we suggest applying the 2%/2 mm criteria, which are more stringent criteria than those of 3%/3 mm, for the global gamma evaluation because it exhibits a tolerable passing rate for all low-dose thresholds. In contrast, local gamma analysis should be used for a lower dose threshold level below 10% to acquire more precise test results, despite the TG-119 recommendation, because it may provide an overestimated %GP by excessively excluding the dose discrepancy of the low-dose region.

**PS05.047 - Dosimetric accuracy of Acuros XB dose calculation algorithm on an air cavity for EBT3 Gafchromic film**

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**Purpose:** This study was to verify the dosimetric accuracy of Acuros XB (AXB) dose calculation algorithm on an air cavity for EBT3 Gafchromic film. Methods: A rectangular slab phantom containing an air cavity was made especially for this study. The phantom with and without the Gafchromic EBT3 films was scanned using Philips Big-bore CT scanner. The digital imaging and communications in medicine CT datasets of scanned the phantom were then transferred to the Eclipse treatment planning system. The central axis doses were calculated by anisotropic analytical algorithm (AAA) and AXB using a single filed of 6 MV flattening filter-free beam from TrueBeam linear accelerator. In phantom, we used various field sizes from 2 × 2 cm² to 5 × 5 cm². The dose profiles were generated at the depth of 4.5, 5.5, 6.5 and 7.5 cm, including the presence of an air cavity. All measurements for film dosimetry were performed under the same condition of the calculation with film. Results: With film in the slab phantom, CADs for AXB and AAA overestimated -5.55% and 131.60%, compared to those of measurements. However, differences of CADs without film were -27.72% and 144.20%. The CAD differences between AXB and AAA reduced with increasing field size and increased relative to the depth increment. The AXB dose calculation in an air cavity showed more agreement than AAA. Also the root means square error (RMSE) value of dose profiles for AXB were within 10%, while those of AAA were more difference than 30%. Conclusions: In this study, we confirmed that inclusion of film within an air cavity has affected on dose calculation with both algorithms. Our experimental phantom study demonstrated that the AXB is significantly more accurate for dose calculation in the region of an air cavity when compared with AAA. Therefore, we recommend the use of AXB instead of AAA for avoiding inaccurate dose calculation, especially on the clinical cases including air cavity.

**PS05.048 - Evaluation of Dosimetric Effects on Metal Artifact: Comparison of Dose Distributions Affected by Patient Teeth and Implants**

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**Purpose:** Implant-supported dentures seem particularly appropriate for the predicament of becoming edentulous and cancer patients are no exceptions. Metal artifacts generated by dental implants cause dose discrepancy in head-and-neck cancer cases due to the inaccurate predicted doses. To verify the theoretical analysis of the metal artifact, streak artifact and dark artifact, and also critical analysis of dosimetric effect which cause by dental implants in CT images of head and neck cancer patients with the patient teeth and implants inserted humanoid phantom. Methods: The phantom comprises cylinder which is shaped to simulate the anatomical structures of a human head and neck. Through applying various clinical cases, made phantom which is closely allied to human. Developed phantom can verify two classes: (i) dose measurement when patient closed mouth (ii) dose measurement when patient opened mouth. RapidArc plans of 4 cases were created in the Eclipse planning system. Total dose of 2000cGy in 10 fractions is prescribed to the whole planning target volume (PTV) using 6MV photon beams. Acuros XB (AXB) advanced dose calculation algorithm, Analytical Anisotropic Algorithm (AAA) and progressive resolution optimizer were used in dose optimization and calculation. Results: In closed and opened mouth phantom, because dark artifacts formed extensively around the metal implants, dose variation was relatively higher than that of streak artifacts. As the PTV was delineated on the dark regions or large streak artifact regions, maximum 7% dose error and average 3% difference was observed. The averaged minimum dose to the PTV predicted by AAA was about 5% higher and OARs doses are also 5% higher compared to AXB. Conclusion: AXB was found to have better dose predictions than AAA and at the tissue interfaces where backscatter occurs. Therefore, AXB is more appropriate to use for dose predictions, especially when low-density heterogeneities are involved.

**PS05.049 - Advancement of Dedicated Phantom to demonstrate Dosimetric Effect of Metal Artifact in Head and Neck Cancer**

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**Purpose:** Implant-supported dentures seem particularly appropriate for the predicament of becoming edentulous and cancer patients are no exceptions. The purpose of this study is to verify the clinical dosimetric effects of metal artifact in clinical cases by developing a realistic head and neck phantom.

**Materials and Methods:** The phantom comprises cylinder which is shaped to simulate the anatomical structures of a human head and neck. Through applying various clinical cases, Fig.1, phantom is closely allied to human. Developed phantom can verify two classes:
MeV. As the target nuclei, we consider 12C, 16O and 40Ca. The calculated results are compared with experimental data.

3. Results and Discussion
Fig. 1 is an example of the results, which shows the mass distribution of the fragments produced in the 12C+12C reaction at E/A=400 MeV. The open diamonds (triangles) represent the results of AMD (QMD) followed by GEM. AMD is found to give comparable results with QMD. In particular, they both give the cross sections of 7Be and 11C close to the experimental data (solid circles). On the other hand, for the neutron cross section, AMD is better than QMD.

4. Conclusion
Since AMD and QMD show the similar results of cross sections, we cannot determine which model is better for 12C+12C reaction. For the 40Ca target case, the difference is noticeable, but there exist too few appropriate data. In order to make simulation more accurate, more data are strongly desired.

Acknowledgements:
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References

Small field dosimetry is clearly recognized as difficult, increasingly (i) closed mouth (ii) opened mouth. Also, the inserted patient tooth can trade places. The phantom was made to enable film to be set-up between two slabs to compare the dosimetric impact and variation of dose distributions. Furthermore, mid-slabs of phantom contain few cylindroid holes for Radio-Photoluminescence Glass Dosimeter (RPLGD), same spots in opened and closed phantoms, where cause the streak and dark artifacts for the dose verification.

Results: The accuracy of dose calculations is essential to the quality of the radiotherapy treatment planning and tumor response. As after scanning the phantom, in closed and opened mouth phantom, because dark artifacts formed extensively around the metal implants, dose variation was relatively higher than that of streak artifacts. The phantom was capable of producing realistic head and neck metal artifact imaging data from which imaging devices and techniques can be evaluated.

Conclusions: The phantom provides a unique and useful tool in head and neck dosimetry research. It can be used in the development of new imaging instrumentation, image acquisition strategies, and image processing and reconstruction methods.

Figure 1,

1. Introduction
During particle therapy, radionuclides are produced in patient bodies and equipment. In the view point of utilizing them for the beam on-line PET, radiation protection, etc., it is important to understand the phenomena induced by therapeutic particle beams, and simulation is essential as well as measurements. Although Quantum Molecular Dynamics (QMD) is frequently adopted in simulation as the model for nuclear reactions, they do not entirely reproduce experimental data. In this study, we focus on Antisymmetrized Molecular Dynamics (AMD), which is thought to have more theoretical validity than QMD, and investigate its accuracy comparing with QMD.

2. Materials and Methods
We use the AMD code developed by Ono1). The QMD calculation is performed with PHITS2). AMD and QMD describe the dynamical processes of nuclear reactions. The resultant fragments may be in excited states, and decay with the statistical process, which is described by a generalized evaporation model (GEM3). The GEM calculation after QMD is done as a sequence of the PHITS calculation. For GEM after AMD, we use the same code as in PHITS. We investigate 12C induced nuclear reactions at E/A=20 MeV - 400 MeV. As the target nuclei, we consider 12C, 16O and 40Ca. The calculated results are compared with experimental data.

3. Results and Discussion
Fig. 1 is an example of the results, which shows the mass distribution of the fragments produced in the 12C+12C reaction at E/A=400 MeV. The open diamonds (triangles) represent the results of AMD (QMD) followed by GEM. AMD is found to give comparable results with QMD. In particular, they both give the cross sections of 7Be and 11C close to the experimental data (solid circles). On the other hand, for the neutron cross section, AMD is better than QMD.

4. Conclusion
Since AMD and QMD show the similar results of cross sections, we cannot determine which model is better for 12C+12C reaction. For the 40Ca target case, the difference is noticeable, but there exist too few appropriate data. In order to make simulation more accurate, more data are strongly desired.

Acknowledgements:
This work was supported by JSPS Core-to-Core Program (No.23003) and KAKENHI (No. 23791419).

References
so as the size reduces, yet consistent data is necessary for accuracy in clinical use, for applications of small fields themselves and also as components of more complex beams. However, the overall reported data in the literature contains relatively large inconsistencies. To consider how to resolve these differences and how to improve the practical approaches and associated uncertainties requires careful standardised measurements, validated Monte-Carlo (MC)-based correction factors and possible new thinking on detectors. In addition it requires clear understanding of what the parameters reported truly describe and clear reporting of data, where values should be correlated to actual delivered dosimetric field size, and not to nominal or set field size, to enable careful comparison between linacs. For very small field sizes, greater attention is required to the experimental measurement and reporting methods, requiring clear guidelines for what is a ‘very small field size’ and for when such more detailed methods are needed.

A range of measurements and MC modelling studies have been reported by our joint collaborative groups. Based on these methods and results, data and recommendations have been published on:

- commissioning/fine-tuning MC models for small field sizes; and the interplay between modelling and measurements to achieve this;
- modelling-based correction factors for a range of shielded and unshielded diodes for 6MV beams; - what constitutes a ‘very small field size’ (essentially fields smaller than 1.5 cm in size for 6 MV), based on the different effects as field size gets smaller and their consequences for uncertainties; - measurement methods necessary to control uncertainties at these smaller field sizes (essentially measuring beam profiles at the same time as output factor, to ensure good alignment, but also to measure the actual dosimetric field sizes; - reporting of output factors for consistent comparison and applications; ie reporting against an effective field size taking into account measured dosimetric field sizes; and not just against nominal field size, in order to reduce the variations in reported data and allow interpolation between reported tabulated data eg on correction factors; - observations on detector design and modelling for possible ‘correction-free’ small detectors (eg scintillators, but also modified standard detectors such as diodes).

The approaches to each of these areas and the practical use of the data must be systematic and consistent. The above sets of work and recommendations provide coherent approaches, which are inter-linked. As national (eg AAPM) and international (eg IAEA) bodies develop protocols for small field dosimetry, it is critical that clear inter-dependent measurement and modelling based methods and data are recommended to improve the consistency and uncertainties involved and to provide the best accuracy possible in these increasingly clinically-used conditions.

**PS05.052 - Determination of Radon/Thoron Concentrations in Some Iraqi Building Materials By Using CR~39**

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Common building materials used for construction of houses, which are considered as major source of radon / thoron gases in indoor environment such as cement, gypsum, sand, and bricks. Samples of these materials had been collected from different factories distributed at different Iraqi areas in Baghdad, south, and in the west. The determinations of ra-don/thoron concentrations have been studied by using sealed can technique and CR-39 track detectors were irradiation for 30 days in a closed can. Standardization of irradiation effects for the same period on CR-39 detectors has been done on samples of known alpha particles emitters’ concentration, which are adopted by the International Atomic Energy Agency (IAEA). Radon/Thoron concentrations have been found to be varying from minimum value of 119.7 ± 2.6 Bq/m3 for Lime to a maximum value of 309 ± 8.6 Bq/m3 for Ordinary black cement. These results show that Iraqi building materials constituents contains low concentrations of background Radon / thoron natural sources of radiation.

**PS05.053 - Evaluation of Scattered Dose Reduction in Interventional Radiology Using Lead-Free Protection Sheets**

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**Introduction**

Occupational radiation dose in interventional radiology (IR) has become a concern due to increasing complexity of the procedures and fluoroscopic time. A lead-free (primarily Bi-83 and Sb-51) protection drape has been introduced to absorb scattered radiation by 50 to 95% at 90 kVp during IR procedures. To ensure the safety of medical personnel working with radiation, it is imperative that the efficacy of protection equipment meets the required standards.

**Aims and Objectives**

This research aimed to establish the physical characteristics and assess the efficacy of the protection drape (RadPad, Worldwide Innovations & Technologies, USA) in reducing scattered dose to the personnel, in comparison to a typical lead shield.

**Methods**

The physical characteristics of RadPad (Orange with a claimed 90% attenuation and Yellow with 75%) were assessed by establishing its attenuating and backscattering properties and its dose reduction profile. The percentage attenuation was measured using two calibrated semiconductor detectors, each placed before and after the protection drape, which was placed on a phantom and exposed at varying X-rays energies. Backscatter properties of RadPad were studied by measuring the entrance surface air kerma on a phantom, with and without the RadPad drape in place. An increase in reading when RadPad is in use would indicate backscattered radiation. RadPad’s dose reduction profile was established by analysing exposed radiochromic films partially covered by the protective drape. Additionally, the films were sandwiched between sheets of 2cm thick Perspex phantom to simulate dose distribution at different depths within the patient body. RadPad’s efficacy in dose reduction was further assessed through scattered radiation dose mapping during a simulated fluoroscopy-guided procedure, in which phantoms were used to simulate a radiologist and a patient. RadPad was placed over the patient phantom and exposure was made using routine fluoroscopy settings. Dose readings were obtained at varying heights on the radiologist phantom (brain, thyroid chest level) and at different positioning of the phantom in the fluoroscopy suite.

**Results and Conclusion**

RadPad significantly reduces scattered radiation dose to staff during prolonged fluoroscopy-guided procedure. RadPad Orange (90% attenuation) shows similar attenuation to 0.25 mm lead-equivalent shield at 90 kVp. However, empirical results show deviation from manufacturer specifications (85.8% and 71.6% for Orange and Yellow instead of 90% and 75% at 90 kVp respectively). Backscattered radiation was detected when RadPad was placed over the phantom, indicating possible increase in patient skin dose. 0.25 mm lead-equivalent produces higher backscatter radiation compared to RadPad, suggesting that RadPad is advantageous in reducing patient skin dose. RadPad has potential as additional radiation shielding, however its lower linear attenuation coefficient compared to lead suggests that it would not be an ideal replacement for lead as the primary personal radiation protection for medical staff.
PS05.054 - Dosimetric validation of Volumetric Modulated Arc Therapy (VMAT) in an upgraded Clinac 2100CD using AAPM TG-119 bench mark plans for Flattening Filter Free (FFF) photon beam

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Introduction: Recently in our center we have upgraded our Varian Clinac 2100CD linear accelerator machine with 6MV Flattening Filter Free (FFF) beam. Even though the dosimetric characteristics of FFF beam have been reported both in experimental and Monte Carlo studies, the application of FFF beams in planning and delivery is complicated.

Aim of this study is to validate the commissioning of upgraded 6MV FFF beam dosimetrically using AAPM-TG-119 bench-mark plans for VMAT and to compare with IMRT plan data for both FF and FFF beams.

Material and Methods: AAPM TG-119 proposes a set of test clinical cases for testing the accuracy IMRT planning and delivery system. For these test cases, we generated two treatment plans. The first plan was done using 7-9 IMRT fields and a second plan utilizing one- or two-arc VMAT. Dose optimization and calculations were performed using 6MV FF & FFF photons in EclipseTPS. Dose prescription and planning objectives were set according to the TG-119 goals and plans were scored based on planning objectives. Treatment plans were compared using dose coverage, con-formity index (CI) for reference dose and homogeneity index (HI D5–D95). Point doses were measured at points recommended using ion chamber CC13. Planner Dosimetry was done using iMatrix with Multicube and gamma evaluation was done using omnipro IMRT software with the criteria of 3% DD and 3 mm DTA.

Results and Discussion: VMAT dose distributions were comparable to IMRT plans. Our planning results were matched TG-119 planning results as shown in figure 1. conformity indices were ranged from 1.02–1.18. The point dose results were within 2% of planned dose values. All gamma evaluation results show gamma less than one for more than 95% data points.

There was a average reduction in treatment time using FFF beam as compare to FF beams for sliding window IMRT. In case of VMAT the reduction in treatment time was not significant as the dose per fraction was low and the gantry speed cannot be increased beyond 4.8°/sec.

Conclusion: The result from the study shows that FFF beam upgraded in Clinac 2100CD satisfies AAPM-TG-119 for the given bench mark plans. They are also helpful to gain confidence in new modalities like FFF based VMAT and to test its capabilities at preclinical implementation stage. Interestingly the study deduced that sliding window IMRT using 6MV FFF beam shows 40% reduction in the treatment time as compared to conventional 6MV FF.
PS05.055 - Study on Ion-recombination effect of 6MV Flattening Filter Free beam at isocenter and tray-level configuration using various detectors

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Introduction: In high energy linac, removal of flattening filter from the path of the beam produces unflat-beam, with increased dose-rate (1400 MU/min for 6MV FFF beam and 2400 MU/min for 10MV FFF beam). The recombination of ions formed by separate ionizing particle tracks is dependent on the density of ionizing particles i.e., Dose-rate. This effect depends on the chamber geometry and applied polarizing voltage (IAEA-TRS398).

VMAT employs dose-rate modulation with Gantry angle, but during Patient specific QA, point dose and 2D-Planar dosimetry calibration is done with a fixed constant dose-rate.

Recently vendors are coming up with 3D-online verification methods using (Transmission) detectors placed near tray-level of the gantry. For 6MV-FFF, the dose-rate at tray-level (SDD=62cm) is 3750MU/min.

The aim of this work, is to study the ion-recombination factor(ks) of 6MV-FFF beam at central-axis and off-axis of the beam using different volume chambers, with available dose-rates and also to study ion recombination effect near tray-level configuration.

Material and Methods: Measurements were performed on VarianTM Clinac 2100CD capable of delivering VMAT. Recently, we have upgraded the Clinac to deliver 6MV FFF beam with a maximum dose-rate of 1400MU/min. Different volume ion chambers FC65G, CC13, PPC05 and A14 with different electrode separation were used for measurement.

For a field size of 10x10cm², SSD=100cm and depth 5cm, ks was measured at central-axis and 2cm off-axis for different available dose-rates. To simulate tray-level configuration ks was measured using PPC05 and FC65G chambers with a build up of 2 cm. ks was calculated using two-voltage method for +300V & +150V and analysed.

Results and Discussion: Ion recombination(ks) was increasing with increase in chamber volume. But for a particular chamber, it was less significant for variations in nominal dose-rate, Figure 1.

At Central-axis the average ks for FC65G (rcav=3.1mm,0.65cc) was 1.0086±0.0014 (1SD) and for CC13 (rcav=3.0mm,0.13cc) was 1.0091±0.0014 (1SD), which was closely comparable. It shows that ks depends not only on chamber volume but also on electrode separation (rcav).

At Tray-level configuration, the average ks was 1.029±0.0034(1SD) for FC65G (rcav=3.1mm) and 1.006±0.0011(1SD) for PPC05 (2mm electrode spacing). However the ks was less significant for variations with nominal dose-rate.

Conclusion: For 6MV-FFF VMAT-QA, small volume chambers can be used for verification without correcting for ks in both CAX and off-axis. For Tray-level measurements, small volume chambers with electrode separation <2mm can be used without correcting for ks. However, at tray-level, Ion-recombination effect should be accounted for when electrode separation is >2mm.
PS06.001 - GEANT4 versus MCNP5: Monte-Carlo ophthalmic brachytherapy dosimetry in the presence of gold nanoparticles for 125I and 103Pd
Author(s): Shervin Vahidian, Mohammad Vahidian, Somayeh Asadi, Mehdi Vaez-Zadeh
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The emphasis of the present work is to compare the effect of gold nanoparticles (AuNps) on healthy human ocular tissues in ophthalmic brachytherapy dosimetry, between water and eye phantoms by utilization of the two most noteworthy Monte-Carlo codes of GEANT4 and MCNP5. The intended study was based upon a simulated model of the human eye consisting different parts such as Lens, Cornea, retina, Choroid, Sclera, skull bone, Anterior Chamber and a melanoma tumor which was latticed to house AuNps required for the dosimetry comparisons of two uniquely defined radionuclides of $^{125}$I and $^{103}$Pd. The effects of the presence of AuNps on the absorbed dose by the tumor have been taken into account using both Monte-Carlo codes mentioned above; furthermore, the aberrations in dose calculations of the simple eye phantom and the realistic eye model were also an element of consideration. The importance of such evaluations on various compositions that are most common in Monte Carlo studies could prove to be rewarding, especially in presence of external anomalies such as AuNps. With respect to the numerous distinctions between codes themselves, it is always fruitful to compare multiple of these programs with one another; hence, a rigorous inspection of the results has been executed, and dissimilarities have been highlighted for better understanding of the advantages and deficiencies of both codes. All in all, it is best stated that interdisciplinary methods of combining diverse therapeutic applications have gained much ground in our current era, and serve to significantly increase efficiency of cures worldwide.

PS06.002 - Clinical Implementation of an Elekta HexaPOD evo RT Couchtop with kV Cone beam Image Guided Radiation Therapy
Author(s): Lourdes M. Garcia, Cathy Neath
Medical Physics, Durham Regional Cancer Centre, Lakeridge Health, Oshawa/ON/CANADA

Image guidance is indispensable in modern radiation therapy, allowing fast and precise correction of misalignments thereby improving the efficiency and accuracy of the patient setup and treatment. The HexaPOD evo RT couchtop is a robotic couch with 6° of freedom, which allows automatic and remote correction of discrepancies between the pre-treatment and reference images. This work details the commissioning and post clinical implementation daily QA results of the HexaPOD installed on two linacs within our centre.

Commissioning of the HexaPOD and iGUIDE 2.0 tracking systems was performed by applying known translations and rotations of the Pentaguide phantom, acquiring and registering a CBCT (XVI 4.5), applying the shifts and evaluating residual error. The rotational accuracy of the 3D-CBCT is a limiting factor in the accuracy of the patient position. This was assessed using the EMMA phantom (SEMENS) which has 12 localization beads at the 3, 6, 9, and 12 o’clock position in 3 planes, -9.5cm, 0 and +9.5cm. The daily QA assurance program established incorporates the Pentaguide mounted on the Tilt Plate (Modus Medical Devices Inc.) with known rotations ($1.25\degree$, $0.7\degree$ and $1\degree$) and translations. A localization scan is performed, registered, shifts applied, and a verification scan is acquired to assess the residual rotation.

Results of the daily QA (Dec 2014–Jan 2015) residual rotation and translation for both HexaPOD systems are illustrated in Table 1 and Figure 1. The average residual rotation is $0.05\pm0.19\degree$, and translation $0.00 \pm 0.01\text{cm}$, over all directions and both systems. The residual rotation is limited by the accuracy of the CBCT reconstruction found to be up to $0.4\degree$ as assessed with the Emma phantom.

The Elekta HexaPOD robotic couchtop is operating within the manufacturer specifications. However, when used in combination with our current XVI imaging system, larger uncertainties are present.

PS06.003 - Ex-vivo experimental study with a new cluster-type microwave ablation antenna
Author(s): Qun Nan, Xiaohui Nie
College of Life Science and Bio-engineering, Beijing University of Technology, Beijing/CHINA

Microwave ablation which has the advantages of minimally invasive and high-efficiency was more and more used into a number of areas such as cancer treatment. When the tumor diameter is less than 3cm the ablation effect is ideal, but for larger tumors it must be a higher ablation time and a higher power which can result in the reduction of the antenna performance, so the uncertainty of curative effect enhanced. Therefore the study uses in ex-vivo bovine liver to explore the performance of a new cluster-type microwave antenna which has three microwave ablation needles. The temperature distribution and $60^\circ$C isotherm which can decide the scope of the effective ablation were explored. The study carries out with net power of 40W, 60W; ablation time was 5min, 10min, 15min respectively. For the power of 40W, the maximum temperature, area, volume, diameter and longitudinal diameter was 88.812°C, 9.0511cm$^2$, 7.917 cm$^3$, 2.902cm, 3.830cm, respectively with the ablation time 5min while 99.184°C, 19.043 cm$^2$, 50.936 cm$^3$, 3.794 cm, 5.835 cm, respectively with the ablation time 10min and 106.094°C, 25.627 cm$^2$, 81.655cm$^3$, 4.612 cm, 6.719cm, respectively with the ablation time 15min. For the power of 60W, the maximum temperature, area, volume, diameter and longitudinal diameter was 100.047°C, 25.372 cm$^2$, 80.345 cm$^3$, 5.343 cm, 6.908 cm, respectively with the ablation time 5min while 108.863°C, 42.216 cm$^2$, 185.716 cm$^3$, 6.319 cm, 8.102 cm, respectively with the ablation time 10min and 110.219°C, 49.803 cm$^3$, 244.865 cm$^3$, 7.228 cm, 8.720 cm, respectively with the ablation time 15min. The $60^\circ$C isotherm was ellipsoid-like. Under the same power, the $60^\circ$C isotherm increase with ablation time and at the same time, the $60^\circ$C isotherm increase with power, too. This study may make an important support for the development and clinical application of the antenna.

PS06.004 - Bio Magnetic Nano Particles (BMNPs) used for cancer treatment via Hyperthermia method
Author(s): AmirSadegh RezaZadeh Nochehdeh, Minoo Sadri, Ali Moahmmedzadeh
Biomaterials Engineering, Materials and Biomaterials Research center (MBMRC), Tehran/IRAN

Magnetic nano particles for various applications in the medical field such as Separation, Immunoassay, Drug delivery, Magnetic Resonance Imaging and Hyperthermia has been developed by many researchers. Therefore, the use of magnetic nano particles for the treatment of various cancers by using heat therapy is a rapidly growing and growing. In contrast, one of the main challenges facing researchers, optimization of properties and mechanism of biological effects induced Hyperthermia to control and minimize it. The purpose of this paper is to investigate, develop and identify different types of bio magnetic nano particles (BMNPs) in the diagnosis and treatment of cancer that has a new approach to the introduction of heat therapy (Hyperthermia) in the treatment of cancer as an alternative to radiotherapy and chemotherapy. Because of the use these nano particles directly in humans and animals, is very

important to evaluation of physical and bio-compatibility properties according to International Standard (ISO 10993) that in this article we have tried to be fully addressed. After studies done on previous research, it was found that the use of basic iron and cobalt nano particles with a bio-compatible coatings of polymer and ceramic compounds are the best option for medical applications. Furthermore, the need for fundamental and applied research in this area was further emphasized.

**PS06.005 - GATE Monte Carlo Simulation for Dual Head LINAC Modeling**

**Author(s):** Seungwoo Park, Han Kyeol Song, Su Chul Han, Haijo Jung, Kum Bae Kim, Young Hoon Ji

Korea Institute of Radiological and Medical Sciences, SEOUL/KOREA

**Introduction**

In this study, we purposed a new LINAC system which had dual head to reduce irradiation time for tumor treatment. In order to design the dual head LINAC, 6 MV photon beam was simulated and evaluated quantitatively with GATE Monte Carlo code as a preliminary study.

**Materials & Methods**

The LINAC head was designed with VARIAN manufacturer’s information. 6 MV photons were generated from the head and the photons irradiated to a water phantom for beam evaluation. GATE simulation was segmented by two stages, the one was to generate X-ray spectrum and the other one was for irradiation X-ray to the water phantom.

**Results**

The dual head irradiation was compared to single head irradiation in terms of the deposited energy which corresponded to treatment time. At single head simulation, the head was fixed along longitudinal axis direction. Whereas in dual head simulation the one head was placed at same position with the single head case but the other head was rotated along transversal axis direction. Fig 1-2 showed the deposited dose at box and sphere phantom, respectively. The efficiency was calculated that deposited dose from dual heads was divided by the dose from single head. At all conditions, dual heads showed higher treatment efficiency. Efficiency was increased about 40 to 60%.

**Figure 1. Comparison of the deposited dose and its efficiency at box phantom**

**Figure 2. Comparison of the deposited dose and its efficiency at sphere phantom**

Conclusions

From the result, the dual head system had a higher dose deposition than a single head system. The dual head system will contribute to the real radiotherapy. However, the treatment planning system for dual head LINAC and dosimetry method are not established yet. The result was that measured deposited dose within the whole phantom size. Therefore, the planning method has to be defined and estimated. The real dual head LINAC system is being built and the specific research will be conducted on with the dual head system.

**PS06.006 - Active control of microbubbles in flow using position and phase variations in three-dimensional acoustic field**

**Author(s):** Kohji Masuda, Shinya Miyazawa, Toi Sawaguchi, Naoto Hosaka, Takashi Mochizuki

Tokyo Univ. of Agriculture and Technology, Koganei/JAPAN

Though many experiments using effective combination of ultrasound and microbubbles for medical treatment, e.g., thermal therapy and drug delivery, have been reported, because injected microbubbles disperse in the human body, there are the following two major problems; low concentration of microbubbles in the target area, and risk of side effects due to unwanted microbubbles. To enhance local concentration of microbubbles, we have reported our attempts for active control of microbubbles by acoustic radiation forces, which were active path selection, aggregation formation, and trapping in flow. Since 2013 we have produced three-dimensional acoustic field of continuous wave to produce three-dimensional acoustic force using a matrix array transducer. In this presentation, we introduce our attempts for active control of microbubbles in flow using position and phase variations in three-dimensional acoustic field.

The flat array transducer has 64 elements on the aperture of 23.9 x 23.9 mm² with the resonance frequency of 1 MHz. A flow path was fixedly floated from the bottom of a water tank filled with water. Also we prepared the suspension of microbubbles with an average diameter of 0.5 µm, which were produced from poly(ethylene glycol)-modified liposomes and perfluoropropane gas.

We have produced time-shared acoustic fields including the pairs of two focal points. Figure shows the successive images of the observation area after injection of microbubbles suspension (concentration of 0.05 mg lipid/ml) with flow velocity of 30 mm/s, where the maximum sound pressure was 300 kPa-pp and the positions of two peaks were moved periodically along the direction of flow. The inner shape of the path was with the thickness of 2 mm and the width of 10 mm. In the first frame, contour lines were superimposed to indicate the magnitude of sound pressure. Streamline of microbubbles was clearly confirmed in the middle of the two focal points, which indicates that most microbubbles were induced between them.

**Figure 3. Comparison of the deposited dose and its efficiency at box phantom**
Here we have to mention that the phase difference between the two focal points in the figure was opposite phase. On the other hand, in case of in-phase between the two points, most microbubbles were trapped in the middle of the path because two points were merged to form greater acoustic field. From this result, acoustic force can be produced from the sound source to not only a propelling direction but also an attractive direction by position and phase variations in three-dimensional acoustic field.

**PS06.007 - Adaptive radiation therapy of pancreatic cancer patients treated using Tomotherapy: Validation of dose accumulation algorithms using deformable image registration in SlicerRT**

**Author(s):** Eric Vorauer¹, Peggy Le¹, Mithunan Modchalingam¹, Daniel Glick¹, Hans Chung¹, Lee Chin²

¹Sunnybrook Health Sciences Centre, Toronto/CANADA, ²University of Toronto, Department of Radiation Oncology, Toronto/CANADA

**Introduction**

Pancreatic cancer is one of the leading causes of cancer death in Canada. Radiation therapy treatments for pancreatic cancer at the Odette Cancer Centre typically consists of 54 Gy administered over 30 fractions. Due to the long treatment course, the patient’s anatomy can shift away from what was used to create the original treatment plan. This interfractional variation can occur due to organ motion, weight loss or a change in the tumour volume. Using the Planned Adaptive™ module from Tomotherapy, planning contours can be rigidly fused to a daily IGRT MVCT image to determine the actual daily dose to the target and surrounding organs at risk and assess the potential dosimetric risk due to such anatomical changes. However, the Planned Adaptive module currently lacks the ability to account for non-rigid changes in organ motion. Deformable image registration has the potential to account for daily deformations by performing a voxel by voxel mapping of the planning contours to the daily IGRT image. Previously, we optimized and validated a DIR algorithm to perform non-rigid deformable image registration of contours between planning KVCT and daily MVCT images using the radiation therapy research toolkit, SlicerRT. In the current work, we verify the accuracy of the developed DIR algorithm for daily dose accumulation and dose volume histogram assessment for targets and organs at risk.

**Methods**

Deformable image registration was performed on the first and last daily MVCT images acquired from the Tomotherapy unit of a patient undergoing treatment for pancreatic cancer. Two methods were performed to validate the potential of the DIR algorithm for dose accumulation.

In the “forwards” registration approach, planning contours are deformed onto the daily image containing a “daily” dose calculated using the original treatment plan. In the “inverse” registration, the dose from the daily image is deformed onto the planning image containing the contours. Both registration directions use the same registration parameters, and in both cases, dose volume histograms are created after deformation. Dose volume histograms of the forwards and inverse methods will be compared using a DVH acceptance agreement criterion. In addition, V20 of the kidneys, V30 of the liver and max cord dose will be analyzed.

**Preliminary Results**

Initial results of the average DVH acceptance agreement from 5 patients are shown in Table 1.

<table>
<thead>
<tr>
<th>Organ</th>
<th>First Fraction DVH Acceptance (%)</th>
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<tbody>
<tr>
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<td>98.3</td>
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**Table 1.** DVH acceptance agreement average for first and last fractions from 5 patients. Criterion is 1% dose and 1% volume.

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**Table 1.** DVH acceptance agreement average for first and last fractions from 5 patients. Criterion is 1% dose and 1% volume.
PS07.001 - Predictive Fluoroscopy: Minimizing Radiation Dose in Planning Endovascular Therapy for Intracranial Aneurysms

Author(s): John S.H. Baxter¹, Peter Johnson², Elvis C.S. Chen¹, Terry M. Peters¹
¹Imaging, Robarts Research Institute, London/CANADA, ²University Hospital, London/CANADA

Introduction: Intracranial aneurysms are vascular abnormalities thought to be the effect of localized weakness in the arterial wall. [1] These often appear as vascular outpouching which have significant risk of rupture causing subarachnoid haemorrhage with mortality rates ranging from 50% to 80% [2]. Endovascular procedures are often used, requiring some form of guidance. The standard-of-care is to employ pre-operative CT and CTA for detecting the aneurysm, followed by peri-operative rotational angiography to determine C-arm fluoroscopic working angles for use during the intervention. Determining the working angle is complex, requiring the interventionist to reason about the orientation and geometry of the aneurysm and surrounding vasculature with many confounding factors making automatic working angle selection problematic. The imaging involved in this workflow also involves significant radiation dose to the patient, which is of major concern.

Objective: Our objective is to develop a peri-interventional system for the selection of fluoroscopic angles for endovascular procedures without the use of peri-operative rotational angiography, resulting in a lower radiation dose to the patient.

Methods: We first co-register the CT and CTA, treating their co-ordinate systems as synonymous. The CT is then registered into a physical co-ordinate space using two peri-operative fluoroscopic views. Our interface uses a custom direct volume rendering [3] class to render the CTA. This view is replicated by ‘predictive’ fluoroscopy derived from the CT with the closest feasible C-arm angles. Once an adequate visualization is chosen, these angles can be programmed into the C-arm prior to the intervention. In total, this system eliminates the necessity of rotational angiography, thus simplifying workflow and mitigating radiation dose.

Future Work: Phantom experiments and retrospective studies using human data will be performed. These studies will determine if the registration accuracy is sufficient and that selected working angles on CTA are not significantly different from those selected using rotational angiography. Additional work in human factors will be used to characterize how users interact with this system, guiding further improvements.

found the closest possible max-flow-optimal segmentation to the gold standard with only 2% of voxels mislabelled compared to 5% from thresholding. This algorithm is a low-cost, automatic method for improving segmentation, readily incorporated into any variation-optimization-based segmentation framework used in modelling or simulation.

Result and Discussion: Theoretically, the use of stream to solve two or more kernels in the GPU program can reduce computing time with a speedup of up to 1.33x. The sequence between photon and electron were then turned into a concurrent process which gives a more flexible transition. The result of streamed code is almost identical to the original code in accuracy. A maximum of 8.67% estimated dose discrepancy compared to ion chamber measurement were achieved in simulating a 6 MV photon beam in homogenous water phantom with 1 billion of particle history. While, the original gDPM code has a maximum discrepancy of 6.34% estimated dose. The simulation were done within 2.37x faster than the original code. gDPM code has a maximum discrepancy of 6.34% estimated dose. The simulation were done within 2.37x faster than the original code.

Conclusion: This study shows that it is still possible to accelerate again in the computation time Monte Carlo along with the development of computing technology. The GPU stream feature slightly increase the efficiency of gDPM code. Although, there should be more investigation due to the accuracy because of the randomness in Monte Carlo method.


PS07.004 - The influence of two different drug infusion profiles on the pharmacodynamics model performance

Author(s): Ana L. Ferreira1, Catarina S. Nunes2, Joaquim Gabriel3, Pedro Amorim2

1Faculdade de Engenharia da Universidade do Porto, Porto/PORTUGAL, 2Universidade Aberta, Departamento de Ciências e Tecnologia, Delegação do Porto, Porto/PORTUGAL, 3Inegi, Faculdade de Engenharia da Universidade do Porto, Porto/PORTUGAL, 4Centro De Investigação Clínica Em Anestesiologia, Serviço de Anestesiologia, Centro Hospitalar do Porto, Porto/PORTUGAL

To model the effect of anesthetic drugs on the Bispectral Index (BIS) of the EEG is of great importance for a reliable predictive response model during surgery. In this study, the impact of using two different drug infusion profiles in a pharmacodynamics interaction model was studied and the methods were compared with respect to their performance. Clinical data of 22 patients were considered. The interaction model was optimized per patient using nonlinear least squares during the induction of anesthesia, and tested for prediction of test patients. In the optimization phase, all models could follow the BIS trend with errors not significantly different from zero. In the test data the choice of drug infusion profile proved to have a significant impact, showing that the performance is greatly influenced by the interaction. Results also show a time delay between the BIS signal and the Modeled BIS in both groups. This delay corresponds to a delay in the dynamics of the patient and could be related to the delay in BIS processing time. This work is an important step to predict the effect of anesthetic drugs.
**PS07.005 - Force Modeling of MRI-Compatible Robot for Pediatric Bone Biopsy**  
**Author(s):** Peyman Shokrollahi¹, Elnaz Shokrollahi², James Drake³, Andrew Goldenberg⁴  
¹Biomaterial And Biomedical Engineering, University of Toronto, Toronto/CANADA, ²Mechanical And Industrial Engineering, University of Toronto, Toronto/ON/CANADA, ³Division Of Neurosurgery, Hospital for Sick Children, Toronto/CANADA  

**Purpose**  
Prediction of forces is pivotal to the success of skull/bone drilling in stereotactic neurological operations and orthopedic surgery [1]. A general mechanical model of this process that would help developing methods of avoiding bone trauma does not exist [2]. Uncontrolled forces can cause bone tissue trauma due to drill-bit breakage, drill breakthrough, and excessive heat generation [3]. Furthermore, controlling the applied force is more complicated inside a magnetic resonance imaging (MRI) system due to the existence of large static and gradient magnetic fields. A model considering the nonlinearities of drilling mechanics as well as the MRI effects is required to determine the optimal design and parameters.

**Methods**  
To perform innocuous pediatric bone biopsy in the MRI, our goal is to model the applied force generated by an ultrasonic actuator and transferred by the biopsy hollow-drill to the bone, while observing MRI effects on the force. Therefore, the initial force was measured outside the MRI to evaluate the range and bandwidth (BW) of the force by implementing the system (Figure 1). The drilling force was applied on the epiphysis, metaphysis, and diaphysis of hen and swine femurs utilizing a bone biopsy drill and a cordless power drill.

**Results and Discussion**  
The penetration force was in the range of 60-80 N for the hen and 80-100 N for the swine, producing a sinusoidal shape with the biopsy drill. However, a step-shape signal was achieved with a force lowered by 20 N when the power drill was used (Figure 2). The BWs of the signals were calculated using the Fourier transform; a maximum BW of 15 Hz was achieved for manual drilling of the swine bone and a minimum BW of 5 Hz for the power drilling of the hen bone. In conclusion, the model is valuable for controlling MRI-compatible bone-drilling tools.

**Figure 1: Bone Drilling System**

**Figure 2: Applied force on hen bone using power drill**

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**PS07.006 - Comparing the Effects of Three MRI RF Sequences on Ultrasonic Motors**  
**Author(s):** Peyman Shokrollahi¹, James M. Drake², Andrew A. Goldenberg³  
¹Biomaterial And Biomedical Engineering, University of Toronto, Toronto/CANADA, ²Division Of Neurosurgery, Hospital for Sick Children, Toronto/CANADA, ³Mechanical And Industrial Engineering, University of Toronto, Toronto/ON/CANADA  

Obtaining accurate force and kinesthetic information produced by actuators is necessary for the success of robot-assistive surgical operations. Access to such information is not readily possible in MR environments due to the effects of giant static and gradient magnetic fields. The goal of this study is to quantify the effects of MRI on the behavior of ultrasonic motors (USMs), while performing bone biopsies on pediatric surgery. In this study, the effects of three sequences (FFE, balanced FFE, and ultra-fast spin echo, SSH-TSE) were considered on the torque generated by a USM, transferred as an axial force by our implemented robot and measured by our developed force feedback system. Different sequences show different effects on the generated axial force while the motor rotates in different directions.

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**PS07.007 - Robotic positioning system of ultrasound transducer for ultrasonic therapy**  
**Author(s):** Shinya Onogi¹, Kaoru Natsume², Takashi Mochizuki², Makoto Hashizume³, Kohji Masuda⁴  
¹Center For Advanced Medical Innovation, Kyushu University, Fukuoka/JAPAN, ²Graduate School Of Bio-applications And Systems Engineering, Tokyo University of Agriculture and Technology, Tokyo/JAPAN, ³Faculty Of Medical Science, Kyushu University, Fukuoka/JAPAN  

Microbubbles are widely used as contrast agents for ultrasound diagnosis. Moreover, microbubbles can also be used for therapeutic purpose; e.g. the heat amplification of high-intensity focused ultrasound ablation or carriers of acoustic targeted drug/gene delivery. However, injected microbubbles in a blood vessel are diffused throughout the whole body; therefore, the efficiency is limited. To address the issue, we have proposed microbubble delivery technique by using acoustic forces of ultrasound, and confirmed microbubbles can be controled in an artificial blood vessel. To apply the technique in vivo, navigation and robotic system are required.
to position ultrasound filed passing through target bifurcations of blood vessel network. In this study, we propose a robotic system for a microbubble delivery technique. The system feasibility was validated.

The system consists of a parallel link robot (Fig. 1) for positioning of a ultrasound transducer, an optical tracking device, in-house navigation software, and an ultrasound imaging device with a phased array 3D probe. To validate the system feasibility, we performed positioning accuracy validation by emitting ultrasound to a hydrophone in an agar phantom, and microbubble induction tests by using artificial blood vessel. Regarding the first experiment, the hydrophone was potted in the agar phantom and the position was measured by the tracking device. Under the guidance of the navigation, ultrasound was emitted to the hydrophone by the robot. The measured sound pressure was compared with the emitted ultrasound. Regarding the second experiment, a Y-shape artificial vessel (1 in and 2 out) was prepared and its Doppler volume was acquired by the 3D ultrasound. As pre-processing, bifurcations of the blood vessel network were extracted by the navigation software. To induce microbubbles into an intended path, the transducer position was controlled by the robot using the bifurcation position. Next, concentration of microbubbles was injected in the vessel, then ultrasound was emitted for induction of microbubbles. In the experiment, microbubbles behavior was observed by a microscope.

In the positioning accuracy validation, the system can position the transducer by 1 mm errors. Also, measured ultrasound pressure was 62.6 % of input pressure. The result includes attenuation. In the microbubble induction test, induced microbubbles were observed.

In this study, we developed and validated the robotic system with the ultrasound navigation for ultrasonic microbubble delivery technique in order to achieve less invasive therapy. We confirmed that ultrasound is surely emitted to a target position and microbubbles are induced by the system.

A novel optical method is proposed for the determination of polymer glass transition temperature ($T_g$) by monitoring the refractive index variation of polymer microspheres with temperature using our method of microsphere imaging. It was demonstrated that the present method can eliminate most thermal lag and has sensitivity about six fold higher than the conventional method in $T_g$ determination. So the determined $T_g$ is more accurate and less change with heating rate than that obtained with conventional methods. The most attractive character of our method is that it can simultaneously determine the $T_g$ of several polymers in an experiment, thus greatly saving time and heating energy. The method is not only applicable for polymer microspheres, but also for the materials with arbitrary shapes, therefore, it is expected to be broadly applied to different fundamental researches and practical applications of polymers.

When medical doctors diagnose participants with ADHD, they evaluate soft neurological signs (SNS) from their motion by a visual observation. Rotational motion of arms (Pronation and supination) is one of SNS. The participant bends elbow to 90 degrees, and rotates the palm and the back of hands. These methods are hoped to be quantitatively established. In previous our study, we developed quantitative and simple evaluation system of pronation and supination using small wireless hybrid sensors. Our system was consisted of acceleration and angular velocity sensors and a notebook computer. We could obtain different features between typically developing children and children with ADHD by our system. In this paper, we compared temporal change of rotational motion speed between typically developing children (TDC) and children with ADHD in order to find features of pronates and supinates at full speed. Firstly, we separated 4 phases in measurement time and calculate FFT peak frequency in each phase. Measurement time is 10 seconds. Sampling frequency is 100 Hz. Subjects are 203 typically developing children and 40 children with ADHD aged from 7 to 12. From this result, we could obtain the different features between 2 groups (TDC and children with ADHD). The rotational motion speed of TDC decreased with time. In rotational speed of children with ADHD, variations were observed in each phase. From these result, rotational motion speed of children with ADHD is not stable compared to TDC. In TDC, the speed of rotational increased as they grew older.
PS09 - TRACK 09: BIO SIGNAL PROCESSING

PS09.001 - Sensitivity of heart rate variability indices for artificially simulated data
Author(s): Aleksandr A. Fedotov, Anna S. Alulova
Lasers And Bioengineering Systems, Samara State Aerospace University, Samara/RUSSIAN FEDERATION

In modern cardiac practice methods for the analysis of heart-rate variability (HRV) are implemented to forecast the detection of different pathologies of the cardiovascular system. The heart rate is an important physiological index, which reflects processes of autonomic, neurohumoral, and central regulation in the cardiovascular system and throughout the entire human organism. In order to form diagnostic HRV indices mathematical analysis for the variability of durations of beat-to-beat intervals, defined as the time interval between two consecutive fiducial points of the biosignals like ECG signal or pulse wave are applied.

The application of modern mathematical methods of processing non-stationary and quasi-periodic data, such as Rescaled range analysis, Detrended fluctuation analysis, Rectified phase signal averaging, for analysis of heart rate variability (HRV) was considered. The mathematical models for simulating artificial cardiac beat-to-beat intervals that take into account the presence of various noise processes were created. The state model of the cardiovascular system based on analysis of self-similarity of heart rate was developed. The theoretical sensitivity of HRV indices to the change of the state of the cardiovascular system for the artificially simulated data was estimated.

The following HRV indices will be described and analyzed in details:

1) Statistical Index RMSSD: the square root of the mean of the squares of the successive differences between adjacent beat-to-beat intervals.

2) Spectral ratio LF/HF – the ratio of the spectral power density of beat-to-beat intervals at low frequency range (LF) (from 0.04 Hz to 0.15 Hz) to the spectral power at high frequency range HF (from 0.15 Hz to 0.4 Hz).

3) Hurst exponent H, calculated by the normalized range method (R/S analysis), characterize the ratio of the strength of the trend to the level of the noise.

4) The coefficient of fluctuations a, determined by Detrended Fluctuation Analysis (DFA). The DFA method enables to study the structure of different processes, including non-stationary processes, from the point of view of statistical self-similarity.

5) Acceleration capacity (AC) and deceleration capacity (DC) of heart rate. These coefficients are non-linear and determine the intensity of the quasi-periodic trends in heart rate and calculated by phase-rectified signal averaging method.

Results:
Statistical comparisons of 50 MI patients and 50 healthy controls using T-Test analysis indicated that the signal smoothness in MI patients valued more than healthy people (0.2 ± 0.12 vs. 0.12 ± 0.03, P-value < 0.001). Also, the area under the ROC curve for this feature was obtained 0.725. In addition, statistical comparisons of 50 MI Patients and 20 MI+VT/VF using Mann-Whitney U analysis showed that the value of signal smoothness in MI+VT/VF was much more than MI patients without any ventricular arrhythmias (0.3 ± 0.22 vs. 0.19 ± 0.11, P-value =0.028(<P< 0.05)).

Conclusion:
In this study, we proposed a new feature and index called curve smoothness in SAECG to differentiate MI patients from healthy controls. The feature represented good results to distinguish MI patients with and without ventricular arrhythmias. Evaluation of other cardiac signals using this new feature may hopefully lead to the valuable results in cardiac electrophysiology studies.

PS09.002 - The Smoothness of a signal as a new feature in Signal Averaged Electrocardiogram that can be used in cardiac electrophysiology diagnosis.
Author(s): Peyman Sheikhzadeh1, Negisa Seyyedi2
1Department Of Biomedical Engineering, University of Ulsan, Ulsan/KOREA, 2Medical Informatics Department, Shahid Beheshti university of medical science, Tehran/IRAN

Introduction:
Sudden cardiac death is the most common cause of death in the world. Myocardial infarction (MI) and ventricular arrhythmias caused by MIs are among the main factors of sudden cardiac deaths. Accurate recognition, discrimination and prognosis of myocardial infarction and ventricular arrhythmias will be able to reduce the mortality. Several ECG-based methods such as Signal Averaged Electrocardiogram (SAECG) have been proposed, however signal analysis and extraction of new features is being investigated.

Methods and materials:
The signals of orthogonal leads from 120 cases containing healthy subjects and myocardial infarction with and without the history of ventricular tachycardia (VT) and fibrillation (VF) were filtered, denoised and averaged following their selection from PTB diagnostic database. After the calculation of vector magnitude, final signal smoothness was obtained which is the smoothness magnitude of the curve in SAECG. In order to measure the smoothness of function y(t) over an interval [0, n], the sum over square of second derivative of y(t) was used, where n is the number of samples (time) and y(t) is the signal amplitude (voltage). To obtain comparable criteria, the acquired values were normalized to the maximum peak in all cases. Finally, the new feature has been evaluated using T-test and Mann-Whitney U statistical analysis for the two groups of MI patients and healthy controls and MI Patients with and without ventricular arrhythmias (VT&VF), respectively.

Results:
The signals of orthogonal leads from 120 cases containing healthy subjects and myocardial infarction with and without the history of ventricular tachycardia (VT) and fibrillation (VF) were filtered, denoised and averaged following their selection from PTB diagnostic database. After the calculation of vector magnitude, final signal smoothness was obtained which is the smoothness magnitude of the curve in SAECG. In order to measure the smoothness of function y(t) over an interval [0, n], the sum over square of second derivative of y(t) was used, where n is the number of samples (time) and y(t) is the signal amplitude (voltage). To obtain comparable criteria, the acquired values were normalized to the maximum peak in all cases. Finally, the new feature has been evaluated using T-test and Mann-Whitney U statistical analysis for the two groups of MI patients and healthy controls and MI Patients with and without ventricular arrhythmias (VT&VF), respectively.

Conclusion:
In this study, we proposed a new feature and index called curve smoothness in SAECG to differentiate MI patients from healthy controls. The feature represented good results to distinguish MI patients with and without ventricular arrhythmias so it can be very effective in prognosis of these arrhythmias. Evaluation of other cardiac signals using this new feature may hopefully lead to the valuable results in cardiac electrophysiology studies.

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When retinal ganglion cells are stimulated ex vivo by electrical current, short latency responses (within 30 ms) and long latency responses (over 30 ms) are evoked. The short-latency response is suspected to be originated from the direct elect-trical stimulation. For optimal stimulation protocol of retinal prosthesis, this short-latency response is getting important more and more. In this paper, we compared and evaluated perfor-mance of the three algorithms for the short-latency spike detection: suppression of artifacts by local polynomial approximation (SALPA), moving average filter
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This paper discusses the use of ultrasound tissue characterization methods to photoacoustic (PA) data to differentiate between tissues with different vasculature structures. The dominant source responsible for ultrasound scattering in soft tissues (including tumors) is not well known in pulse echo ultrasound. PA imaging is based on the detection of ultrasound waves generated by optical absorption. Since the hemoglobin in blood dominates the absorption of light in soft tissues (at particular laser wavelengths), the PA signal is dominated by the contribution of the vasculature. Organized and chaotic vasculature trees were simulated using a fractal model to represent normal and tumor vasculature, respectively. The generated PA signals from these vascular were simulated through the solution of the photoacoustic wave equation using the Green’s function approach. Ultrasound resolution PA signals generated were detected by simulating a 256 element transducer with a 10–50 MHz bandwidth. Reconstructed images were acquired using a delay and sum method. Image analysis was performed by fitting the image probability density functions (PDF) of Rayleigh, Nakagami (NG), and Generalized Gamma (GG) distributions to the histogram of the reconstructed images. The speckle sizes of the reconstructed PA images were calculated using autocovariance. Spectrum analysis of the ultrasound frequency components of the photoacoustic signals was performed by linear regression analysis of the power spectrums of the radiofrequency (RF) data, as done in conventional ultrasound tissue characterisation. The results suggest that the Rayleigh, NG distributions, and the power spectrum regression analysis can be used to differentiate between the simulated normal and tumor vasculatures. The changes in these parameters correlate to a higher density of tumor vasculatures than normal vasculatures.

PS09.005 - The algorithm for the diagnosis of ventricular tachycardias from electrocardiogram

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Ventricular tachycardias (VT), fibrillations (VF) and flutters (FL) are heart rate disturbances ranked among life threatening arrhythmias. We designed and tested an algorithm for automated detection of VT, VF, and FL events from Holter ECG data. The algorithm is based on the detection in a frequency domain, which is supported by the detection in a time domain. The algorithm was tested using ECG signals including VT, VF, and FL taken from AHA and MIT-BIH databases. Overall performance of the algorithm was sensitivity 80.9% and positive predictivity 66.8% (whole data set). The results show a discrimination of VT, VF, and FL from the normal sinus rhythm and its discrimination from the noise. The importance to reach high sensitivity is reflected in the detection. The algorithm achieved a very high resistance to the power line interference and random noise. It provided very good results, in particular with well-balanced ratio between sensitivity and positive predictivity.

PS09.006 - Modelling of Platelet and White Blood Cell in Dengue Patients using Bioelectrical Impedance Analysis technique

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Abstract This paper presents a modelling for predicting white blood cell (WBC) and platelet (PLT) in dengue patients by using bioimpedance analysis (BIA) technique. Analysis was done using multiple regression analysis to find predictive equations for WBC and PLT. All BIA parameters, patient’s symptoms and demographic data were investigated to find best predictors. In this analysis, best predictors are phase angle (PA), extracellular mass (ECM), total body water (TBW), dizziness, myalgia and petechial rash to predict WBC. For PLT, best predictors are resistance (RES), ratio of extracellular water to intracellular water (ERI), vomiting and epigastric pain. However, PLT and WBC modelling are able to predict 18.4% and 24.9%, respectively. METHODS Dengue database was obtained from Ibrahim, F. 2005. 210 adult patients aged 12 years and above, admitted in Hospital Universiti Kebangsaan Malaysia (HUKM) with confirmed dengue infection were prospectively studied. Before BIA measurement, patients were asked to refrain from eating and drinking at least 4 hours. Data collected were in the form of patient’s clinical and epidemiological data, including fever onset, symptoms, signs, physical examination, blood results and BIA measurements. For BIA measurement, patient was asked to lie supine and two sets of electrodes were placed on hand and foot at right-hand side. As patients admitted at different stages of illness, data collected was based on day of defervescence, where the fever subsided below 37.5°C. Day 0 was used to represent defervescence day. Thus, PLT and WBC modelling was evaluated on fever day 0 as most patients’ condition worsen and deteriorate suddenly. The statistical data analysis was done using simple linear regression and multiple linear regression tests to predict significant predictors for both models, using SPSS software. RESULTS From analysis done, resistance (RES) and ratio of extracellular water to intracellular water (ERI) were found as significant predictors for WBC. The adjusted R2 was around 1.8%. Gastric and vomit were also the significant predictors as well and when added to the model, the adjusted R2 improved to 18.4%. Hence the model can be written as follow: PLT = 47.468 + 7.806(RES) + 11.145(ERI) – 25.588(vomit) – 18.574(gastric) Multiple regression analysis was used to find the best predictors for modelling WBC. As dizziness, myalgia and petechial rash were also found as significant predictors, they explained 15.9% of the WBC’s variation. When PA, ECM and TBW were added into the model, adjusted R2 was around 24.9%. Hence the model can be written as follow: WBC = 6.774 – 0.115(RES) + 0.090(ECM) + 0.115(TBW) + 1.227(dizziness) + 0.612(myalgia) – 1.771(petestial rash) CONCLUSION Future work is to improve the PLT and WBC modelling using BIA technique by increasing the number of samples and using an advanced artificial intelligence method. REFERENCE Ibrahim, F. Prognosis of Dengue Fever and Dengue Haemorrhagic Fever using Bioelectrical Impedance, PhD Thesis, Faculty of Electrical Engineering, July 2005, 1-398 ACKNOWLEDGMENTS We would like to thank University of Malaya High Impact Research Grant UM-MOHE UM.C/625/1/HIR/MOHE/05 from Ministry of Higher Education Malaysia and University of Malaya Research Grant (UMRG: RP009A-13AET) for supporting our research.

PS09.007 - Combination of Multiple Signal Processing Techniques for Multi-class Motor Imagery Detection using Mu Rhythm

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BCI (Brain-Computer Interface) can be classified into two types, that is, input type to send information to the brain and output type using reversal direction of information. We focused on the output type because it is a technology capable of controlling the external equipment at will and processes the measured brain signals in the
computer. Especially, noninvasive motor imagery based brain-computer interface (BCI) is an appropriate solution for upper limb stroke rehabilitation. However, in multi-class brain activity detection with scalp EEG, robustness against background EEG are required for practical use. We proposed the combined application of signal processing techniques such like independent component analysis (ICA), coherent analysis and so on to solve the problems. These are the techniques to separate and enhance each signal source with multi-channel mixed source signal. In this study, multi-channel scalp EEG signals recorded during hand and leg movements were used for the evaluations and the analysis. Figure1 is an example of the measured mu rhythms from four electrodes with hand movement in 2-5 seconds. In mu rhythm, he amplitude is reduced while movement including pre-movements and recovery after movements however it must be processed with some techniques for applications because this phenomenon is unstable. This study also tried to apply the signal processing techniques to improve it. Multi-channel scalp EEG signal measurement was performed with four electrodes placed on the primary motor area along central sulcus. Slides for instructions were used to notify the timing of movements the subject. EEG signals measured from primary motor area were analyzed by ICA. Then the signals in which event-related desynchonizations were found were compared with the original signals. The results by using ICA show that the components with and without desynchonizations were separated. The results on the rate of amplitude degradation from event-related desynchonizations show that ICA could enhance event-related desynchonizations by separating background scalp EEG component. For further improvement, additional signal analysis is in progress. Techniques which can enhance the phenomena induced by the different motions such like coherent analysis have been applied to the ICA output.

They focus on rest and postural tremors that are rated relatively accurate because of steady state. However, although kinetic tremor, especially finger-to-nose test, includes several tremor factors such as intention tremor (goal-directed movement), action tremor (voluntary movement), and postural tremor (stretch forward and stay at target), there have rarely been researches about finger-to-nose test. Especially, kinetic tremor is difficult to assess by visual observation because of movement of a body part.

This study was approved by the Institutional Review Board of Seoul National University Hospital (IRB No. D-1407-011-590). 31 patients with PD participated in the kinetic tremor examination. All patients provided written informed consent prior to study participation. The number of patients was 9, 10, 7, and 5 according to mean UPDRS 0, 1, 2, and 3, separately.

Our device integrated tri-accelerometers and tri-gyroscopes (± 8 g and ± 2000 dps) was attached on the patient’s index finger. Patients moved slowly their finger from their nose to the target repetitively. The sampling rate was 125 Hz. Measured accelerometer and gyroscope signals were scaled and integrated. Then, root mean square and peak power were calculated as features. The average UPDRS of two clinicians was used as standard.

Two filtering methods for removing voluntary movement during finger-to-nose were compared. The movement velocity considerably depends on patients. First, fixed frequency filter, 1 Hz or 2 Hz high-pass-filter that did not affect tremor frequency band (3-12 Hz), was used. Second, adaptive filter, Multivariate Empirical Mode Decomposition (MEMD), was utilized. The signals were expressed by the sum of the intrinsic mode functions in tremor frequency band. Moreover, two classifiers, linear Support Vector Machine (SVM) and Hidden Markov Model (HMM), were compared, because kinetic tremor is time dependent signal. Features were extracted from 3 s moving window with 1.5 s overlapping for HMM. Leave-one-out Cross-validation was used for performance evaluation.

Tremor severities were estimated as 0, 1, 2, or 3 by combination results of accelerometers and gyroscopes. When using fixed frequency filter to remove voluntary movement, the accuracy of tremor severity estimation showed 64.5% on SVM. However, the performances from MEMD filter increased to 83.9% on SVM. Moreover, the results from HMM had 93.5% accuracy that was higher than 83.9% accuracy from SVM.

Therefore, adaptive filter was suitable for removing background noise and voluntary movement during kinetic tremor and HMM classifier fits for time dependent tremor signals. Tremor severities are objectively and accurately assessed through this methods on rest and postural tremors as well as kinetic tremor.

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PS09.008 - The comparison of severity assessment methods of kinetic tremor in Parkinson's disease using wearable sensors

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Tremor is involuntary and rhythmic shaking movement of a body part and one of symptoms in Parkinson's disease (PD). Gold standard method for PD tremor assessment is the Unified Parkinson's Disease Rating Scale (UPDRS). Because UPDRS is based on visual observation, tremor severities are subjectively rated depending on clinical expertise. Several studies have reported objective tremor assessment methods using accelerometers, EMG, and actigraphy.

They focus on rest and postural tremors that are rated relatively accurate because of steady state. However, although kinetic tremor, especially finger-to-nose test, includes several tremor factors such as intention tremor (goal-directed movement), action tremor (voluntary movement), and postural tremor (stretch forward and stay at target), there have rarely been researches about finger-to-nose test. Especially, kinetic tremor is difficult to assess by visual observation because of movement of a body part.

This study was approved by the Institutional Review Board of Seoul National University Hospital (IRB No. D-1407-011-590). 31 patients with PD participated in the kinetic tremor examination. All patients provided written informed consent prior to study participation. The number of patients was 9, 10, 7, and 5 according to mean UPDRS 0, 1, 2, and 3, separately.

Our device integrated tri-accelerometers and tri-gyroscopes (± 8 g and ± 2000 dps) was attached on the patient’s index finger. Patients moved slowly their finger from their nose to the target repetitively. The sampling rate was 125 Hz. Measured accelerometer and gyroscope signals were scaled and integrated. Then, root mean square and peak power were calculated as features. The average UPDRS of two clinicians was used as standard.

Two filtering methods for removing voluntary movement during finger-to-nose were compared. The movement velocity considerably depends on patients. First, fixed frequency filter, 1 Hz or 2 Hz high-pass-filter that did not affect tremor frequency band (3-12 Hz), was used. Second, adaptive filter, Multivariate Empirical Mode Decomposition (MEMD), was utilized. The signals were expressed by the sum of the intrinsic mode functions in tremor frequency band. Moreover, two classifiers, linear Support Vector Machine (SVM) and Hidden Markov Model (HMM), were compared, because kinetic tremor is time dependent signal. Features were extracted from 3 s moving window with 1.5 s overlapping for HMM. Leave-one-out Cross-validation was used for performance evaluation.

Tremor severities were estimated as 0, 1, 2, or 3 by combination results of accelerometers and gyroscopes. When using fixed frequency filter to remove voluntary movement, the accuracy of tremor severity estimation showed 64.5% on SVM. However, the performances from MEMD filter increased to 83.9% on SVM. Moreover, the results from HMM had 93.5% accuracy that was higher than 83.9% accuracy from SVM.

Therefore, adaptive filter was suitable for removing background noise and voluntary movement during kinetic tremor and HMM classifier fits for time dependent tremor signals. Tremor severities are objectively and accurately assessed through this methods on rest and postural tremors as well as kinetic tremor.

ACKNOWLEDGMENT: This study was supported by a grant of the Korean Health Technology R&D Project, Ministry of Health & Welfare, Republic of Korea (No. HI13C0455).

PS09.009 - Unobstructive blinking detection wearable device utilizing transparent conductive ITO film for smartphone users to prevent of computer vision syndrome

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About 90% of the people who spend three hours or more a day at a visual display unit device such as a computer screen or a television were affected computer vision syndrome (CVS), according to the National Institute of Occupational Safety and Health. CVS is resulting from focusing the eyes on visual display terminal for protracted periods of time. It includes some symptoms such as headaches, blurred vision, and dry eye. Recently, the risk of the syndrome has been boosted by the prevalence of smartphone. Decreasing of
predicted and measured MM values yield the lowest mean square error, is taken to synchronize the signals.

This reconstruction method has been applied to the independent datasets of 92 adult subjects and 60 school-aged children. The adult group included 35 healthy (HA), 19 COPD, 13 CF, and 25 AS subjects, among the school-aged children, there have been 18 HA, 21 CF, and 21 AS children. The reconstruction proved independent from the health status, and the mean coefficients of determination calculated over all adult and school-aged subjects, and over the datasets separated by their health status yield values very close to 1 with standard deviations close to zero. Thus, the proposed reconstruction method fulfills all requirements to become the standard method of choice within the DTG-SBW, since it is simple and has a high reliability and reproducibility. Using a standard reconstruction method avoids variability within the datasets coming from different methods, and it makes the datasets comparable among each other.

**PS09.011 - Mirror Movements in Writer’s Cramp—A Study with Multi-Channel EMG**

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The purpose of present investigation is to design and fabricate multi-channel EMG to differentiate between those with concordant(C) and discordant(D) mirror movements(MMs) in Writer’s cramp (WC), in order to establish that there is a quantifiable difference between these two groups.

This study was conducted at Nizam’s Institute of Medical Sciences (NIMS) a tertiary-care-centre in Hyderabad(India). A suitable multi-channel EMG was designed—fabricated (with an input impedance of 200MegaΩ to record digitized EMG signals simultaneously with a set of five, innocuous microelectrodes 50µ). The basic signal data consisted of EMG-signals gathered from5muscles of RH, when subject (patient) first wrote with RH and then, with LH i.e., right-hand-writing-signal(RHWS) and left-hand-writing-signal(LHWS). Duration of signal-recording was10seconds, with3kHz-Sampling-frequency, giving30,000readings for each-muscle. The study showed significant quantifiable EMG differences in the signals seen while writing with R and L hands between those WC-subjects with concordant MMs(C-group) versus those with discordant MMs(D-group).

This was mainly seen in the measures-of-dispersion of signal(standard-dispersion), variances and their-ratio(F-ratio). These were statistically significantly different between two groups(C-and-D), and pattern-of-differences were consistent with the hypothesis that the D-group had a compensatory-force which overcame the dystonic-force resulting in the final abnormal-posture. This was seen in the form of larger-variances and standard-differences in the RHWS in D-group as compared to C-group, as the dystonic and compensatory-forces both contribute to the instability. These differences were robust and seen in every measure-of-dispersion, such as in the patterns of significance of f-values for ratios of variances. Cluster and more sophisticated-analyses using advanced-multivariate-techniques leading to effective data summarization and measures of dissimilarity between subjects as reflected in the signals recorded and consequent possible clustering among them, however, did not lead to any meaningful clinical conclusions. These analyses could possibly be applied to longitudinal follow-ups and correlations with a normal control population in future to better comprehend WC phenomena.

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**PS09.010 - A Simple, CO2-Based Method to Reconstruct the Molar Mass of the Dried Respiratory Gas within a New Double-Tracer Single Breath Washout**

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A new single breath washout (SBW) using sulfur hexafluoride and helium as tracers has been proposed, which offers a considerable potential for the early detection of obstructive airway diseases like cystic fibroses (CF), chronic obstructive pulmonary diseases (COPD) and asthma (AS). After normal breathing of medical air, just one single breath of the double-tracer gas (DTG) that has the same molar mass (MM) as medical air, is necessary, a major advantage especially for elderly and very young patients since the measuring time is very short and only normal tidal breaths are required.

For the diagnosis, the expiration phase just after inspiration of the DTG is of interest. The respiratory flow and the carbon dioxide concentration (CO₂) of the undried gas, as well as the MM of the gas dried in a nafion tube, are measured. Specific parameters could be determined from the difference between the MM-signals with and without DTG. However, during this phase the MM without DTG is unknown and first needs to be reconstructed from the values of the MM- and the CO₂-signals measured without DTG. From these data, the first 25% but not more than 5s and the last 500ms are deleted. This precludes artifacts resulting from insufficient sealing of the mouth piece at the beginning of the measurement, and the rise time of a spike, which occurs at the inspiration of the DTG. Additionally, we use a 2nd order Bessel low pass filter with a cutoff frequency of 3Hz for the CO₂-signal to adapt its shape to that of the MM-signal, which due to dispersion effects within the nafion tube is low pass filtered.

With the results, the ordinary least squares regression method is applied to determine the slope and intercept values needed for the prediction of the MM-signal from the CO₂-signal. To compensate for the time delay between the MM- and the CO₂-signals, which are measured at different sites, we apply the regression method for different time shifts between both signals. The time shift, at which the frequency of blinking might cause dry eye. Conventional method of blinking is electrooculography (EOG) which requires direct electrical contact between the skin and Ag/AgCl electrodes via conductive gel. However, using of such electrodes is not adequate since it would cause skin irritation. Alternative methods which are image-processing approaches available for use with a video camera. However, these require the user’s face to be within the angle of the video camera at a fixed distance. To resolve the lingering shortcomings of these alternative approaches, we propose a blink detection system based on a non-direct electrical contact electrodes which are capacitively coupled electrodes. We developed unobstructive blink rate detection wearable device which is glasses utilizing transparent conductive films. The films were attached to the lens of conventional glasses and able to measure eye blink while not blocking field of vision. When a user blinks the eye, significant positive peak was detected through the pair of films and acquired signal was transmitted to a computer. 4 Healthy subjects who were no symptom of dry eye were participated in this study to validate proposed system. Blinking rate was measured at rest state, during playing a smartphone game and searching the internet with smartphone for 5 minutes respectively. We counted the number of blinking at different task. According to the result, we found that the device didn’t miss any blinking signals in comparison to reference EOG signal. We also found that blinking rate is decreased by up to 50% when the users using their smartphone in comparison with resting state. We expect that the proposed device with visual or auditory feedback when the rate of blinking is below certain threshold is able to prevent dry eye when smartphone users are using their smartphone.
**PS10 - TRACK 10: REHABILITATION MEDICINE, SPORTS MEDICINE, REHABILITATION ENGINEERING AND PROSTHETICS**

**PS10.001 - Human Knee Simulation Using CMAC ANN**
**Author(s):** Roberto A. Lima, Lourdes M. Brasil, Vera R.F.D.S. Marães, João P. Martins
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This paper aims to show the use of a CMAC (Cerebellar Model Articulation Control), a kind of ANN (Artificial Neural Network). The CMAC is based on cerebellum of mammals, but despite this characteristic, actually, what promotes its use, is its very fast operation, which makes it suitable for adaptive control in real time. This type of control is needed, for example, to control an active transfemoral prosthesis. Simulation of knee angular velocities, based on collected data from the contralateral knee, is presented. The simulation is available as open source software.

**PS10.002 - Development of New Method to Create In-school Tactile Maps for Visually Impaired Children**
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Adequate information support for visually impaired children and adults is necessary. In particular, there is a demand for information support tools that ensure students with visual impairment have access to necessary information in public facilities (e.g., schools). Teachers and visually impaired students at schools for the blind require tactile maps that allow the students to grasp the arrangement of school facilities and classrooms. On the other hand, because much time is needed to read and comprehend tactile maps, audio information support is also required. In this study, we established a method for creating in-school tactile maps (trial version) that can allow visually impaired students at schools for the blind to grasp the arrangement of school facilities and classrooms. In particular, we developed a device to create Braille and tactile maps using ultraviolet curable resin ink (Figures 1), and created tactile maps (trial version) with high tactility. We also improved the usability of a voice-reading interface (pen type) that allows visually impaired students to obtain audio information from tactile maps (Figures 2). Moreover, instead of using a stand-alone model for the pen-shaped interface, we placed voice-reading data on a network server, which allowed voice outputs of registered data from terminal units such as tablets. Therefore, it became easy to update the voice data. In addition, we conducted interviews with teachers in the field of education for the blind and visually impaired students to research the usability of in-school tactile maps. Their comments showed that almost all of the teachers and students who participated in this research found our proposed in-school tactile maps highly usable. This study led to the proposal of a method for creating in-school tactile maps that allow visually impaired students to grasp the arrangement of school facilities and classrooms.

**PS10.003 - Experimental Study on Usability Evaluation of a Hydraulic Jack Lever**
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Hydraulic jacks can be used to rescue drivers trapped inside vehicles during car accidents or victims trapped under debris during earthquakes. However, firefighters using hydraulic jacks have indicated that they apply excessive workloads on the body. Therefore, the workload on the body should be reduced and their usability should be improved. The purpose of this study is to evaluate the physical load during lever operation of existing jacks and to determine the appropriate posture for lever operation, as an initial research step.

As an experimental task, subjects squatted to the side of a jack and operated the lever up and down with one hand. We used Blackhawk Automotive Porto-Power hydraulic cylinders for the hydraulic jacks. There were three experimental conditions consisting of squatting positions relative to the jack lever. The three conditions are as follows: a near condition (side1), a far condition (side2), and a front condition (front), as shown in Figure 1. The operating speeds were one second each for lifting and lowering the lever, and each trial was performed in 30 s. A Motion Capture System and floor reaction force sensor were used to measure operating postures and floor reaction force, as shown in Figure 2. In order to evaluate muscle loads, surface EMG sensors were used. For subjective evaluation, interview surveys during operation were investigated in 50 stages from 1 (extremely light) to 50 (maximal exertion).

From the results of the experiment, we found that the near condition experienced fewer loads than the far and front conditions. The
results of the EMG showed muscles such as deltoid, biceps, and triceps are active. In addition, erector spinae muscles are believed to be also active in maintaining a squatting posture. Since the lever requires repeated operation, it is necessary to reduce the muscle loads.

PS10.004 - Neuromuscular Reconnection Methodology By Cap Sense Absorption And Diffusion Signal
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According to statistics from the World Health Organization (WHO), approximately 250,000 to 500,000 people suffer from different types of spinal cord injury every year, therefore making the need for neuromuscular rehabilitation a global goal which seeks to continually improve the ability to return as much quality of life as possible to these patients. Spinal cord injuries type Asia A and type Asia B are potentially risky due to the possible development of secondary pathologies, therefore treatments should aim to regain communication from the sensorimotor cortex to isolated areas as promptly possible. Early treatment of spinal cord injuries by reconnecting the injured, isolated areas to the sensorimotor cortex prevents the development of secondary conditions that diminish quality of life for the patients. Systems such as brain computer interface (BCI) recover the motor signal generated from the brain but under current applications the signal is used to generate motion of a robotic prosthetic, without use of the muscles thus leading to muscle atrophy in the muscular system. World news about cell transplantation of olfactory mucosa to completely regenerate the human spinal cord provides an optimistic treatment option but the time between neurological reconnection, mobility and sensitivity is too long causing the process to be more aggravating for the patient. Pathway afferent and efferent signals can be reconnected to the generated signal by the respective cortex when the original signal is captured by CapSense and processed as resistance, inductance and analyzed as a nerve branch which is induced by hydrogel and characterized electromagnetically with ion doping. Potential somatosensory stimulus on the skin is captured by CapSense which manipulates a matrix of amplified mobile phone which activates various functions via cutaneous stimuli. Current technology changed for medical purposes provides emulation for some organic functions for medical treatments that are effective to complete rehabilitation.

PS10.005 - The Development of an Isokinetic Adapter for Prosthesis Users
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Upper limb amputations can have a significant impact on daily function and affect the quality of life of an individual. There have been significant advances in the materials used to build prosthetic devices resulting in lighter and stronger artificial limbs; however, users have indicated that improved function and control strategies are desirable to become more in line with able-bodied limb function. Quantitative clinical assessment has been challenging due to the complexity of the muscle physiology of those with amputations. In addition, most clinical research has focused on studying isometric (stationary) limb movements. In order to develop more robust systems, it is critical to study muscle mechanics of those with amputations under dynamic (moving) movements. One method of safely examining dynamic movements is the use of isokinetic dynamometers. These machines allow measurement of upper and lower extremity isokinetic movements at controlled angular velocities while ensuring no stress is placed on the individual (even if the participant is unable to move the lever arm). For able-bodied participants, this does not present a problem. However, there is currently no commercially available isokinetic dynamometer adapter for prosthesis users. The purpose of this project was to develop an adapter that can be used by those with amputations to safely and effectively operate the...
There were three stages to the development of this new tool: prototype development, refinement and testing. During the prototype development stage an isokinetic dynamometer (Cybex) was examined to determine the method of attachment. From this a preliminary design was created. Refinements to the first prototype were then completed including attaching a mechanism to allow the user to change the elbow angle to improve the robustness of the device. Modifications were also required to allow the device to mould to the shape of the residual limb of a prosthesis user. The device was also lined to ensure safety and comfort of the user. Finally, the prototype adapter was tested for comfort on a willing below elbow amputee.

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The subject was asked to fit the adapter on his existing prosthetic limb to ensure safety and comfort of the user. Finally, the prototype was tested for comfort on a willing below elbow amputee. The subject was asked to fit the adapter on his existing prosthesis with the end attachment removed, as well as to wear it without the prosthesis. The test subject showed no discomfort with either protocol. The tool that was developed connects to the arm of the dynamometer and is adjustable for different prosthesis users.

Table 1: Classification accuracies for hand open (HO), hand closed (HC), pronation (PR) and supination (SP). All values are %.

<table>
<thead>
<tr>
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<th>HO</th>
<th>HC</th>
<th>PR</th>
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<tr>
<td>Mean Pattern Classification Accuracy</td>
<td>87.9 ± 14.5</td>
<td>95.7 ± 11.1</td>
<td>86.4 ± 17.1</td>
<td>92.2 ± 13.6</td>
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A HDEMG system was used to evaluate four different hand movements (hand open, hand closed, pronation, and supination) at a self-selected medium contraction level. Twenty able-bodied individuals (mean age = 31.6 ± 12.0 years, 9 females and 11 males) participated in this study. Sixty-four channels of EMG were collected from electrodes placed in an 8 by 8 grid formation over the forearm region. The areas on the forearm that experienced muscle activity during given movements were illustrated in topographical (colour) maps for each trial. Pattern recognition was performed to determine how well each contraction could be distinguished using a Linear Discriminate Analysis (LDA) classifier. The colour maps were visually inspected to determine any changes in intensity (amplitude) and pattern repeatability between trials. Pattern classification accuracies were computed for all movements (Table 1). Visual examination of each colour map suggests that both pattern and intensity changes differ in relation to classification accuracy with those with higher classification accuracy having more consistent colour maps. However, a mathematical relationship between classification accuracy and colour map changes is yet to be established.

These results suggest that classification accuracy differ according to both pattern and intensity changes, however the exact relationship remains elusive. Understanding this connection may help to provide better understanding of muscle activity for improved prosthetic control as well as develop new imaging techniques for those with reduced muscle activation due to injury or disability.
Recently, many tactile guide maps have been installed at various public facilities. Designers have used raised dot patterns to display drawings on a tactile guide map. However, there is a lack of quantitative data on the discrimination of raised dot patterns for the design of easily understandable tactile maps. In this study, we investigated the influence of dot distances on the discrimination of the dot patterns used in tactile guide maps by conducting an experiment to find highly discriminable dot pattern combinations by comparing pairs of dot patterns (Figures 1 and 2). A total of 10 visually impaired persons (expert users) and 14 sighted persons (beginner users) participated in this experiment. The results showed that combinations of dot patterns with larger differences in the distances between dots had higher discriminability (Figure 3). When the differences were the same, the combinations with larger dot distances had lower discriminability. Dot patterns with differences between dot distances greater than 5 mm were highly discriminable for sighted persons, whereas those with differences greater than 4 mm were highly discriminable for visually impaired persons. This knowledge will be helpful in discussions among map makers on how to design tactile guide maps.

**Figure 1. Test piece used in this experiment.**

**Figure 2. Direction of the boundary lines.**

**Figure 3. Results of perception rates.**

**Figure 1. Experimental picture during touching test pieces.**

**Figure 2. Test piece used in this experiment.**

**Figure 3. Results of perception rates.**

**PS10.009 - Statistical Evaluation of Objectivisation of Rehabilitation Process**

**Author(s):** Iva Novotná¹, Michaela Tomanová², Lenka Lhotská³

¹Cybernetics, Czech Technical University, Prague/CZECH REPUBLIC, ²Czech Technical University, Prague/CZECH REPUBLIC

Aim of the research described in this paper is to find the most objective and least stressful measurement and successive evaluation of the rehabilitation process based on the comparison of effectiveness of the treatment before and after application of a special rehabilitation INFINITY Method. As basic requirements we defined non-invasiveness, lower time demand, patient comfort, possibility of
comparison of temporal development and ease of examination for the medical professionals. We focused on well-known basic plantographic and posturographic parameters. Furthermore, we focused on patient’s subjective pain recorded by visual analogue scale (VAS) before and after treatment. Data were collected from patients hospitalized in the Rehabilitation Centre Brandýs nad Orlicí. Three studies containing 33, 100 and 331 patients were used. Student’s T-test and Wilcoxon signed-rank test were applied for statistical analysis. Majority of measured patients (60.6 %) showed an improvement in all relevant parameters, in the first study. According to VAS, relieve of pain came in 91 % of patients. The difference in the efficacy of therapy with INFINITY Method and without is almost 20 % (p < 0.001) according to VAS. We evaluated statistically significant differences between the parameters measured in four standing positions in the third study. The overall results imply that in all four standing positions two parameters were statistically significant (p <0.05). Therefore, experiments proved suitability of the proposed methodology. We succeeded in identification of the most informative parameters relevant to the course of the rehabilitation process. In this paper we will focus on statistical evaluation of the measured parameters and will discuss the reached results.

**PS10.010 - Satisfactory Vibrating Conditions of Latissimus Dorsi Tendon to Induce Illusory Horizontal Shoulder Flexion**

**Author(s):** Yumi Umesawa¹, Kouki Doi², Hiroshi Fujimoto¹

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Motor images of the human body can easily deteriorate – for example, due to quadriplegia or the fracture of a bone. In this study, we focused on the illusion of kinesthesia to develop practical applications that can be used for training or to enhance motor images. However, basic knowledge regarding the presence of illusions and vibrating conditions is lacking. In this study, we investigated satisfactory vibrating conditions for inducing illusory horizontal shoulder flexion and conducted an experiment to examine the satisfactory vibrating conditions. The participants in this study were 20 young people. The experimental factors were the vibration frequencies of 30, 50, 70, 90, 110, and 130 Hz. We subjectively assessed the presence or absence of an illusion and its vividness on a five-point scale. At the same time, we measured the perceptual time it took for an illusion to appear and the maximum illusory angle. The results showed that when the vibration frequency conditions were within 70–110 Hz, the occurrence rate of the illusion was 98% (Figure 1). In particular, when the vibration frequency condition was 110 Hz, the vividness of the illusion and the maximum illusory angle reached maximum (Figure 2). It took approximately 7 s for an illusion to appear, regardless of the vibration frequency conditions. Under these stimulation conditions, we found that horizontal shoulder flexion can be easily produced. Based on this knowledge, we plan to develop an interface device that will only provide kinesthetic sensations without the actual motion. This device could potentially be used in the rehabilitation and education fields for training on motor images.

**Figure 1. Occurrence rate of the illusion**

**Figure 2. Vividness of the illusion**

**PS10.011 - Satisfactory Vibrating Conditions of Extensor Digi torum Tendon to Induce Illusory Finger Flexion**

**Author(s):** Yumi Umesawa¹, Kouki Doi², Hiroshi Fujimoto¹

¹Human Science, Waseda University, Tokorozawa/JAPAN, ²National Institute of Special Needs Education, Yokosuka/JAPAN

Motor images of the human body can easily deteriorate – for example, due to quadriplegia or the fracture of a bone. In particular, because a high level of dexterity is needed for finger movement, this movement is the most difficult to recover during rehabilitation. We focused on the finger movement illusion of kinesthesia to develop practical applications that can be used for training or to enhance motor images of high-dexterity behaviour with finger movement. However, basic knowledge regarding the presence of finger movement illusions and vibrating conditions is lacking. We investigated the satisfactory vibrating conditions for inducing illusory finger flexion. In this study, we conducted an experiment to examine these conditions for the metacarpophalangeal joint of the index finger. The participants in this study were five young people. The experimental factors were the vibration frequencies of 50, 70, 90, 110, 130, 150, 170, and 190 Hz. We subjectively assessed the presence or absence of an illusion and its vividness on a five-point scale. At the same time, we measured the perceptual time it took for an illusion to appear and the maximum angle of the Illusory finger flexion. The results showed that when the vibration frequency conditions were within 50–130 Hz, the occurrence rate of the illusion was 100% (Figure 1). In particular, when the vibration frequency condition was 90 Hz, the maximum angle of the Illusory finger flexion reached...
In experienced people.

In this study, we measured the cerebral blood flows of voluntary subjects when they watch the scene of the penalty kick, using Near Infra-Red Spectroscopy (NIRS), because we focused on the prefrontal activity. We ordered subjects to sit down on the chair placed in front of the LCD monitor and watch the video. We also ordered subjects to concentrate to the scene of the video. Fig. 1 shows the results of blood flow of the prefrontal area of inexperienced people when the kicker kicked the ball. Fig. 2 shows that of trained football players. As the result of the experiment, we found that specific region of prefrontal area reacts strongly in a trained football player. Therefore, we suggest that prefrontal activity will be an index for state of training in the football.

**Fig. 1 Blood flow of the prefrontal area of inexperienced people**

**Fig. 2 Blood flow of the prefrontal area of trained football player**

**PS10.013 - Effect of the moderate high pressure circumstances to metabolism**

**Author(s):** Masaki Yoshida1, Miho Asano2

1Department Of Physical Therapy, Osaka Electro-Communication University, Shijonawate/JAPAN, 2Open University of Japan, Chiba/JAPAN

The high pressure air capsule was developed for the purpose of medical treatment. Recently, this capsule is attracting the attention of health enthusiasts and is used for the conditioning or anti-aging. However, some people have experienced pain in their ears due to high pressure. We hope that many people will be able to easily access this technology by lowering the air pressure. Therefore, we considered whether the same effect could be expected from moderate high pressure in this research. We made a moderate high pressure chamber (MHPC). The air pressure in MHPC is set 120 hPa higher than outside air pressure. In addition, the carbon dioxide density in the chamber increases with the carbon dioxide included in the expiration of the subject, but is regulated not to exceed 5,000 ppm. 13 subjects (20 - 40 years old, 3 females and 10 males) participated in this study. The subject stayed in the chamber for 60 minutes. We measured blood partial pressure of oxygen and carbon dioxide of the subject. Furthermore, we measured the basal metabolism before and after MHPC treatment. Fig. 1 shows the change of blood partial pressure of oxygen and carbon dioxide of the subject in the chamber. Blood partial pressures of oxygen increase rapidly just after the start, but gradually decrease afterwards. The blood carbon dioxide partial pressure rises from 30 minutes later. It became clear to affect the human being in the moderate high pressure circumstances. For a physiology
ABSTRACTS | IUPESM 2015 WORLD CONGRESS ON MEDICAL PHYSICS & BIOMEDICAL ENGINEERING

PS11 - TRACK 11: NEUROENGINEERING, NEURAL SYSTEMS

PS11.001 - Objective Evaluation of Likes and Dislikes by Prefrontal Blood Flows

Author(s): Miho Asano1, Masayuki Nambu2, Masaki Yoshida3, Yasuhiro Kawahara1
1Open University of Japan, Chiba/JAPAN, 2Healthcare System Institute, Seika/JAPAN, 3Department Of Physical Therapy, Osaka Electro-Communication University, Shijonawate/JAPAN

It is difficult to know the emotion of likes and dislikes. Questionnaire is the only method to know likes and dislikes, and has low reliability because it is not objective evaluation method. In this paper, we reported about a technique to distinguish the likes and dislikes objectively by measuring prefrontal blood flows, because emotions were based on prefrontal activity. We show images of selected solid colors which were red, blue, orange, indigo, yellow, purple, green, black, and white, and we measured the blood flows of the subject, using near infra-red spectroscopy (NIRS). In addition, we asked subjects about likes and dislikes with the color by the order after the experiment. The result of an experiment shown in fig.1. By the way, artifacts based on the body motion or change of the blood pressure are included the signal of the NIRS which is shown in fig. 1. Therefore, we obtained the approximation of the artifact using polynomial approximation algorithm. Then we subtract the approximation from the original signal. As the result of the subtraction, we confirmed the artifact was reduced as shown in fig.2. As the result of the experiment, the level of the oxyhemoglobin when the subject answered “I don’t like” was relatively high, compared with the level of the oxyhemoglobin when the subject answered “I like”. We consider that undesirable stimulus is more impressed than desirable stimulus. Furthermore, we consider that we will distinguish that likes and dislikes by measuring the cerebral blood flows in the future.

fig. 1

Fig. 1 Blood partial pressure of oxygen carbon dioxide

Fig. 2 Basal metabolism
Brain-Computer Interfaces (BCIs) are systems developed to improve the daily life of people with disabilities. Nevertheless, this assistive technology is yet far away from the patients’ home and the BCI should adapt to the requirements of the user. This paper presents a practical BCI based on Steady-State Visual Evoked Potentials (SSVEP) currently being used by people with disabilities. The BCI was applied to navigate a wheelchair at two ranges of SSVEP frequency, increasing the possibilities of its application. Two stimulation systems were used: checkerboards flickering at low-frequency range and LED flickering at high-frequency range. Five volunteers with disabilities tested the SSVEP-based BCI. They attempted to command the wheelchair in order to accomplish four different navigation tasks. Then, the volunteers answered a questionnaire about their comfort and performance. Average accuracy detections of 54% and 51% were achieved at low- and high-frequency stimulation, respectively. Volunteers reported lesser visual tiredness when high-frequency LED stimuli were used. The flexible BCI system here developed showed that people with disabilities could operate a robotic wheelchair using visual stimuli in two ranges of frequency. Moreover, preliminary results indicated that visual stimuli flickering at high frequency were more comfortable than low frequency stimuli.

Brain-computer interfaces (BCIs) are a revolutionary technology enlisting the neural activity, or cognitive capacity, of its user in order to operate a certain device or application. Since BCIs do not require any motor input, the technology has significant applications for individuals with severely impaired motor control, such as those with amyotrophic lateral sclerosis or locked-in syndrome. BCIs have been largely examined in the lab setting and under controlled conditions, however, the ultimate target for its use lies in real-world situations such as homes and clinics, which are often rife with distractions. Distractions can cause an enhanced burden on the cognitive processes of BCI users through an increased expenditure of cognitive resources, which are already largely occupied by the BCI task at hand. Distractions can therefore potentially limit the resources available for BCI control, and in turn jeopardize BCI performance. The purpose of this proposed study is twofold. This study will look to determine the effect and extent of distractions on cognitive load and to compare this to the effect on BCI task performance. The study will also look to examine whether or not performance can be enhanced in the presence of distractions through techniques that reduce cognitive load. These techniques include emphasizing the BCI task visual interface or repeating the BCI task signaling stimuli in order to redirect attention from the distraction back to the BCI task. Following BCI neurofeedback training, 10 able-bodied participants will be enlisted to undergo a motor-imagery based EEG-BCI protocol in conditions of no distraction, visual distraction, and cognitive-load reducing techniques in the presence of distraction. Cognitive load will be determined via objective measures such as the Youden Index and EEG alpha band pattern, and subjective measures such as the NASA-TLX, and will be compared to measures of BCI performance for each condition. It is expected that optimal BCI performance will be attained in the no-distraction condition where cognitive load is relatively low, while the presence of task-irrelevant visual distractions will increase cognitive load and cause a decreased BCI performance. Redirection of attention to the BCI task stimuli, through emphasis or repetition, is expected to attenuate cognitive load and rescue BCI performance. The findings of the proposed study is expected to demonstrate the impact of task-irrelevant information on cognitive resources, its consequent influence on BCI performance, and will emphasize the potential importance of considering the effect of cognitive load on BCI systems, especially in real-world environments. With accounting for uncontrolled environmental factors, BCI systems can be robustified such that its translation from the lab to the home, or where the end-users are likely to use the technology, will be more effective.
Stimulations to Basal Ganglia and the Efficiency of Microminiaturized Electrode Recording (MER) to Quantify STN Neurons with Deep Brain Stimulator (DBS)— the Lead Point in Parkinson Diseased Conditions

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Deep brain stimulation (DBS) of bilateral subthalamic nuclei (STN) is an efficient method of rehabilitation in subjects with advanced idiopathic Parkinson disease (PD). Accurate targeting of STN neurons and placement of microelectrodes are paramount importance for optimal results after STN-DBS. Stereotactic assessment, intra-operative microelectrode recording and intra-operative stimulation effects have all been used in targeting, albeit the individual role of each modality is still not known. Microelectrode recordings of STN were detected in a mean of 3.5 ± 1.1 channels on right hemisphere and 3.6 ± 1.04 on left hemisphere. Final channel selected were most commonly central seen in 42.3% followed by anterior in 33.7%. Concordance of final tract with the channel having the highest recording was 58.7%, with the channel showing maximum depth of recording was 48% and with either was 64%. Absence of any recording in the final tract chosen was seen in 6.52%, in these subjects the tract was chosen based on stimulation results. The depths of microelectrodes were detected by microelectrode recording in 75.6%. Microelectrode recording is useful to identify and confirm the tract in which DBS electrodes are placed and is most useful in determining the depth of electrodes placement but has to be taken in consideration with effects seen on macro-stimulation.

Schizophrenia: Interaction between factors

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1Electronic Engineering, Technological Federal University of Parana, Curitiba-PR/BRAZIL, 2Electronica, Technological Federal University of Parana, Curitiba PR/BRAZIL

Background

Schizophrenia is an endogenous and multifactorial disease that causes for the person that suffers, disconnections with reality, difficulties at real facts processing, difficulties of cognition and memorization, disorders on social, affective and personal life. The disease is classified in six types and the causes are related with each brain area that is damaged. Like the disease is multifactor, is difficult to the doctor to view patient history as a whole. The panoramic view about the disease for each patient and the relations with and between them, the aim of this work, allows to the doctor perceives the patient by globalized and correlated form and no segmented, since the disease happens with the interaction the various factors together.

Methods

The research about possible causes and hypotheses for disease was raised through articles published on the fifteen years last and positioned at Block Diagram, according with main factors of the disease and relations between them.

Results

It was found six main factors of the disease: Genetic, Physical, Metabolism, Nutrition, Psychic and Environment. All the points studied can be positioned into this six main factors and it was possible to realize the relations between them.

Conclusions

The main purpose is to allow to the doctor perceive the patient by globalized form and facilitate the treatment preventing the consequences by interventions realized by medicines and its side effects or adverse, nutrition or therapy. The secondary purpose is to perceive where can be made interventions for to mitigate the causes of the disease for the next generations.
PS12 - TRACK 12: MEDICAL DEVICES

PS12.001 - Challenges and opportunities in home-based monitoring of cardiac dynamics

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Advances in sensor and data acquisition technologies, Big Data, rising health care costs, public awareness of improving the quality of life, has spurred a boom in wearable “health-tech” in the smart device market. Tele-monitoring of cardiac dynamics (or ECG analysis) using smart devices is becoming a popular choice as it helps the consumer in maintaining daily fitness, food intake, and also helps cardiac patients in proper treatment such as medicine intake times, relaxation or activity break times, or even calling the nearest health care facility in case of emergency. Although these devices give the user a nice graphical output about the cardiac state, their signal analysis is still challenging with regards to device capability and the significance of clinical data [1, 2, 6].

Our survey indicates that clinical ECG exceeds the smart-device ECG, in terms of signal quality, low artifacts and information content [1-6]. Despite their reliability, hospital-based cardiac monitoring tools are cumbersome and don’t support transfer to a home-based ECG monitoring environment [2]. Although some currently available devices (such as smart watches, wrist bands etc) are capable of monitoring cardiac health, their analysis is quite limited and may not be helpful from a clinical perspective [6]. Meaning, the signals acquired through these devices may depict only a portion of the entire heart’s dynamics, and cannot be interpreted into meaningful information by the consumer. Hence their usage is still questionable without the ground truth from clinicians [8]. Such type of unsupervised data acquisition and pattern recognition systems could also question the type of ECG data collected, its format, the storing methods, privacy and confidentiality of consumers. These wearable devices may be a lifestyle improvement choice for the underserved healthy population, but they may not be useful for subjects who have a tendency for severe cardiac disorders. Analysis of biosignals such as ECG requires an algorithm which can extensively perform artifact removal, feature extraction, pattern recognition and highly optimized for processing hardware in terms of power and area requirements. Recommendations of a reliable and practical home-based ECG monitoring include the following specifications: [i] user friendly [1,2], [ii] compact and wireless hardware design, [iii] non-invasive and comfortable to use sensors, [iv] standardized data acquisition and security, [v] user understandable informed decision and output, [vi] provision for data synchronization with local healthcare provider, [vii] reliable signal quality, [viii] low power and memory consumption, [ix] low data processing time, and [x] cost effectiveness.

PS12.002 - Application of Support Vector Machines in Intelligent Monitoring of Cardiovascular Health on a Mobile Device

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Cardiovascular Disease (CVD) is the leading cause of death in the developed world. There are many risk factors and early treatment through pharmacotherapy and lifestyle changes can reduce the severity of CVD. Due to this, patients at risk for CVD are closely monitored. Current monitoring techniques include periodic visits to the doctor, which causes stress on the healthcare system. Increasingly, mobile devices with unobtrusive sensors are providing patients with information regarding their own health. However they provide an abundance of data that patients and health care professionals do not use. In the case of wearable devices this has contributed to the low long-term usage of such devices.

Recent work has focused on the use of a support vector machines (SVM) for analyzing medical data. SVM is a flexible algorithm that can learn from data rather than following an explicit program. In a previous study, a SVM was developed for continuous monitoring of a patient’s electrocardiogram (ECG) in real time. However this SVM was used for the comparison of a single variable and did not consider the wide variety of factors that contribute to CVD. Another study developed a multi-variable SVM algorithm that was used to monitor the effectiveness of drugs in diabetes patients in a smartphone device. It depended on user input and analyzed multiple factors however it did not make use of the data collected automatically by smartphone devices. A similar CVD device has also not been developed to analyze multiple factors on a mobile platform.

The focus of this project would be a SVM-based program that will be used on smartphones to monitor the vitals of a patient with CVD. The device will obtain input data for a SVM algorithm through sensors and electronic health records (EHR). Sensors will be used to monitor the patient’s real-time vitals. EHR provide information regarding the patient’s basic information (gender, age, sex etc), medical history and demographics. Together, these sources of data will provide the SVM a comprehensive overview of the patient’s health.
A SVM is a supervised, classification algorithm which is trained using known data provided from clinical databases. The algorithm is ideal for studying CVD because it can create solutions to complex problems where it is impractical or impossible to program a solution directly. The algorithm will be able to identify and present only the relevant data to health care professionals and patients.

The SVMs will be evaluated by determining its accuracy in analyzing new data. It will improve on current monitoring systems because the SVM will allow for the integration of a wide range of factors and can be adapted for individual patients. The patient would be an active contributor in the management of their own disease. This will reduce stress on the healthcare system by informing health care professionals about serious cases and can be used in preventative medicine. The factors can then be further analyzed to determine if pharmacotherapy or lifestyle changes are necessary.

PS12.003 - Design and Implementation of the Software for Multi-parameter Patient’s Monitor
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Features of design and implementation of the preliminary version of the main software for a multiparameter patient’s monitor are presented. Alarm Control Subsystem is highlighted. The design fulfills requirements of standards for monitoring systems. The software was designed with multi-layer architecture conformed by four layers.

Functions for acquiring, processing and visualization of signals and values are connected but, at the same time, are independent. Software was implemented using Qt environment tools like multi-thread, object oriented programming and signals-slots. It provide to the doctors and nurse with different configuration options like setting variable limits and customize the performing of visual and sound alarm notifications. The software was implemented to be used on a monitoring device with a main board based on ARM-9 microprocessor. Using multi-layer architecture it is possible to verify each subsystem independently and to make more easy update and maintenance tasks. Monitoring and operational performance of the monitor reached expected results.

Steps for validation of QRS detection algorithms in real time.

The proposed strategy was tested using a patient monitor based on ARM-9 and Linux architecture which acquires until three ECG channels with a sample rate of 250 Hz. For validation were re-sampled 50 ECG signals from the MIT-BIH Arrhythmia Database. Running a “Test Mode” option the program acquired signals in real time from re-sampled files. The functions of QRS detection algorithm were included in an external library that later could be included in another
similar application. Annotation files were created for each re-sampled signal. A Qt application was developed with visual interface for review signals and comparison of annotation files. This program implements functions for creation of re-sample ECG signals files and for generation and comparison of annotations files. The strategy defines the steps for validation of algorithms for ECG analysis in real time systems.

The created application has a friendly interface for viewing and analyzing validation results generated for algorithms used in real time system or those used offline.

**PS12.005 - Basic Study on Variability of Measured Data from Touch Test Using Semmes-Weinstein Monofilaments**

**Author(s):** Manabu Chikai1, Emi Ozawa2, Noriyo Takahashi2, Shuichi Ino1, Showa Inan General Hospital, Komagane/JAPAN, 2Tokuyukai Rehabilitation Clinic, Toyonaka/JAPAN

The aim of our research was to develop new equipment for easily and noninvasively diagnosing diabetic peripheral neuropathy (DPN). The International Diabetes Federation (IDF) reported that 387 million people have diabetes. Diabetes is associated with life-threatening health risks. One of these risks is DPN, which causes hyposthesia in a patient’s toes. The early and easy detection of DPN in a clinic is the hope of diabetic patients and medical staff. Several methods are used for DPN screening tests. One of these is a touch test using a device with nylon Semmes-Weinstein monofilaments (SWMs) embedded in a plastic handle. A low pushing force is applied at the handle to bow the filaments. A member of the medical staff presses the filaments at nearly a 90° angle against the patient’s hand or foot until they bow. A previous study reported that the SWMs did not generate the same values on repeated tasks. However, it was uncertain whether the variability of the measured data was caused by the mechanical property of the nylon fiber or the operator’s hand motion. In this study, we elucidated the variability of the SWM test data.

We carried out two experiments on (1) the effect of the number of compressions on the buckling force of the SWMs and (2) the effect of the human operator variability using the SWMs. This study used 5.07/10g SWMs. In experiment 1, the SWMs were pressed using an X-axis positioning stage. We measured the buckling force of the SWMs using a force sensor. The stage moving speed was 10 mm/s. In experiment 2, the SWMs were operated by individual participants. Ten participants (6 men and 4 women) ranging in age from 20 to 60 years (mean age 42 years) were recruited. We measured their hand motion using an optical motion capture system, and measured the buckling force of the SWMs using a force sensor.

Based on the experimental results, the average buckling force of the first compression was 8.2 g, and it was 7.5 g after ten successive trials. The average force of all the compressions was 7.7 ± 0.5 g. The average hand motion velocity for all the participants and the average buckling force were 0.23 ± 0.1 m/s and 7.5 ± 0.6 g, respectively. Thus, the hand motion during the SWM tests varied by participant. Therefore, the SWM test results varied from both the effect of repeated tests and the effect of the operator’s hand motion. In other words, an SWM test needs to consider the number of test cycles, and manual training needs to be developed for the medical staff.

We elucidated the variability problem of sensory testing using SWMs. The buckling force of the SWMs was decreased through numerous test trials, and the hand motion varied by participant. In future work, we will find a solution to the variability of the SWM test results and develop a new testing system for tactile sensitivity for DPN screening.

**PS12.006 - Design and construction of temperature and humidity control channel for a bacteriological incubator**

**Author(s):** Carlos R. Duharte1, Ibrain Ceballo2, Carmen Busochn1, Angel Regueiro1

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During the study and research of microbial growth in biological samples, it is essential to have an incubation station. This incubator permits to control the temperature and humidity for an adequate characterization of the different stages of growth of microorganisms, especially pathogens. This paper supports the development of new methods for rapid detection of these microorganisms, not only applicable to industrial biological samples (food, raw materials, etc.) but also to clinical samples (urine, blood, etc.).

The paper discusses the design and characterization of a lab incubator prototype to support studies of Microbiology, particularly for research phase of bacterial growth in biological samples through integrating optical methods (photo stimulation and turbidimetry) and bioimpedance measurements. The basic stages of electrical design and operation are described as well as the control program (software) developed based on these of microcontroller AT89C51. Furthermore, the results of simulation and experimentation of the proposed design are shown for measurement channels of the variables of interest (temperature and humidity), in which high linearity and adequate strength from the selection of system components was obtained.

**Figure 1. Mechanic design of incubator**

**Figure 2. Diagram of the design of channel of temperature sensing and regulation.**
PS12.007 - High-Reliability Nerve Stimulator For Aiding Regional Anesthesia Procedures
Author(s): Carlos A. Ferri, Antônio A.F. Quevedo
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In the last decades, the use of nerve stimulators in nerve blockade anesthesia procedures has shown benefits to patients, since it allows a better location of the nerve plexus, leading to correct positioning of the needle through which the anesthetic is applied. However, many of the nerve stimulators available in the market for this purpose do not comply with minimum recommended features and specifications for a good stimulator. This can lead to risks to the patient. This study aims to develop an equipment that meets all the characteristics for a successful blockade. We developed a high-quality and high-precision device using embedded digital and analog electronics for accurate control for all stimulation parameters. The system consists of modules for generation and overall control of the current pulse, the patient interface, and communication interface with a personal computer. The results show that the proposed system fits into suggested specifications for a good neurostimulator to be used for nerve location during regional anesthesia procedures.

Material and methods: The first step was to identify the different Institutions and universities private and public as well as companies that do research or service in medicine genomic, also the different lines that medicine genomic has been developing, the kind of technology that use each Institution and their general technical specifications. Other action was to identify for each research line the kind of technology necessary and their importance in the different research.

An important point was know technical information, cost, sales level with the manufactures of genomic technology.

After we create a database and their contacts, we analyzed the information and we create a format for identify exactly that kind of technology have each Institutions. For this was necessary create indicators for determine that level of impact of each technology and focus the information only to technology with high impact.

At the same time we analyzed the variables of census that did SNIICyT (National system of information of science infrastructure and technology in Mexico), this information is only for government institutions.

Finally we used tools of market research for identify the variables for integrated in the inventory format.

Result: we create a format in paper and digital which can be used in the national inventory of genomic technology, applicable to private and public organizations as well as different kind of Institutions academic and not academic.

Conclusions: Is necessary have a reliable inventory that help to scientists and managers of genomics technology to generate collaborative project that make more efficient the resources, increasing the number of research that will impact in the public health.

PS12.008 - A study of pressure-volume characteristics of the cuff for hemodynamic parameters measurement
Author(s): Jan Dvořák, Martin Tuček, Jan Havlík
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This contribution deals with the pressure-volume characteristics of the cuffs used for blood pressure measurement. The linearity of characteristics is a very important factor for the accurate conversion from volume change to pressure change. Several cuffs were tested during the study, including new cuffs, old cuffs, cuffs with different sizes, volumes and clamping systems. Results of the measurement in the range between minimal diastolic to maximal systolic pressure have been statistically evaluated.

Conclusions: The cuff with new technology is the most reliable and has a lower cost per unit.

Finally we used tools of market research for identify the variables for integrated in the inventory format.

Result: we create a format in paper and digital which can be used in the national inventory of genomic technology, applicable to private and public organizations as well as different kind of Institutions academic and not academic.

Conclusions: Is necessary have a reliable inventory that help to scientists and managers of genomics technology to generate collaborative project that make more efficient the resources, increasing the number of research that will impact in the public health.

PS12.009 - Format for National Inventory of the Genomic Technology
Author(s): Beatriz Hernandez
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Introduction: The scientific research in health is an important activity for development of the countries. In Mexico there are many Universities, private and public Institutions and companies that work in different research project. However this institutions needs money for buy laboratory equipment, solutions, materials and payroll.

In the last decade medicine genomic has had a big impact in medicine around the world, many countries have been spending many money for obtain infrastructure and laboratory devices for the different projects, but is necessary to make more efficient the existing technology. Mexico is a country that need improve the health. Mexico has priority in resolve the principal health problems that affect at the population, so research in medicine genomic is necessary for this goal.

For this is important have a national inventory where the scientific can obtain information about the kind of technology, conditions, specifications and location. The reserved information is very common in research it is a factor that not has permitted know about the different resources that each Institution have.

Objective: identify the information necessary that allow do one national inventory and know where is the laboratory devices, their specifications and which are their operational conditions. Looking for an more generation of collaborative agreements to decrease spending on technology.

Conclusions: The inventory that create is a tool that allow to the users to have a free access of the information that need to make an efficient research.

Finally we used tools of market research for identify the variables for integrated in the inventory format.

Result: we create a format in paper and digital which can be used in the national inventory of genomic technology, applicable to private and public organizations as well as different kind of Institutions academic and not academic.

Conclusions: Is necessary have a reliable inventory that help to scientists and managers of genomics technology to generate collaborative project that make more efficient the resources, increasing the number of research that will impact in the public health.

PS12.010 - Development of the bedridden person support system using Kinect.
Author(s): Kouhei Ichimura, Kazushige Magatani
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The purpose of this study is to support the bedridden and physically handicapped persons who live independently. It is not so easy for them to control home environments, home appliances and to communicate with family or nursing care staffs. Therefore, some supports are necessary for them. Our objective is to solve these problems. We developed a home environments and home appliance control system using Kinect. And then this system was tested and the results of experiment were assessed.

Fig.1 shows the system overview. The system consists of the control interface, a personal computer and control objects. In our system, the control interface consists of sensors which are used for hand motion recognition and the display which indicate the application menu for operation. A control interface senses hand and finger motion and recognize these motions (raising a hand, grasp and release). Recognized results are used to operate the system. And this interface is also used to show the control applications on the display. Our system is constructed as the interactive system, and simple operations for the bedridden and physically handicapped user are realized.

We used Kinect which is a kind of infrared ray sensing system to detect hand motions. OpenNI2 and NITE2 were also used as software developing libraries in our system. The skeleton detection that is supported by these libraries cannot use for the user who lays on the bed. So, the gesture applications which is provided by NITE2 were
used in order to track hand motions. In our system, electric devices which support a user are controlled by a personal computer using a programmable infrared ray remote control interface. In other words pre-programmed infrared ray code according as objective is sent to the target device. In this paper, target devices are lighting equipment, a television and an air conditioner.

Our developed system was tested with some normal subject and results of the experiment were evaluated. In this experiment, all subjects laid on the bed and tried to control our system. As results, most of subjects were able to control our developed system perfectly. However, motion tracking of some subject’s hand was reset forcibly. It was difficult for these subjects to make the system recognize his opened hand. From these results, we think if this problem will be improved our support system will be useful for the bedridden and physically handicapped persons.

Results: The absolute detection thresholds of the lateral skin stretch at the foot ranged from approximately 10 to 30 μm for healthy subjects. The thresholds at the fifth toe and first metatarsal head were higher than those at the other plantar sites (p < 0.01). The tactile sensitivity of each site mainly improved as the stretch speed increased. Significant difference in threshold value was observed between the healthy adults and the patients with early-stage diabetes (p < 0.001). Meanwhile, relatively weak correlations were found between the detection threshold and skin hardness at the foot sole.

Conclusion: The present study demonstrates that the detection threshold (μm-order resolution) of the lateral skin stretch was highly sensitive in comparison with a two-point discrimination threshold (mm-order resolution) that was well known in sensory testing. The experimental results also suggest that our testing method based on the plantar sensation elicited by a lateral skin stretch may be a simple, noninvasive method for the quantitative screening of diabetic neuropathy.

PS12.011 - Quantitative sensory testing using lateral skin stretch at the foot for simple screening of diabetic neuropathy

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Objective: Changes in food behavior and lifestyle have resulted in a considerable increase in the incidence of diabetes. Many people with diabetes have reduced quality of life because of diabetes-associated complications, which include neuropathy, retinopathy, and nephropathy. About half of the people with diabetes in the world, however, are unaware of their condition. One of the healthcare challenges is how to best implement screening, educational, and treatment programs for the prevention of diabetes. Conventional noninvasive diagnostic techniques for diabetic neuropathy have several problems, including the accuracy of a quantitative estimation, durability, and the time of testing. Therefore, the aim of this study was to develop simple point-of-care equipment to quantify plantar tactile sensitivity for early diagnosis and tracking of peripheral neuropathy caused by diabetes.

Methods: We focused on reducing the tactile sensation at the peripheral regions such as the foot and hand, which is a common symptom in patients with diabetic neuropathy and appears at a relatively early stage of disease. The tactile stimulation of our testing method is adopted for lateral skin stretches, which is more sensitive than perpendicular skin indentations. A new system of quantitative sensory testing for screening of diabetic neuropathy consists of a plantar tactile stimulation platform with a small moving contactor to stretch the skin tangentially, a response switch for each tactile stimulus, a motor control box, and a personal computer for psychophysical data processing. Seven healthy adults (3 women and 4 men; mean ± SD age, 39.6 ± 8.6 years) and one patient (woman, aged 77 years) in the early stage of diabetes were examined to measure the absolute detection thresholds of the lateral skin stretch on the plantar surface using the system of quantitative sensory testing. The stretch stimulations were applied to five different sites (the first toe, fifth toe, first metatarsal head, fifth metatarsal head, and heel) of the right foot. The skin hardness of the plantar sites was measured using a durometer.

Conclusion: The present study demonstrates that the detection threshold (μm-order resolution) of the lateral skin stretch was highly sensitive in comparison with a two-point discrimination threshold (mm-order resolution) that was well known in sensory testing. The experimental results also suggest that our testing method based on the plantar sensation elicited by a lateral skin stretch may be a simple, noninvasive method for the quantitative screening of diabetic neuropathy.

PS12.012 - A development of the robot hand for the disability which include sensory feedback.

Author(s): Tomohiro Iwaki, Kazushige Magataki
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SEMG is an electrical signal associated with the activation of the muscle. Various artificial hands and robot hands which act according to SEMG patterns have been experimentally developed. Most of them can grasp and release an object according to the instruction from generated SEMG. However, most of them cannot feedback grasping power to the operator. Therefore, it is difficult to grasp an object using correct power in most systems. If an operator can feel grasping condition, more accurate operation will be enabled.

So, our objective of this study development of the feedback system which can defects grasping power of the artificial hand or robot hand and feedback this power to the operator as air pressure to the finger. Our developed system consists of two parts. One is the robot hand (the artificial hand) which acts some hand motions according to generated forearm SEMG pattern. The other is the grasping power feedback system which defect grasping power and feedback this condition to the operator.

In the robot hand system, 48 channel forearm SEMG are measured and analyzed. Motion of the robot hand was controlled according to analyzed result. And we also suppose that muscle power is proportional to the amplitude of SEMG. If analyzed result of hand motion is grasping, grasping power is calculated using SEMG amplitude, and grasping power of the robot hand is also controlled using this result.

In our robot hand, pressure sensors are set on the hand surface and...
we can measure real grasping power. The grasping power feedback system consists of these pressure sensor, a micro-processor, a syringe and an air pressure display. The piston of a syringe is driven by a stepping motor which is controlled by a micro-processor. A rubber balloon which is connected with output of the syringe displays grasping power to operator’s finger by change of air pressure. A block diagram of this system is shown in Fig.1.

The developed grasping feedback system was tested with some normal subjects and characteristics of this system were evaluated. In the experiment, all subject could feel the grasping condition of a robot hand. However, it became clear that there is some time delay in the response of the feedback system. From the experimental results, we think that if these problems are improved, our system will be useful system for the amputee.

**PS12.013 - Motor cortical excitability enhanced by paired-pulse transcranial magnetic stimulation with biphasic pulse-form**

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Introduction: Motor threshold is a commonly used measure of corticospinal excitability in transcranial magnetic stimulation (TMS) determined by stimulating the primary motor cortex. Conventionally, the immediate excitability of the motor cortex has been modulated by the use of paired-pulse TMS using monophasic pulses with an inter-stimulus interval (ISI) of 1.5-200ms. Monophasic pulses are more easily produced by the stimulator as compared to biphasic pulses, which instead are more energy-efficient. The problem with the biphasic pulse-form to produce biphasic pulses has been the low recovery-rate of the stimulator. However, provided that this problem can be overcome, it would be possible to produce same excitability modulation with biphasic pulses as with monophasic pulses, but with better energy-efficiency and with lower stimulus intensities, meaning that maximum stimulator output could be greater. This would make the biphasic paired-pulse paradigms better applicable in patients with reduced cortical excitability.

Materials and Methods: Nexstim Plc produced a prototype stimulator for biphasic paired-pulses, effect of which was studied in 8 healthy volunteers. Resting motor thresholds (rMTs) were determined from the subjects using single-pulse paradigm from the right and left hand abductor pollicis brevis muscles, and the right tibialis anterior muscle by targeting neuronavigated TMS to the corresponding targets on the motor cortex, mapped prior to rMT measurement. Then, 20 single-pulse motor evoked potentials (MEPs) were gathered at an intensity of 110% of rMT. Subsequently, rMTs and MEPs were measured using 3 paired-pulse setups (ISI = 3ms, 7ms or 15ms) from all muscles in randomized order. In the paired-pulses, the stimulus intensity of the second pulse was 80% of the first pulse intensity.

Results and Discussion: We found that the ISI had a significant effect on the rMTs, meaning that rMTs were lower than the corresponding single-pulse rMTs and MEPs with biphasic paired-pulses were also higher than with single-pulses (Figure). The effect was emphasized at 3ms ISI.

Our findings suggest that the application of biphasic paired-pulses is possible and the potential applications are not limited similarly to monophasic pulses. For instance, paired-pulse stimulation with biphasic pulse-form could potentially be applied in repetitive TMS, in order to enhance therapy effects.
PS12.015 - Value of information analysis for use in health technology assessment

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Nowadays every decision is, less or more, associated with uncertainty. In everyday life we are intuitively trying to reduce this uncertainty by collecting new information, e.g. reading newspapers or watching TV. In health technology assessment, where we should consider besides health effects also safety, technical parameters, economic impacts etc., we can do it in more sophisticated and specific ways - through the specialized literature, consultation with experts, certain decision problems or collection of new evidence in additional research. Theoretically, we can do this over and over until we have enough evidence to confirm our decision. Practically, facing limited resources, mostly financial, we have to find balance between information gathering and our resources and here we can use value of information analysis.

PS12.016 - Development of a Software Tool for Quick Re-entrainment of the Circadian Pacemaker

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According to the Stat Canada, over a million people per month take trans-oceanic flights from Canada to overseas countries and vice versa. In all of these travels exceeding five time zones, the misalignment of circadian phase, known as “jet lag”, can cause health problems for the travelers. Other than frequent travelers, as of 2006 there were approximately 1.5 million Canadians, excluding US residents, living abroad who suffer from jetlag whenever they travel to their motherland. The adverse effects of jet lag impair the judgment of business people and politicians, compromise the performance of athletes, and pose a threat to public safety as it degrades performance and operational readiness of deployed military personnel. However, despite several studies suggesting protocols for designing interventions that facilitate re-entrainment to a shifted sleep-wake schedule, there is yet no standard scheduled light therapy protocol. Furthermore, although light seems to be the main stimulus to the circadian system, but the combined effect of it with other stimulants, such as melatonin pills, has not received enough attention. In this paper, we have distilled a common denominator in the literature for the response of the circadian system to light and melatonin pills and have developed a software tool that can recommend optimal timing for light exposure/avoidance as well as taking melatonin pills and have developed a software tool that can recommend optimal timing for light exposure/avoidance as well as taking melatonin pills to compensate for the loss of alertness. The produced schedule is based on returning the time of minimum body temperature, known as Tmin, into its correct location in the sleep cycle. Contrary to the most of available solutions, our software took into account individual circadian-phase differences by using Horne-Ostberg Morningness/Eveningness Questionnaire (MEQ) to quantify the differences and use them in calculating Tmin. This questionnaire consists of nineteen four-choice questions that can be optionally answered by user. Moreover, in the proposed software the average duration of the light exposure in each day can be estimated by user which affects the amplitude of phase shift. The produce schedule for re-entrainment is developed in both form of graphic output and simple text instructions(not shown here).The figure of the software and its produced schedule is provided below for better illustration:

PS12.017 - Which one is better in detecting the speed and quantity of intravenous infusion in the hospital, transmissive or reflective optical method?

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We developed an infusion monitoring system using a reflective optical sensor which can detect the infusion speed and quantity. The system detect infusion drips and calculate the amount of intravenous fluid left. We use both reflective and transmissive optical sensor to detect the infusion drips, and compare the results.

Intravenous (IV) therapy is one of common treatment in the hospital for medication delivery, blood transfusion and chemotherapy. IV therapy primarily employ a drip chamber to prevent air embolism. Based on the individual prescription, the speed of IV infusion should be adjusted by medical staffs. Medical staffs observe the number of drips in the drip chamber and manually adjust the speed using a regulator. Furthermore, regular monitoring is required during IV therapy to prevent malfunction such as embolism, back flow and fluid overload. Thus, medical staffs need to frequently check the IV therapy and the patient’s status. To overcome these inconveniences, a new system

![Figure 1](image-url)
that automatically detects the infusion speed and quantity is required. Several researches to automatically monitor the IV therapy have been conducted using weight measurement, capacitance, or optical methods. The optical method is using a sensor attached to the drip chamber to detect infusion drips and calculate the infusion speed. The optical method can detect abnormal status such as blockage and fluid overflow. Regardless types of solution bags, the optical method is compatible because sensors are attached to the drip chamber. Figure 1 (a) shows conventional transmissive method to detect drips in the chamber. Since the detection range of transmissive method varies depending on the angle of the drip chamber and the deviation of the output sensitivity, we suggest reflective method (figure 1 (b)).

Two experiments were performed using the infusion set. We compare the performance between the transmissive and the reflective optical sensor. First, the drip detection rate was compared depending on each position angles using both transmissive and reflective methods. Second, the error rate of drip detection of the transmissive and reflective methods was respectively measured under the same condition.

In both experiments, the drip detection rate was significantly improved when using the reflective method. The reflective sensor showed a low error rate of less than 11%, in comparison up to 65% error rate of the transmissive sensor.

In this study, the reflective optical sensor was much more reliable than the conventional transmissive optical sensor.

Figure 1 Concepts of optical sensors; (a) conventional transmissive method, (b) suggested reflective method

PS12.018 - The effect of stented valve oversizing on hemodynamic flow in the diseased right atrium
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Tricuspid regurgitation (TR) occurs in many individuals and is usually considered mild but severe TR is life-threatening. Even so, many patients with severe TR are denied of the replacement valve surgery because their old age or co-morbidities put them at high risk for conventional open heart surgery. With the advent of transcatheter technology, it is now possible to deliver the valve to the desired location without the need for open heart surgery. However, so far, there has been no commercially available transcatheter tricuspid valve. This may because of the complex tricuspid valve anatomy and lack of an anchorage zone. Thus, the next best anchorage zone is the vena cava. Placing the valves in the superior and inferior vena cava will prevent the back flow of blood into the venous structures and possibly reverse peripheral edema and ascites which are caused by the elevated venous pressure. The hemodynamic characteristics of these valves are tested in a mock circulatory system (MCS) which emulates the physiological pressure and flow conditions in the cardiovascular system. The sizes of the valves implanted onto the vena cava also affect the flow. In this study, we analysed how valves of different sizes affected the flow patterns as well as the magnitude of the velocity. Particle image velocimetry is used to study the flow characteristics in the MCS.

PS12.019 - Device trial to improve blood flow rate with controlled pressure for blood flow at venous side in single needle dialysis
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Single needle dialysis can be performed using only one needle. However, because blood is both removed and returned with only one needle, the dialysis effect is less than when two needles are used. If the blood return time can be reduced when using controlled pressure for blood flow at venous side in the single needle method, improved blood flow rate and dialysis rate can be expected over time. In conventional single needle dialysis, air is compressed in a vein air capture chamber. Therefore, it isn’t possible to actively control the return time. In the present study, we used air pistons run by solenoid in an attempt to reduce return time and to safely improve the efficiency of single needle dialysis. To design and test a device to improve blood flow rate in single needle dialysis and to compare this device with previous methods. The conventional method uses the force of compressed air within the air capture chamber to return blood. This method reduces pressure in the second half of blood return, which further reduces the amount of blood returned. The present device prevents the reduction in pressure using the solenoid. The blood in the vein air capture chamber is constantly pressured by the solenoid. This makes it possible to prevent a reduction in the sent blood flow rate. Results, the present device, when compared with conventional methods, significantly increases blood flow rate. The present device, although simple, can reduce blood return time and increase blood flow rate. Indicate that this device can be anticipated to improve dialysis efficiency.

PS12.020 - An Embedded Software Solution for Rest ECG Devices
Author(s): Gisela Montes De Oca, Maite Cañizares, René González-Fernández
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This paper discusses the design and implementation of a software solution to be used in the development of digital electrocardiographs. These electrocardiographs acquire simultaneously the standard 12-lead electrocardiogram, display the waveforms (ECG) on a high-resolution graphic display and print the ECG with several formats. The software also performs measurements and diagnostic interpretation. ECGs and their associated information are stored on a database. The information can be transmitted to any informatics systems like HIS and expert consulting opinion systems which help physician on actions to take with the patient being treated. Software solutions were developed by using the Integrated Development Environment (IDE) Qt Creator and the cross-platform Qt library. The design and programming process employed object programming techniques developing classes to encapsulate all the functions used by the system. The hardware solution used the processing board CID 300-9, based on the S3C2440 microprocessor with ARM9 architecture and Linux operating system. The technical parameters of the equipment and software were assessed according to the requirements of the IEC 60601-2-25 standard, with satisfactory results.
PS12.021 - Development of innovative gas phase sterilization technology for nucleolytic degradation

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With the worldwide major trends of next generation medical technology development, such as regenerative medicine and gene therapy, it is getting urgent need to establish and improve advanced aseptic (germ and virus-free) manufacturing environments of fabrication plant for quality assurance of the products. But there still remain critical problems with conventional sterilization method due to its limited spectrum, environmental pollution, health impairment and such, especially at present, there is no available decisive decomposition method for nucleic acid.

Recently we have developed innovative technology as the catalytic reaction type mixed gas generating system using methanol as a raw material, (Biovector, pat.no.5463376), and its remarkable efficacy of sterilization effect, as well as nucleic acid decomposition will be reported.

The Biovector system consists of a mixed biogas generator, a small experimental chamber and a scrub exhaust device for detoxification equipped with catalyst detoxification apparatus. The system enables to make continuous monitoring of inside temperature and humidity as well as the hydrogen concentration and other biogas elements.

We investigated sterilization effect of Biovector by biological indicators (BI) of both Bacillus. atrophaeus and Geobacillus. stearothermophilus (RAVEN Co.), and determination was evaluated according to Food and Drug Administration Guidance for Industry and Japanese Pharmacopoeia sterility testing. For evaluation of nucleolytic degradation efficacy of Biovector, DNA samples were purified from HeLa cell lines, and fragmented DNA was analyzed by real time PCR method and Bioanalyzer (Agilent Technologies) system for sizing and quantitation.

By the Biovector gas exposure for 5 minutes at 50 ℃, the complete eradication effect was observed in all of BI applied in the amount from 106 to 108, which resulted in achievement of sterile assurance level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also in the evaluation of nucleolytic degradation ability, the complete degradation effect of DNA into 10 or less base level (SAL) of 10-6. Also

Methodology: Our platform is a real-time processing machine, designed with robust, versatile and flexible hardware architecture of 64 physically independent channels, expandable to 128. It is based on analog front-end circuits for the excitation of transducers in transmission mode and initial signal conditioning of received echoes. The core signal processing is left to reprogrammable integrated circuits, Digital Signal Processor (DSP) and Field-Programmable Gate Arrays (FPGAs), composing the digital back-end system.

The architecture consists of two identical 32-channel analog transmission boards and one 64-channel analog reception board along with four digital boards based on Virtex-6 FPGA. The digital boards are arranged so that one of them controls the two beamforming transmission boards and the reception board. An extra board is used to connect the DSP. The backplane integrates connectors for two probes and delivers signals from the power supply to the entire complex. A Personal Computer (PC) accounts for user interface, medical applications and image display.

The firmware architecture was designed to work as a mechanism of a data-flow machine. Thus, to develop algorithms for beamforming in addition to image and signal processing, we adopted the Model-driven Engineering approach using MATLAB to initially model their blocks and then to automatically generate Verilog/VHDL and C/C++ codes. This allowed rapid proofs of concept and reduced project costs.

The equipment works by setting a protocol (e.g. cardiac exam) using proper PC-based user interface, initializing medical application software. The protocol generates a service request to the hardware control, a role played by DSP. The DSP acts as a manager, first receiving settings from the PC and determining the beamforming parameters that is sent to the FPGAs. After receiving the pre-processed signals from FPGAs, the DSP performs image processing and delivers them back to the PC to be displayed on the screen.

At this stage, the developed system is able to generate B-mode and M-mode ultrasound imaging, with a module for Doppler Imaging (Color and Power Doppler). The system accepts ECG signals for proper coupling to cardiac applications. Although being able to work in faster modes, it was decided to run the platform achieving at least 30 frames per second. The several university groups working on the platform are developing special modules as add on applications such as elastography, coded excitation, breast cancer detection and others.

Conclusion: Preliminary results have shown that the developed platform can be employed as a useful and low cost medical ultrasound system with great potential to test and innovate on medical (and non-medical) ultrasound imaging techniques.

PS12.022 - Ultrasound Modular Platform: a general purpose open architecture system for medical imaging research

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Introduction: A demand signaled by the Brazilian Ministry of Health has led to the development of an Ultrasound Modular Platform which aims to medical imaging research. It was conducted in a partnership between top Brazilian universities, led by the University of Campinas jointly with Eldorado Research Institute, a top Brazilian center in IT and innovation engineering. In this paper we present the achievements and experiences gained in this recent development.

Methodology: Our platform is a real-time processing machine, designed with robust, versatile and flexible hardware architecture of 64 physically independent channels, expandable to 128. It is based on analog front-end circuits for the excitation of transducers in transmission mode and initial signal conditioning of received echoes. The core signal processing is left to reprogrammable integrated circuits, Digital Signal Processor (DSP) and Field-Programmable Gate Arrays (FPGAs), composing the digital back-end system.

The architecture consists of two identical 32-channel analog transmission boards and one 64-channel analog reception board along with four digital boards based on Virtex-6 FPGA. The digital boards are arranged so that one of them controls the two beamforming transmission boards and the reception board. An extra board is used to connect the DSP. The backplane integrates connectors for two probes and delivers signals from the power supply to the entire complex. A Personal Computer (PC) accounts for user interface, medical applications and image display.

The firmware architecture was designed to work as a mechanism of a data-flow machine. Thus, to develop algorithms for beamforming in addition to image and signal processing, we adopted the Model-driven Engineering approach using MATLAB to initially model their blocks and then to automatically generate Verilog/VHDL and C/C++ codes. This allowed rapid proofs of concept and reduced project costs.

The equipment works by setting a protocol (e.g. cardiac exam) using proper PC-based user interface, initializing medical application software. The protocol generates a service request to the hardware control, a role played by DSP. The DSP acts as a manager, first receiving settings from the PC and determining the beamforming parameters that is sent to the FPGAs. After receiving the pre-processed signals from FPGAs, the DSP performs image processing and delivers them back to the PC to be displayed on the screen.

At this stage, the developed system is able to generate B-mode and M-mode ultrasound imaging, with a module for Doppler Imaging (Color and Power Doppler). The system accepts ECG signals for proper coupling to cardiac applications. Although being able to work in faster modes, it was decided to run the platform achieving at least 30 frames per second. The several university groups working on the platform are developing special modules as add on applications such as elastography, coded excitation, breast cancer detection and others.

Conclusion: Preliminary results have shown that the developed platform can be employed as a useful and low cost medical ultrasound system with great potential to test and innovate on medical (and non-medical) ultrasound imaging techniques.
Polyvinyl alcohol (PVA) cryogels are widely accepted as an accurate mechanical tissue analog and will be used to simulate both the bulk fatty, fibroglandular tissues of the breast and pathological inclusions. PVA cryogels exhibit wide ranges of elasticity and are tunable based on different preparation methods; predominantly varying the number of freeze-thaw cycles and concentration of PVA in the cryogel solution. Dynamic mechanical compression testing is conducted to validate the protocol to achieve elastic modulus values from literature comparable to that of fibroadenoma and invasive lobular carcinoma. The representative benign fibroadenoma is characterized by well-defined boundaries, and the malignant invasive lobular carcinoma has a speculated shape integrated into the surrounding tissues. The key contribution of this design is the shape of both the benign and malignant pathologies; derived from physician-annotated patient MRI images. A 3D mesh of the inclusions are exported into Solidworks and 3D printed into a thermoplastic polyester mold. Unlike existing phantoms, the breast phantom described combines anthropomorphic and mechanically validated inclusions to facilitate the development of diagnostic imaging devices and techniques.

PS12.024 - Evaluation and Analysis of the Results of a prototype Medical Device Vigilance System (MEDEVIPAS)

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Biomedical Technology has contributed decisively to the impressive progress of modern healthcare over the last half century and at the same time medical devices play a vital role in the delivery of high quality healthcare. Although recent technological advancements have led to much more reliable and safer Medical Devices (MDs) unfortunately the potential risk of failure on medical devices and the associated adverse incidents cannot be neglected. In fact, adverse incidents, due to MDs, have recently increased in absolute terms, because of the exponential increase in the number of devices used nowadays. Therefore, MD recalls by manufacturers contribute to the safe function of the devices, in order to avoid incidents that could lead to injuries and deaths.

In terms of technology, in order to create a safer environment, providing rapid and accurate information on adverse events, is necessary to avoid their repetition. The traditional approach of MD Vigilance based only on official user reports of adverse incidents has been proven inadequate today. A modern approach to the problem is based on the introduction of additional means, such as data mining, extraction, standardization and codification of the information, from different direct and indirect sources worldwide, and its systematic classification and archiving in dedicated databases. The aim is to timely extract the information on potentially hazardous MDs and make it available where appropriate.

Process evaluation involves collecting and analyzing information about a program's activities, characteristics, and outcomes and consequently yields the information needed to make adjustments to strategy implementation in order to strengthen effectiveness. Particularly, the system evaluation process performed included both data verification/validation and software evaluation. In some cases, the results were cross-checked using specific multiple approaches, assets and different dedicated techniques. The procedure for data processing included the determination, transformation, modelling and codification of the data in order to highlight relevant information, as well as to support decision making and conclusions.

To demonstrate and objectively assess the quality and usability of the design, questionnaire of the vigilance system has been created and filled-in by users and reviewers. Moreover an analysis of the databases has been conducted aiming to provide a comprehensive interpretation of the results of this investigation. Additionally, various methods and techniques have been used to identify specific characteristics of the MDs failures and, based on that, forecast trends in areas requiring special attention were investigated. In conclusion, it has been demonstrated that MEDEVIPAS System could be a very effective tool for world-wide use advancing MD vigilance.

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PS12.025 - Medical Device Development - Risk Management

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Risk Management is critical, and challenging to implement pragmatically during early phase development.

Pragmatic, compliant Risk Management currently challenges many medical device manufacturers in hospitals and start-up companies. The harmonized risk management of medical devices standard, ISO 14971:2012, gives presumption to conformity to some aspects of the Medical Devices Directive (MDD) along with other harmonized standards. ISO 14971:2012 is a process standard that establishes the requirements for risk management to determine the safety of a medical device. The challenge for developers is to determine how best to implement the standards during the ‘proof-of-concept’ as at this point of development it is not clear if the device is feasible in terms of technology and market-need.

A further challenge is to consider how to maximize investments in prototypes when the appropriate risk management approach has not been followed from the start.

I have come across many sophisticated prototype medical devices requiring regulatory approvals in hospitals and industry. Challenges arise when a prototype device is further developed and is to be approved in the absence of Risk Management documents relevant to the initial stages. Whilst undesirable, if the safety and efficacy of the device can be assured then a carefully structured and planned retrospective risk management file may be accepted for ISO 14971:2012 submission. The approach will still involve following all processes described in the standard but in a different perspective. It will require a carefully prepared risk management plan to address the risks that were not addressed in the prototype development stage.

Putting in place the right risk management processes and tools, is important for your development, and knowing how to use them correctly is critical.

The gap analysis above may be based around FTA, FMEA or FMECA depending on the status of prototype development. The scoring in the analysis plays an important role in identifying risks within the system. Many manufacturers are uncertain as to how best to construct their risk matrix tables – what is an acceptable risk? Whether to use qualitative or quantitative scoring for probability scores? Whether to use ‘detectability’ or ‘P1-and-P2’ scoring? [Here, the probability score P1 is a likelihood of failure occurring and P2 is likelihood of this failure resulting in harm] Such decisions are important as they have significant impacts on safety and compliance with the standard. To clarify the differences, consider a motor analogy - if a car braking system fails and the car is designed to detect the failure, then the ‘detectability’ score is high which would reduce the overall risk score significantly (but would not necessarily
reduce the potential for harm). If P2 score is used for the failure then the score will not reduce until the car system is designed to not only detect but also prevent harm.

Even after deciding the scoring mechanism, the next challenge is how to score the severity of the failure. Where should we set the score in the analysis – is it correct to use the worst case or the most likely?

PS12.026 - Analysis of the terminology to name medical devices used in Intensive Care Units - ICUs

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The purpose of the proposed study is to analyze the terminology of medical products used in Intensive Care Units - ICUs in Brazil, focusing on their morphological and semantic aspects. The research aims to understand the terminology used in this particular branch of medicine, with emphasis on the following specific objectives:

a. Raising the names of medical products used in ICUs with the help of experts in the field;

b. Searching variants of the selected terms;

c. Observing the existence of synonyms and the coordination relations between terms;

d. Describing the morphological and semantic behavior of the terms found.

For this research, it was first studied the theories regarding terminology, lexicography and word formation. After this step, we started collecting the terms relating to medical products used in ICUs in documents issued by the governmental regulator agency - ANVISA. Through documents called “Resolutions of the Board of Directors – RDC”, ANVISA adopts procedures and determines behaviors for all groups and institutions involved with the issue at hand. In the case of this study, we used as a reference specifically the Resolution of the Board of Directors RDC number 7, of 24 February 2010, which details the minimum requirements for Intensive Care Units operation. In a meeting with specialists, we concluded that we would use as corpora for this research the manuals of equipment manufacturers, since it is through them that the first contact between medical technologies and users is established.

The analysis of the manuals was made through Terminus, a software developed by the IUATERM Group, Institut Universitari of Applied Linguistics at Universitat Pompeu Fabra – Barcelona – ES. After validation of the terms that referred to medical devices by the specialists, were selected five of the 34 terms that name the medical products for a preliminary study.

From the analysis of selected terms and all its variants, we proposed conceptual relationships based on examples from the manual and, we notice complex relationships between the terms and an expressive number of syntagmatic formations.

PS12.027 - Determination of Breath Acetone in 298 Type 2 Diabetic Patients using a Ringdown Breath Acetone Analyzer

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Breath analysis is a promising new technique for nonintrusive disease diagnosis and metabolic status monitoring by testing exhaled breath components. The detection of exhaled nitric oxide has been used as a tool in support of asthma diagnosis for some years. Breath acetone has long been known as a biomarker for diabetes. However the results from published data by far have been inconclusive regarding whether breath acetone is a reliable index of diabetic control. Huge variations exist among the results of different studies because there has been no “best-practice method” for breath-acetone measurements as a result of technical problems of sampling and analysis. Over 90% of diabetic patients have Type 2 diabetes (T2D). In this work, a near-real-time on-line breath-acetone analyzer based on cavity ringdown spectroscopy was developed and used for breath-acetone measurement of 298 T2D subjects and 42 healthy subjects, one of the largest numbers of T2D subjects ever used in a single study. Four breath samples were taken from each subject under each of four different conditions: fasting, 2 h post-breakfast, 2 h post-lunch, and 2 h post-dinner. Simultaneous blood glucose (BG) levels were also measured using a standard diabetic-management blood-glucose meter. For the 298 T2D subjects, their exhaled breath acetone concentrations ranged from 0.1 to 19.8 ppm; four different ranges of breath acetone concentration, 0.1–19.8, 0.1–7.1, 0.1–10.9, and 0.1–10.6 ppm, were obtained for the subjects under the four different conditions, respectively. For the 42 healthy subjects, their breath acetone concentration ranged from 0.1 to 2.6 ppm; four different ranges of breath acetone concentration, 0.3–2.6, 0.1–2.6, 0.1–1.7, and 0.3–1.6 ppm, were obtained for the four different conditions. The mean breath acetone concentration of the 298 T2D subjects was determined to be 1.5±1.3 ppm, which was 1.5 times that of 1.0±0.6 ppm for the 42 healthy subjects. No correlation was found between the breath acetone concentration and the blood glucose level of the T2D subjects and the healthy volunteers. This study using a relatively large number of subjects provides new data regarding breath acetone in diabetes (Type 1 diabetes and T2D) and suggests that an elevated mean breath acetone concentration exists in T2D. However it arguably still too early to draw a general conclusion on the use of breath acetone as a reliable substitute of BG for diabetes diagnostics and screening on the basis of the currently limited data. The relationships between breath acetone level and BG level and other bioinformatic variables need to be further investigated with a large number of subjects (e.g. thousands) by use of a high-data-throughput real-time online analytical technique.

PS12.028 - A study of the differences between uncompressed sound source and compressed sound source gives EEG of human

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In recent years, the way of sell music has changed CD into digital distribution. Mp3 is the representative of compressed sound source in online music distribution service.

Mp3 formatted sound quality is inferior as compared with CD-DA formatted sound quality, because mp3 has less information as compared to pre-compressed data. The objective of this study is by analyzing EEG to determine if people can recognize such difference as differences in sound.

In the experiment, one subject (Healthy adult, Male, Age: 22 years
PS12.029 - Evaluation of the interface pressure characteristics over a temperature regulating air-mattress under different surgical positions

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Introduction

Intraoperative acquired pressure ulcers (IAPU) are deep tissue injury resulted from prolonged tissue compression during anesthesia. There exists clinical evidence showing that the onset of IAPU was associated with hypothermia during surgery. To maintain body core temperature, warm blankets are commonly used on the operating table. Recently, a temperature regulating air-mattress (Warmcloud, KanMed, Sweden) was introduced as an efficient patient warming system with pressure ulcer prevention. However, there are few scientific reports about the effectiveness of using Warmcloud to reduce the interfacial pressure generated during different surgical positions.

Methodology

Ten healthy volunteers (5 males, 5 females, average age 23, BMI: 22.3±5) participated in this study. Four surgical positions: supine, lateral, prone and lithotomy were evaluated at various inflation pressures of the Warmcloud system. Interface pressure was measured using a capacitive sensor mattress device (Xsensor, Canada). During the experiment, the temperature setting of the Warmcloud was set to 36°C. The average pressure, contact area, percentage of area below 33mmHg and peak pressure over bony prominences and other anatomical locations at risk of pressure ulcers were recorded. Comparisons of interfacial pressures were made between use and without use of the Warmcloud mattress on the operating table.

Results

Comparing to the operating table, contact area over the body-support interface with Warmcloud is significantly larger (p<0.05), varied
between 7 to 87% in the 4 surgical positions. The area of contact that experienced below capillary closing pressure also increased significantly (between 6-15%) when Warmcloud is in use. In terms of average pressure over the entire support surface, Warmcloud only provided significant pressure reduction during supine lying. For peak pressure loadings, different anatomical sites are involved. For supine, peak pressure was found at the sacrum and the heels. Compared with lying on the operating table, use of Warmcloud significantly reduced the peak pressure by 53% and 70% at the sacrum and the heels respectively. In lateral position, while the majority (n=8) had reduction of peak pressure underneath the axilla, two subjects experienced pressure increase during the use of Warmcloud. In lithotomy position, Warmcloud significant reduced the peak pressure at the sacrum. For prone position, peak pressure at the anterior iliac spines, chest and knees varied between use and without use of Warmcloud. Furthermore, our data also showed that the recommended pressure for inflating the Warmcloud mattress may not give the best pressure reduction outcome.

Discussion

This study revealed that the Warmcloud mattress can significantly reduce the average and peak interface pressure during supine and lithotomy positions. In lateral posture, we found that gel pad used underneath the axilla may introduce unwanted high pressure loadings at the interface which could be detrimental. For prone position, as chest pad is usually used during surgery, usage of Warmcloud may not be effective. Furthermore, we also found that the recommended inflation pressure for the Warmcloud system based on patient’s BMI may not give the best pressure relief characteristics. For best protection to patients, pressure measurement of the body support interface on the operating table needs to be carefully considered.

PS12.030 - Continuous cuff-less estimation of systolic blood pressure from pulse wave transit time measured in a chair

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Introduction: To control blood pressure, especially hypertension, long-term monitoring of blood pressure at home can be effective and reliable compared with regular monitoring in a physician’s office. This requires the development of more convenient blood pressure monitors to replace cuff-type sphygmomanometers. In this work, we propose a new method of non-invasive continuous cuff-less estimation of systolic blood pressure (BP) at home from pulse transit time.

Principle:

The cuff-less BP monitor estimates the BP by pulse wave transit time (PWTT). Generally, if BP is higher, the PWTT is faster. The PWTT is obtained from the R wave of the ECG and the peak of the first derivative of the PPG signal. Although the blood flow and PWTT depend not only on BP but also stiffness and tonus, PWTT is primarily related to BP.

Systolic blood pressure is estimated with the following equation:

\[
P_e = P_b - \frac{2}{\gamma T_b} \Delta T
\]

where is the based blood pressure level, \( T_b \) is the PWTT corresponding to the pressure, \( \Delta T \) is the change in PWTT, and \( \gamma \) is the peripheral resistance.

Method: The cuff-less BP monitor consists of three fabric electrodes attached on both arms of a chair: a plus electrode for ECG installed on one side and a minus electrode and grand electrode for ECG are installed on the other arm. A PPG sensor is also installed on one arm. From ECG and PPG signals, we estimated BP. Seven healthy subjects aged 20–65 years participated in the experiments. Subjects sat in the armed chair and touched the electrodes and PPG sensor. Subjects also attached a continuous blood pressure monitor (Finometer; Finapres Medical Systems Corp.).

To evaluate the method, the continuous blood pressure monitor was used as a reference. The simultaneous recordings of the continuous blood pressure and the cuff-less BP monitor were monitored. The deviations and RMSE of the errors were calculated.

Results: Preliminary experiments showed that the errors in most results were under 10% compared with the reference. The deviations and RMSE of most results were not above 10 and the error ratios of most results were also below 10%.

Discussion: We attempted to estimate systolic BP from PWTT. The results were promising. We are satisfied with the current evaluation stage but more precise monitoring is needed to replace cuff-type sphygmomanometers and for predicting diseases related to high BP.

References


PS12.031 - A development of the pressure distribution display which is used in robot hand for the disability

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We are now investigating about a robot hand control system for the amputee which is controlled by SEMG. From previous studies, it became clear that a robot hand can be controlled by SEMG which is measured from a forearm. And we also developed the robot hand control system which could measure grasping power and feedback this power to an operator. In this system, a pressure sensor for one point was used for feedback system. For this reason, our previous system could not feedback the pressure distribution on the hand surface to the operator. It is thought that if the pressure distribution of the grasping object is known, the operator will be able to know the detail of the object. So, our objective of his study is a development of the sensor which can measure pressures of multi-point.

The pressure-sensitive conductive rubber is used in order to construct a multi-point pressure sensor. In this rubber, conductive material is uniformly spread. Thus, the resistance value of this rubber changes according to the stress that is given to the rubber. A construction of the sensor is shown in Fig.1. In our developed sensor, 25mm square pressure-sensitive conductive rubber sheet was used as a sensing material. As shown in this figure, 4 conductive lines are set on each row and column. And the rubber sheet is set between these lines. This sensor can sense pressure each 16 lattice points as conductive value. In our sensor, the sensing point is changed by analog switch driven a microprocessor.

A developed sensor was set on a robot hand and tested using aluminum object. Grasping power of the robot was set from 0.8 to 3.3 kg, and the response of a developed sensor was measured. From the experiment, following results become clear. 1) The sensitivity of all sensors are almost equal. 2) There are small crosstalk at each sensing point. However, these crosstalk of each point are almost equal. From these experimental results, we have
concluded that our developed sensor will be useful for the multiple sensing of the distributed pressure.

Fig1. construction of sensor

**PS12.032 - Prototype Development Generating Vacuum for Treating Chronic Wounds Negative Pressure Level Laboratory**

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At present time, the medical care is being referred not only to treatment of a diagnosis disease itself, but also their complications and variations that could become chronic and therefore more devastating. With the known increase in overall life expectancy, we know that we are facing a whole different types of diseases. A case of these chronic wounds; which is a condition that has generated a very high cost both in financial perspective, and the health complications that such diseases generate. Negative pressure therapy is a procedure that has caught the attention of health professionals due to its effectiveness. But for many of them still remains unknown the biochemical process behind this therapy. On the other hand, is a process becomes costing up to $ 40,000. As only a small percentage of the population or health systems that could afford to use a system of this type in order to treat a condition of chronic wound. For this project a methodology that involves the development of a negative pressure prototype for chronic wounds is proposed. The scope of this paper is to analyze the variables involved in the negative pressure system in order to generate models of fluids and colloids for the study of the variables that are in the process of healing of chronic wounds. This with the intention of support research and development in the area of devices negative pressure therapy inexpensive that could expand the range of use and users.

**PS12.033 - Tunable Irradiation System for Corneal Collagen Cross-linking**

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An optical arrangement has been set up for spectroscopically measure the transmittance of UVA light through 10 human preserved corneas of over 400µm thickness during the corneal collagen cross-linking procedure under the current procedure protocol for early stage keratoconus treatment. To enhance absorption of UV radiation, Riboflavin solution (0.1% and 400 mOsm) was applied prior to and during exposure. The UVA beam - 365nm ± 5nm at 3mW/cm² ± 0.003mW/cm² was focused directly onto the corneal stroma. To enhance absorption of UV radiation, Riboflavin solution (0.1% and 400 mOsm) was applied prior to and during exposure. To enhance absorption of UV radiation, Riboflavin solution (0.1% and 400 mOsm) was applied prior to and during exposure. The UVA beam - 365nm ± 5nm at 3mW/cm² ± 0.003mW/cm² was focused directly onto the corneal stroma. Our studies on the UVA transmittance of the cornea during the cornea collagen cross-linking have shown that without Riboflavin, there is a 61.6% transmittance of UVA light toward the endothelium and at the very end of the treatment it decays to 12.6%. However, the transmittance differs in each of the stage of the treatment. In our experiments, the average transmittance in terms of energy during the 30 minutes irradiation procedure fluctuated from 0.67 to 0.38mW/cm². (figure 1). These results indicate different levels of UV transmittance during treatment and lead to the development of new technologies and consequently new protocol considering using tunable UVA irradiation system and delivering different doses at each stage of the treatment, therefore to minimize irradiation time, reducing treatment time consumption

**Figure 1: Transmission spectrum of a human cornea with CCT = 571µm during the collagen cross-linking procedure. (Base UV= Baseline; Base Cornea = cornea without epithelium and no application of Riboflavin; Rib = 1 drop of Riboflavin application; Xlink = Riboflavin + UVA irradiation; the numbers following the Ribs and Xlinks indicate the time interval in minutes that an event has been performed during the procedure).**

**PS12.034 - Electromagnetic high-hydrous gel phantom at a low-frequency band - Improvement in the electrical characteristics by using a carbon microcoil and investigation of its mechanism**

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This paper presents an improvement in the electrical properties of a high-hydrous gel phantom by adding a carbon microcoil (CMC). A mechanism to improve the relative permittivity by the addition of the CMC is introduced. The CMC functions as an inductance at a certain frequency range. Adding a CMC to the conventional phantom is useful in improving the electrical characteristics at a frequency range of 10 MHz to 30 MHz, thereby increasing the relative permittivity.
**PS12.035 - Examination of Bisphenol A Elution Concentration in Dialyzers**  
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**[Objective]**

Bisphenol A (BPA)—a chemical substance with an endocrine disruption effect—is contained in polycarbonates used in membranes, housing, constituents, etc. of dialyzers, and exposure of dialysis patients is unavoidable. We measured and examined the BPA elution concentration in various membranes used for hemodialysis therapy and dialyzers with various sterilization methods: here we report the results.

**[Method]**

RENAK PS-1.6 (AC sterilization, g-ray sterilization, and non-sterilization), APS-15SSA, TS-1.6U, FDY-150GW, KF-15C, NV-1.6U, PES-15Eaeco, PES-15Saeco, VPS-15HA, PN-140, and NF-1.6H were the target dialyzers. For wet-type products, 1 ml of filling fluid was sampled first, then the blood side was cleaned using 1 L of purified water for 5 min at 200 ml/min, and 1 ml of the cleaning fluid remaining in each of the dialyzers was sampled for measurement. Portions of the hollow fiber and the housing were cut out and immersed in purified water at 70°C for 1 h. A 1 ml aliquot of this immersion fluid was used to measure the BPA elution concentration from the constituent. High Sensitivity BPA ELISA Kit (Tokiwa Chemical Industries Co., Ltd.) was used as the measurement method.

**[Results]**

The BPA concentration of the filling fluid was the highest for NF-1.6H, and was equal to or less than the detection sensitivity for APS-15SSA. The BPA concentration after cleaning was 0.86 µg/L for FDY-150GW: the highest value reported. The BPA concentrations of the filling fluids for RENAKPS1.6 with the AC sterilization, the g-ray sterilization, and the non-sterilization were 0.18 µg/L, 0.18 µg/L, and 0.28 µg/L, respectively. The BPA concentrations after cleaning were 0.18 µg/L, 0.14 µg/L, and 0.13 µg/L, respectively. Thus, different sterilization methods did not lead to noticeable differences in results. The BPA elution concentration from the constituent was the highest for FDY-150GW for both hollow fiber and housing.

**[Conclusion]**

The BPA elution concentration in dialyzers was the highest for FDY-150GW after cleaning, and a different sterilization method in RENAP-S-1.6 did not lead to different results. BPA was detected in both membrane materials and the dialyzer constituents. It is important to minimize the amount of eluted BPA by improving the cleaning effect on BPA while suppressing the elution of BPA.

**PS12.037 - Effectiveness of Ozone-Liquid Mass Transfer aiming Ozone Therapy**  
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The effectiveness of ozone therapy depends on the efficiency of the mass transfer phenomenon between gas-liquid phases. Many variables are involved in this process, whose techniques aiming biological applications require constant optimization. This study aimed to compare ozone-water mass transfer held by a Venturi and a Bubble Diffuser. The results show that the turbulence associated with increased liquid velocity in the Venturi is capable of generating ozone concentration of up to 6 times higher than Bubble Diffuser, or 0.87 mg/L in 20 minutes to the Venturi, and 0.15 mg/L for Bubble Diffuser. The use of Venturi in mass transfer processes in gas-liquid phase can promote the application of ozone therapy in biological systems, since turbulent processes do not damage the fluids involved in this process.

**PS12.038 - Impedance plethysmograph based on reconfigurable hardware for the study of superficial vessels**  
**Author(s):** Laura L. Castro  
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Impedance Plethysmography (IPG) is a simple, low cost and non-invasive method to research and assess circulatory and vascular diseases in humans. An important feature of this method is that the volume changes of the blood flow in different organs or body parts can be detected. This paper aims to develop, simulate and implement a bioimpedance measurement system for the characterization of blood flow in surface vessels. Howland’s scheme is implemented for current injection. Quadrature demodulation of bioimpedance signal is used to preserve both amplitude and phase information. The bioimpedance signal processing and a user interface based only in FPGA and basic peripherals (monitor, keyboard and mouse) linking
is achieved within the FPGA.

The implementation of this technique on reconfigurable hardware is a considerable advantage for the development and updating of design, allowing design flexibility and real-time processing due to parallelism offered by FPGA. The user interface greatly reduces system cost as it allows visualization and control of bioimpedance signal without using a computer.

**PS12.039 - The study for bioelectric properties of tissue and organ measured by electrical impedance**

**Author(s):** Toshiaki Nagakura1, Kouya Watanabe1, Yoshio Yasumura2, Michiko Kido2, Moe Yokoyama2, Kenji Yamada3, Yuko Ohno3, Toshiaki Nagakura1, Kouya Watanabe1, Yoshio Yasumura2, Michiko Kido2, Moe Yokoyama2, Kenji Yamada3, Yuko Ohno3

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About 60% of weight of the human exist as various solutions with water. And the dissolved substance concentration and localization in the solution are controlled severely. Each concentration is an important parameter for diagnosis and treatment, but there is very few continuous quantitative measurement method. From the physiologic point of view ion concentration and components of the biotissue are different, electrical specification is different. Though this is well known, and also the electrical measurement has the advantage that continuous measurement is possible, there are not developed the clinically useful measurement system. Therefore we tried to study the system for clinical application to measure a living body electrically. We applied the alternating voltage (5[Vpp]) of the level not to cause macro-shock to a living body and measured a frequency characteristic of frequency 0 - 20[MHz]. We measured the electrical specification (impedance and phase) change such as solutions of an electrolyte and the protein which there was to a living body. The impedance of most material in tissue including the liquid decreases to from 0 - 1MHz approximately monotonically. On the other hand, we found that it had quantitative tendency even if we injected electrolytic solution and a protein solution into biotissue. Moreover, with the measurement under various conditions, we measured the variance condition of the electrical specification in different kind of tissue and organ.

Figure 1 The relationship between the impedance of chicken muscle and concentration of solution. We were able to lead a difference and the tendency of the electrical characteristics in tissue and organ by this study. We could estimate that the solute and solvent transfer of an organ which having electric specificity of living body. We improve these results to be able to do clinical application.

**PS13 - TRACK 13: INFORMATICS IN HEALTH CARE AND PUBLIC HEALTH**

**PS13.001 - A Method for Parental Engaged Consent in the Perpetual Secondary Usage of Health Big Data**

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**Introduction**

Knowledge discovery from the analysis of Big Data has contributed to significant breakthroughs in health care. However, personal health information is typically sensitive and identifiable thus presenting unique ethical and legal challenges when used for secondary research purposes. Our case study context, due to our recent research is Neonatal Intensive Care as the data that is generated by monitoring devices, generates a Big Data problem. In the case of neonatal research, parental engagement within the consent process is often required. Increased engagement with parents in ongoing studies requires a multileveled consent process that can be changed over time. Therefore it is important that the consent model respects their preferences and allows them to modify such preferences whenever possible and at their convenience over time.

Artemis is a platform for concurrent multipatient, multidisciplinary, and multistream Big Data analysis for clinical management and research that uses continuous physiological data streams. The Artemis platform is composed of five components consisting of the data acquisition, online analysis, knowledge extraction and the redeployment components. Currently, the Artemis platform does not support flexible consent over time. The primary and secondary usage of physiological data collected by the Artemis platform has already contributed to new clinical discoveries related to conditions, specific to the neonatal population.

Our research focuses on engagement of the parental community who have or have had an infant in the NICU with the use of a flexible consent model which will provide researchers with the ability to integrate the patient selection process with the data mining component of the research study.

**Objective**

In this work we extend the current Artemis knowledge discovery component. These extensions to the current consent model will support parental preferences regarding the consent and use of their infant’s physiological data over time.

**Methods**

To address the research aims, new tables were defined within the Artemis database model to enable parental consent. The extensions not only enable this consent to be more explicitly tied with the data, but enable the consent to be changed over time or have parents engaged regularly for consent based on their chosen degree of consent through a web based portal.

**Results**

The extensions to the knowledge discovery component support parental engagement in the secondary use of their child’s data through a continuum of secondary use of data retrospective studies. The architecture is currently being tested as part of our research into Apnoea of Prematurity.

**Conclusions**

Parents are surrogate decision makers for their infant. A flexible con-
sent model will be beneficial to various stakeholders including the parental community and researchers. Engaging parents or patients empowers them in the research process and enables their consent preferences to be respected. For researchers it is a platform that allows them to maintain continuous contact with the parental community thus maintaining a pool of potential research participants for them to contact for future recruitment purposes in addition to assisting with the results dissemination process to interested parents upon completion of the study.

PS13.002 - RENEM – Brazilian National List of Equipment and Materials
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To ensure the actions of the Brazilian Unified Health System (SUS) can be achieved with universality, integrality and gratuitous, the Ministry of Health (MoH) provides investment programs for institutions to acquire equipment and materials for the operation of its services. As the budget is always limited, the MoH implemented a methodology to make improvements in their processes of adoption and investment, divided into four fronts: (1)-Adoption of a National List of Equipment and Materials (RENEM); (2)-Regulatory processes for incorporation and management of RENEM; (3)-Creation a bench of prices; and, (4)-Automation of investment analysis. RENEM was adopted after systematic standardization of nomenclatures culminating in the preparation of equipment combos distributed according to the complexity of healthcare environments, eliminating issues of requests not according to their profile service. A computerized system was developed to manage the structure of RENEM and the entire process of investment analysis, streamlining routines and paper elimination. Regulating incorporation of RENEM items established the minimum requirements of scientific evidence and deadlines for decision making. A cooperation program was created to capture economic and technic information and a function was introduced into the system that provides the technical features of the equipment in multiple choices. Each technical feature has a monetary value associated that represents the impact on the final price. Thus, the system performs a dynamic price setting which automatically adjusts to the selected specification. A tool that performs the historical search of the quantity and value of equipment financed by state, city and institution allowed the creation of ABC curves and Pareto analysis, identifying the key items of RENEM that require further attention. As a main result, the number of investments approved in 2014 was almost four times higher than the previous year with significant improvement in projects quality.

PS13.004 - Design and Implementation of an Application for ECG processing in Mobile Phones
Author(s): René González-Fernández, Margarita Mulet-Cartaya
Division Of Medical Devices, Central Institute of Digital Research, Havana/CUBA

The aim of this paper is to discuss the main features implemented in an Android application for ECG processing. The software was designed to use a mobile phone, connected to a battery-powered ECG device, as a signal acquisition layer in a Telemedicine platform oriented to implement several health services such as arrhythmia follow-up and remote pacemaker evaluation. The ECG device should be able to acquire and transmit, via Bluetooth, a bipolar ECG lead; the transmission time can be set previously. A friendly user interface was implemented for data entry and to display signals and result: all input data is validated according with its type and length. Error handling is focused on ensuring data reliability and the proper application functioning. The Android application receives the ECG data according to a simple protocol defined by the authors. Each data block is composed by a header byte, signal samples, electrode status and pacemaker spike identification. When a complete ECG strip is received, the electrocardiographic signal is filtered using a FIR moving average filter. QRS complexes are detected and classified, as premature or not, RR intervals are measured and heart rate is computed. An auxiliary function based on the Teager Energy Operator was combined with two thresholds to detect QRS complexes. The same function was applied to identify P wave regions previous to each QRS complex detected. P wave were delineated combining baseline estimation, a baseline-correction algorithm and heuristic rules. ECG strips are classified as arrhythmic or not taking in count the quantity of premature QRS complexes. A SQL database was designed to store patient general data, each ECG strip with the signal processing results and the data and time when the strip was captured. All these information is uploading to a web site using GSM/GPRS network and HTTP protocol. Also, all the data is store in a database implemented in the phone; this feature allows downloading that information into a personal computer when connectivity facilities are not available. The software was programming in Java language using Eclipse SDK and SQLite database engine.

The proposed software has been tested with five models of Android phones, running Android operation system version 2.3 or higher. The user interface was rated as excellent by users involved

Ubiquitous sensors, devices and networks are paving the way towards a smart world in which computational intelligence is apply at all levels of the physical environment to provide reliable and relevant services to patients. This ubiquitous intelligence will change the computing landscape and environment around the patient, because it will enable new breeds of applications and systems to be developed and the realm of computing possibilities will be significantly extended. By enhancing everyday objects with intelligence, many tasks and processes could be simplified. The physical spaces where patients interact like the homes and hospitals could become more efficient, safer and more enjoyable. Ubiquitous computing, or pervasive computing, uses these many “smart things” to create smart environments, services and applications.

The Internet of Things is a new concept for telecommunication development. The Ubiquitous sensor Network is one of the general components of Internet of Things. A smart thing can be endowed with different levels of intelligence, and may be context-aware, active, interactive, reactive, proactive, adaptive, automated, sentient, perceptual, cognitive, autonomic and/or thinking. Research on ubiquitous intelligence is an emerging research field covering healthcare needs. A series of challenges exist to move from the current level of computing services in healthcare to the smart world of adaptive and intelligent services.

PS13.003 - Becoming of Ubiquitous Sensors for Ubiquitous Healthcare
Author(s): Sergio A. Dadunashvili
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Ubiquitous healthcare has become one of the prominent areas of research in order to address the challenges encountered in healthcare environment. Ubiquitous healthcare requires networks of intelligent sensor nodes that could be deployed “anywhere, anytime, by anyone and anything” and is a permanent part of the human presence. Management of systemic diseases via technology based ubiquitous patient monitoring services has been widely proposed as a viable option for economizing healthcare resources, and providing efficient, quality healthcare.
in testing process. Errors were not reported in Bluetooth communications when the distance between the ECG device and the phone was less than ten meters. QRS complex detection algorithm was tested with MIT-BIH database and the QRS detection sensitivity was 99.24%; false positives were not identified. P waves coupled to QRS complexes were studied in fifteen ECGs of the same database; sensitivity was 92.48%. It could be considered as a good performance, but the test has to be complete with the complete database.

The developed software seems a powerful tool to convert a mobile phone, combined with the appropriated ECG device, in a medical device for several Telecardiology services.

PS13.005 - A Telemedicine System to follow-up the Evolution of Chronic Diseases in the Community
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A system was designed to follow-up three chronic diseases: cardiac arrhythmia, hypertension and diabetes mellitus. Patient evolution can be studied daily without hospitalization and the objectives are:
- To document the evolution of the studied chronic diseases.
- To correct medical treatment as soon as it is necessary.
- To avoid inconvenience to patients because of the frequent visit to the hospital.

Patients are registered in the system during their first visit to the physician; they are trained to make the appropriated test at home to get the necessary measurements. The medical devices will be: a commercial blood pressure device, a commercial glucometer and a one-channel ECG device designed by the authors of this paper. If glucose and blood pressure device have Bluetooth capability, data is wireless transmitted. When this feature is not available, values are entered manually using a friendly interface implemented in the mobile telephonic terminal. Two alternatives are available for that terminal: an Android mobile telephone running an application developed by the authors and a specific telephonic terminal designed by the authors too. The physiologic data is processed, when it is necessary, in the mobile telephonic terminal and the results are uploaded to a website. A web application stores the uploaded information in a SQL database. Physicians log in the web application to study their patients; specific graphic tools were developed to help this analysis. This operation mode allows medical treatment can be adjusted as soon as it is necessary and medical care is improved. The following algorithms were implemented in Java and C languages for ECG processing: a FIR moving average filter to minimize noise presence; QRS complex detection and classification based on an energy collector combined with two thresholds and heuristic rules; heart rate measuring and ectopic beat rate measuring. Two prototypes of the ECG device and one of the mobile telephonic terminal were manufactured; plastic cases and print circuit boards for that prototypes were designed using CAD-CAM tools. The first version of the Android application and the web application were ended. The ECG device was evaluated according to the IEC 60601-2-47 standard with good results in all tests. The Bluetooth communication was tested with 600 one-minute simulated ECG strips without errors; received signal were identical to those originally transmitted and never data transmission was aborted because of fatal errors. ECG processing algorithms were evaluated with twelve thirty-minute ECG strips from the MIT-BIH arrhythmia database; the sensitivity in QRS complex detection was 98.77% and no false positives were identified.

PS13.006 - Developing an Appropriate and Affordable Expert System for Medical Diagnosis (ESMD) in Developing Countries
Author(s): Kenneth I. Nkuma-Udah, Gloria A. Chukwudebe, Josiah Ahae, Kenneth O. Ejeta, Gideon I. Ndubuka
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Bringing intelligent healthcare informatics to bear on the dual problems of reducing healthcare costs and improving quality and outcomes is a challenge even in countries with a reasonably developed technology infrastructure. In the developing countries, like Nigeria, introduction of intelligent healthcare informatics then becomes constrained by considerations not only of affordability but also of appropriateness of the innovation. This research sets out to develop an appropriate and affordable expert system for medical diagnosis ESMD in developing countries. ESMD is designed to enable clinicians to identify diseases and describe methods of treatment to be carried out taking into account the user capability. The ESMD was designed using the C Language Integrated Production System (CLIPS). CLIPS is rule-based expert system tool, which means that knowledge is represented in rules, based on experience. ESMD shell has four modules: the user interface, the explanation system, the inference engine and the knowledge base editor. The knowledge base of ESMD was organized among several clinical signs, symptoms and features associated to drug therapy. The prototype of the ESMD was ready for use after nine months. The system does many random questions in order to enable clinicians make diagnosis and suggest therapy. The system is user-friendly and presented good time-response to give therapy advice. The knowledge base is editable and can be used to generate personal configuration based on population characteristics.

PS13.007 - Assessment of Mobile Health Applications
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Biomedical Engineering Unit, University of Patras, Rio-Patras/ GREECE

During the last years, the usage of smartphones has rapidly infiltrated a plethora of daily functions. The health related applications which can carry out both simple functions such as recording vital signs or more complicated such as operating as computer-aided diagnosis systems, are amongst the most popular. In 2014 more than 100.000 mobile health applications (mHealth apps) have been found in the “medical” and “health and fitness” categories. It is estimated that in 2015 mHealth apps will be used by more than 500 million users worldwide, in which consumers, patients and healthcare professionals are included. This rapid development of mHealth apps revealed the need for their evaluation, assessment and regulatory compliance. This need is imposed by their particular nature, since lack of quality and specificity, or misuse of the information provided, may compromise user’s health status, as well as security and privacy of the personal health data issues which are also of primary importance. The FDA and the European Commission of the EU are releasing standards have been published by the private sector along with end-user assessment methods which have been also proposed. It is expected that in the following years the adoption of the mHealth applications usage will improve the quality of the patients’ lives and will promote the importance of prevention, user education and public awareness. It may also help to reduce the cost of healthcare, while increasing the frequency of interaction between patients and doctors and generally to greatly contribute to ameliorate Healthcare. Therefore it is necessary to develop a framework of adaptive
evaluation and assessment, along with a well balanced regulatory system, especially in cases where an external part is attached to the smartphone that could be considered as a medical device. In this work, it is presented how mHealth apps may in some example-cases replace medical devices and in which parameters their evaluation should rely on. Applications vary from simple devices such as a simple thermometer to more complex ones like an ophthalmoscope. Applications which do not require the attachment of an additional device or sensor, are also examined such as sharing medical images or supporting management of a chronic disease, like diabetes.

Concluding, the need of an evaluation framework for mHealth apps is investigated, and among the basic elements of this analysis is confidentiality, security issues, the importance of usability of mHealth apps, as well as measurements’ accuracy.

**PS13.008 - An Investigation into using Pulse Rate Variability to Predict Clinical Events**

**Author(s):** Usman Raza¹, David Maslove², Evelyn Morin¹, Karen Rudie¹

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Heart rate variability (HRV) describes the natural variation in time intervals between heartbeats, and is usually measured using R-R (peak to peak) times from the electrocardiogram (ECG). Reductions in HRV have been shown to correlate with cardiac events such as myocardial infarction and sudden cardiac death, as well as other critical illnesses such as sepsis. While ECG is the traditional method of collecting peak-to-peak data, it is expensive, cumbersome to use, and does not lend itself to ambulatory use.

It has been shown that pulse rate variability (PRV) is a sufficiently accurate estimator of HRV and can be calculated using photoplethysmography (PPG) [Schafer and Vagedes, International Journal of Cardiology, 2013]. Photoplethysmography uses two light emitting diodes, one red and one in the IR spectrum, and a light sensor to measure pulse oximetry, which can in turn be used to measure PRV. Devices that perform pulse oximetry are cheap, portable, and ubiquitous in clinical settings.

The aim of this work is to develop a prognostic system that can be used in hospital settings as a data-enabled early warning system. Using a stream of patient PRV data the system will be able to predict clinical events and alert a rapid response critical care team earlier than traditional methods. The system will be composed of two main components, the prediction software and a wireless pulse oximeter.

The prediction software will utilize a supervised training algorithm to develop a model using HRV metrics and clinical data. The large-scale incidence of PRV and HRV events will be determined using data stored in the MIMIC II database that contains clinical records and a matched set of multiple physiological signals for 2,809 ICU patients. A subset of the ICU patients that experience specific clinical events (Set A) will be identified and the PPG data in the associated waveforms will be used to calculate HRV metrics.

The algorithm will use a subset of Set A as a training sample and identify features that are highly correlated to the specific clinical events identified earlier. Once a feature-set has been determined, the remainder of Set A will be used to see whether the correlated features discovered in the training subset are also correlated in the testing subset. Iterative adjustments to the feature set and algorithm will take place until the prediction accuracy meets a satisfactory level. Once the system is accurately able to predict clinical events, it will be reconfigured to work with a live stream of clinical data collected across all 32 beds in the Kingston General Hospital ICU.

Concurrent to the development of the predictive system is the prototyping of an inexpensive and robust pulse oximeter that can transmit data over Bluetooth and Wi-Fi and be deployed to all admitted patients at a hospital. The current prototype can wirelessly transmit pulse oximetry data to an online database in “real-time” (~ 3 second delay). Future work on the module aims to reduce its size and power consumption and create an interface between it and the proposed predictive system.

**PS13.009 - A simple device producing electrolyzed water for home care**

**Author(s):** Koichi Umimoto

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The prevention of opportunistic infection for the elderly is important in home care. When water containing sodium chloride is electrolyzed with a electrolytic cell having two chambers of equal volume, strongly acidic electrolyzed water with strong bactericidal ability due to the available chlorine (AC) is generated on the anode side. Weakly to slightly acidic electrolyzed water (WSAcEW, pH 4.0 to 6.5) is physiological pH and is suitable for biological applications. For producing WSAcEW simply and at a low cost, the present device was made of an asymmetric structure having a large anode chamber and a small cathode chamber. As a result, the pH and AC concentration of conventional electrolytic device were 2.3 and 27 ppm and this water was strongly acidic water, however, those of present electrolytic device were 4.0 and 31 ppm, respectively. WSAcEW was obtained directly by this experimental device and this water showed a strong bactericidal activity against bacteria. This device is useful for producing WSAcEW as a disinfectant to employ at home care, since it returns to ordinary water after use.

**PS13.010 - Developing predictive models using retrospective study of liver cancer patients treated with radiation therapy.**

**Author(s):** Jason R. Vickress¹, Michael Lock², Eugene Wong², Rob Barnett², Slav Yartsev³

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Introduction: Radiation therapy is one of the primary treatments for cancer logistically providing an accumulation of information specific to each individual patient’s treatment. A patient’s electronic record in radiation therapy includes demographic data, diagnostic images, CT simulations, radiation planning and delivery parameters and verification imaging describing the patient’s cancer treatment in great detail. Our goal is to harness this vast supply of treatment data along with outcome information in order to tailor radiotherapy treatments for future patients.

**Methods:** Selected radiation therapy planning parameters and outcome information were gathered for 118 patients treated for liver metastases at London Regional Cancer Program between 2004 and 2010. Planning and treatment information was available through an in-house designed system. Outcome information including patient survival, disease recurrence and blood work was collected prospectively. Multivariate Cox proportionality hazard ratio calculations were performed using SPSS version 22 (IBM) across combinations of all parameters in predicting the patient survival and disease recurrence. Patients were stratified into risk groups based on their hazard ratios of the most predictive parameters. All Kaplan-Meir curves were plotted and log rank tests of significance were performed for the patients separated by the median hazard ratio value.

**Results:** The most significant predictive parameters are presented in Table 1 for different numbers of covariates. Improvements of predictive power characterized by p-value were observed through
the increase in significance and mean values of Kaplan-Meir curve separation for each outcome individually. The minimum number of two covariates required for optimum prediction of specific outcome was determined. Mean differences between Kaplan-Meir curves for survival were 7, 10, 11.5, and 17.5 months if 1, 2, 3, and 4 covariates (Bilirubin, Serum Albumin, BED and GTV), respectively, were considered.

**Conclusions:** Multivariate modeling predictions obtained on the data for 118 patients provide physicians with quantitative parameters for more reliable interpretation of the implications and foreseen outcomes for patients receiving radiation therapy based on their proposed treatment and patient’s medical history. A larger patient cohort study will be performed to check the robustness of model predictions.

Table 1. Significance (p-values < 0.05 in bold) of predictions for Liver cancer treatment outcomes and mean separation (in days) between Kaplan-Meir curves when using up to 4 covariates. (Dose/fx = dose per fraction, #fx = number of fractions, BED = biological effective dose, GTV = gross tumor volume, Vx = liver volume receiving > x Gy)

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<th>Covariates</th>
<th>Survival anywhere</th>
<th>Survival in-field</th>
<th>Survival out-field</th>
<th>Recurrence anywhere</th>
<th>Recurrence in-field</th>
<th>Recurrence out-field</th>
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<td>V30</td>
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<td>8</td>
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<td># fx</td>
<td>BED</td>
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<td>n/a</td>
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<td>8</td>
<td>10.5</td>
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**PS13.011 - A Study on the Problems for People to have Colorectal Cancer Screening Tests in Japan—From the Results of Interviews for 30 Adults—**

**Author(s):** Naoko Fujiwara¹, Miki Inagaki², Kenyu Yamamoto³, Misao Yoneda⁴, Masami Azuma⁵  
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In late years, colorectal cancer fatalities and morbidity are increasing together and the rate for people to have colorectal cancer screening tests is regrettably sluggish in Japan. For future decrease in the mortality of colorectal cancer, we performed interviews for Japanese citizens about the factors influencing their behaviors to have colorectal cancer screening tests.

The contents of interviews were organized to four categories with 7-17 subcategories. These results suggest several important factors for people to have the screening test. They are frequent supply of concrete knowledge on the screening tests and the condition of cancer, continuous and life-related motivation to the behavior for the screening test and forming the system available for people to have the test.
**PS14 - TRACK 14: INFORMATION TECHNOLOGIES IN HEALTHCARE DELIVERY AND MANAGEMENT**

**PS14.001 - DermApp: an application for Android mobile devices for reception and transmission of skin images**

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Unlike general practitioners, pediatricians and obstetrician-gynecologists, dermatologists are highly localized in large public hospitals or private clinics, which limit the possibilities to distant patients for care. Telemedicine is then useful for querying skin diseases.

DermApp is an application for Android mobile devices that covers the basic needs of specialists in the field of dermatology for better diagnosis, storing, transmitting and receiving skin images in any place where the doctor is present. DermApp allows a remote medical assistant to use a dermatoscope to capture images of skin lesions and select the most representative for transmission to a backup server that in turn sends the images to the dermatologist’s mobile device.

A dermatoscope is a surface manual microscope widely used by dermatologists to visualize the pigmented structures in epidermis and dermal-epidermal junction for different skin phototypes. The phototype is the set of characteristics that determine whether a skin tan or not to sun exposure and the extent to which it does.

The used dermatoscope, DermLite II Red Hybrid m, has patented technology that combines non-polarized illumination with polarized light, with or without skin contact. This device offers high light output thanks to its 24 LED and a large 25mm lens.

To determine parameters for image quality, a survey was run to nine dermatologists in which images captured with mobile devices having different resolutions were presented. The minimum acceptable resolution was 3 MP. They also felt that the application had better functionality within the skin phototype III (darker white) which corresponds to a considerable percentage of the Venezuelan population.

From the evaluation of different mobile devices existing in the market we decided to use a smartphone with Android open OS for the facilities and other utilities in terms of programming offered by this operating system environment. In addition, we used a JPEG format because besides being compatible with most existing mobile devices on the market, it allows the transfer of files over a range of acceptable time without affecting markedly the image quality.

A VPN and SSH protocol were used to connect the mobile device with a backup server. Files were transferred with FileZilla program through the TCP protocol.

**PS14.002 - Use of mobile devices for prevention in youngsters of risk factors common to chronic noncommunicable diseases**

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Promoting behaviors and healthy lifestyles is today one of the most used mechanism for the prevention of chronic non-communicable diseases such as cancer, diabetes and CVD, which are leading causes of mortality in Venezuela (86%) and the world.

The application of telemedicine in the field of health education provided for the prevention of these diseases through the use of advanced technologies that help disseminate information about common risk factors and unhealthy diets, physical inactivity, stress, consumption of tobacco and alcohol.

Promoting healthy behaviors through a telemedicine preventive system is sought by the use of mobile devices, based primarily on the technology of instant messaging (SMS) or social network Twitter widely used by youngsters in Venezuela and a query system via email.

Mobile phones and social networks are popular among the population. According to CONATEL (National Telecommunications Commission of Venezuela) 27 billion SMS text messages (1000 per capita) were sent in 2012. According to Semiocast (France) Venezuela was the 12th country on Twitter accounts and 6th in activity in 2012. Both media can be exploited to disseminate information about healthy behaviors and preventive factors of chronic non-communicable diseases.

The management system for instant messaging SMS and Twitter is implemented by a server to the database, a desktop application and a website. Text messages on physical activity or nutrition, prepared by students advised by psychologists, are sent to each of the mobile phones of youngsters through a modern connected to the GSM network. These youngsters can then use the system to consult psychologists and nutritionists.

Preliminary work was supported by a survey: randomly selected students were asked about their beliefs and attitudes to the risk factors of chronic non-communicable diseases and implementation of a platform for dissemination are measured content on healthy lifestyles. They were also asked about the preferred methods of communication (email, SMS, presentations, advertising) and most used social networks (Facebook, Twitter, Google+, LinkedIn, Instagram, MySpace or other) which can be used for the prevention of chronic non-communicable diseases.

The system is safe, accessible and easy to use and can be extended to different areas for the dissemination of information.

**PS14.003 - Telemedicine in the Universidad Católica Andrés Bello (UCAB), Venezuela: an academic experience**

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Universidad Católica Andrés Bello (UCAB) is the oldest private university in Venezuela (1954). The School of Telecommunications En-
gineering started its academic activities in October 2001, pioneered Venezuela in this discipline with its own profile, which emerged in cooperation with Universitat Politècnica de Catalunya (UPC), Spain. In some autonomous public universities, Telecommunications often is a specialty in the program of Electrical Engineering.

The program requirements include a one-year special project in addition to regular and complementary courses. Based on the experience made since 1998 in the Group of Medical Physics, Faculty of Sciences of Universidad Central de Venezuela (UCV), one of the authors (IE) suggested the possibility of developing some special projects in telecommunications applications to the area of health. Unlike UCV, UCAB does not have a medical school, but a health center that provides outpatient medical care in various clinical specialties as part of social work at the University.

The first project started in October 2005, the second one in March 2006. In August 2006 there was a meeting Ministry of Health - Universities to establish a “Pilot project for sustainable development of the National Telehealth Network” which contemplated five subprojects to be executed in three years: Connectivity, Standards, Medical Informatics, Tele-specialities and Tele-education. Although the national project ultimately was not implemented our School maintained the development of one-year special grade works in the area of Telemedicine.

The interest for this area quantified in 164 students in nine years, which is almost 20% of 900 graduates. These works developed two lines of investigation: Telematics and Connectivity. Telematics projects have addressed issues in areas such as Imaging, Medical Informatics and use of mobile devices with open OS for Endocrinology, Dermatology, Cardiology, Spirometry and Remote Monitoring. Connectivity Projects took place mainly in non-urban care centers in counties of various states in Venezuela, sometimes in cooperation with the Medical Informatics Center (CIM), Faculty of Medicine of UCV. Fifty-nine students have also completed short internships at the Medical Informatics Center (CIM).

In October 2008, a new sixteen-week course, Topics in Telemedicine, incorporated as an elective course in the Telecommunications Engineering program. This course is primarily a seminar and also has a five-week workshop on Introduction to Tele-radiology that involves students with programs that allow viewing of medical images, image transfer between two terminals and access them via web. Another workshop with mobile devices to capture and transfer bio-signals will be included soon.

Telemedicine has been an important experience for inter-institutional and interdisciplinary activity and in just over nine years has opened a line of applied activity in addition to the more usual lines in the telecommunications area framed in Communications Technology, Electronics and Informatics.

The main objective of our Telemedicine Group has therefore been the contribution to social welfare by implementing telecommunications networks to support medical research activities and its applications to health and the use of mobile devices. Some results have been presented in eleven national and five international events (including WCMPBE 2009 and 2012).

PS14.004 - Passage from analog to digital in radiodiagnostic processes

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The use of information technology in the medical field is becoming more and more popular, and healthcare companies recognize the benefits deriving from it and are converting themselves to digitized workflows over paper, both for economic reasons and to simplify the work of operators (administrative, clinical, health ...). Among the various analog-digital conversions, the Ris/Pacs is one of the most interesting for its complexity. Digitizing an entire radiology department requires a very careful analysis phase, in order to model workflows with adequate accuracy. Modeling workflows is of fundamental importance, as there must be absolute correspondence between model and reality. Several steps are needed before completing the final project and it is very important to satisfy all the specific requirements of the health care company in order to increase productivity and efficiency. The current computer systems allow to implement ambitious projects, however guidelines and regulations have to be respected. It is clear that the state of art about analog-digital conversion rules are several from the technical point of view, but lacking for quality management. The present study aims to analyze all the aspects related to the passage of analog-digital radiology department, carefully assessing and detailing every aspect of the whole project.
PS16.001 - Increasing the health value per dollar spent: How Human Factors can help inform procurement of healthcare technology

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Introduction: Use of technology systems is increasingly prevalent in healthcare and important in medical providers’ efforts to promote quality health care delivery. Some healthcare organizations have already realized major gains through the implementation of multifunctional, interoperable healthcare technology systems. However, as with any well-meaning and innovative medical advance, these technologies bring both intended and unintended consequences to clinicians’ work practices and patient safety. The widespread implementation and adoption of healthcare technology has been limited by a lack of generalizable knowledge about what types of healthcare technologies and implementation methods will improve care. In Healthcare the value per dollar spent in new technology is often of little value.

Inclusion of Human Factors (HF) in the procurement of healthcare technology is new to Spain. Through collaboration with HumanEra, Canadian experts in HF, Evaltec, a newly formed HF team, based at the Hospital Universitario Marques de Valdecilla, Spain, began to apply HF.

Objective: The aim of the present study is to describe a combination of human factors (HF) assessment techniques that were used to assess technologies and inform procurement, and implementation of a next generation device in a Spanish hospital.

Method: We present a case study in which two HF techniques (i.e. ethnographic field observations and heuristic evaluations) were used to inform the procurement of infusion pumps. Specifically, ethnographic field observations were conducted to study, in situ, use of the intravenous infusion pumps currently in use in the hospital to better understand the barriers and facilitators to the use of the device. Furthermore, heuristic evaluations were conducted to uncover design deficiencies of infusion pumps that are currently in use. This information was used to better understand users’ needs and the system elements that must be in place prior to the procurement and implementation of the next generation pumps.

Results: The use of HF techniques provided a new lens with which to observe the healthcare system (i.e. technology, people and environment) and revealed several issues that had not previously been identified. Ethnographic field observations provided an understanding of institutions’ current practices surrounding use of intravenous infusion technologies and barriers to the optimal use (e.g. lack of a match between the physician orders and drug libraries). Heuristic evaluations were effective for quickly identifying potential user interface design problems (e.g. clarity, consistency, and familiarity in the language and labeling used on the pump interface). Together, these results identified the importance and broad impact of both usability and safety issues and informed procurement requirements.

Conclusion: From this collaboration, the Evaltec team has realized the importance of applying Human Factors methods to the evaluation of medical devices. The knowledge gained from this experience will help ensure that the imminent procurement of the next generation of infusion pumps considers the user needs, reduces the waste of consumables, increases the efficient use of the pump, and increases the health value per dollar spent. The present study demonstrates how the application of HF can help inform the design of systems and ensure that unsafe devices are not introduced to healthcare facilities.

PS16.002 - Using Heuristic Analysis to support Usability Evaluation of a low risk medical device under development process

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New technologies in the healthcare area have increased the possibilities to diagnose and treat the patients but also have added complexity and associated risks by use errors and users dissatisfaction during the use of complex machines. This paper deals with a new medical device under development in Brazil. The device is classified in the country as a low risk, but the device is intended to give comfort and to prevent futures problems to the patient under its use. The manufacturer wants to evaluate the usability of the device to provide user satisfaction and efficient use of it. The heuristic analysis was the method chosen to evaluate the device, early as a prototype, in order to identify problems in the developing interface. The analysis was done by six specialists in Human Factor Engineering & Usability Lab in Federal University of Itajuba. We conclude that the heuristic evaluation was appropriate to evaluate the equipment in question, since helped identify relevant points that should be considered by the manufacturer to meet your customer and contribute with safety and efficiency in use.

PS16.003 - First Contact with Human Factors and Usability Evaluation in a Junior Research Project by a Biomedical Engineering Student

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This study reports the experience of an undergraduate student enrolled at a junior research project in Human Factors Engineering (HFE) and Usability Evaluation of Medical Devices. The student was undergoing the third year of Biomedical Engineering, without any previous knowledge on HFE. The student was required made a literature review about the important concepts in the area first. The second part of the project consists on running a usability evaluation comparing two digital blood pressure monitors. A tutor, who is a human factors expert from another university, helped the student on setting up the methods, building the protocols and questionnaires.

In Brazil, Biomedical Engineering is a growing profession. The core curriculum of a Biomedical Engineer course is characterized by interdisciplinarity. Although, it is uncommon to have disciplines related to HFE in undergraduate programs. HFE usually is taught as a small part of product development or in risk management related disciplines. This leads to biomedical engineering students with little knowledge on HFE, even with a high probability of working in the
development of medical devices in his career.

The junior research project was designed to give the student its first contact with HFE. It consists on comparing two digital blood pressure monitors, as if the student was required to choose and acquire one of them. Various HFE methods were presented and the student had to select the most appropriate ones. By understanding the basic functions of the equipment, with task analysis and cognitive walkthrough, the student developed protocols to perform the usability testing. There were two user groups of six participants, one for each device. Both groups had problems. The main issue was the difficulty of device installation and proper use, the clamp being one of the problems. Some of the functions, as memory, were also a source of problems. It is an important feature for patients who make a periodic pressure control, but it raised confusion on how to record and read the data, on both devices. The users pointed that they rather write down the values on a paper than using this function. The student found out that 83% of users ignored the instruction manual, even for the device that offered a quick guide. The instructions for use and the device labels were also conflicting. Another confusing point was the device alarms of high and low pressure, which caused misinterpretation.

Even though this was the first experience of the student performing the usability evaluations, she could raise a comprehensive list of considerations about the usability of the two products, with very interesting results. Unfortunately, the topic of HFE for medical devices is still unexplored in Brazil, even at academic environments for students training. With this research, the student could become aware of the importance of the issue, get to know HFE methods and applied them to the evaluation in real devices. The research also gave the student a better understanding on the importance of these topics in a product development.

PS16.004 - Non-Contact Measurement of Arterial Compliance (NCMAC)
Author(s): Delran Anandkumar, Steve Greenwald, Ragu Prakash Ratnakumar
Blizard Institute Of Cell And Molecular Science Pathology Group, Barts and the London School of Medicine and Dentistry, London/UNITED KINGDOM

Introduction

Increased arterial wall stiffness (especially in the aorta) is implicated in cardiovascular disease (CVD). Pulse wave velocity (PWV) as a measure of arterial stiffness is a powerful prognostic indicator for CVD morbidity and mortality. However, current methods used to measure PWV require highly trained staff undertaking lengthy procedures to obtain reliable results, making PWV assessment unsuitable as a diagnostic tool. We propose a novel non-contact reflectance photoplethysmography (PPG) method (NCMAC) of measuring PWV with the aim of making PWV assessment more accessible and therefore suitable for routine screening in a primary care environment. The device is designed to detect the pulse wave in the intercostal arteries and relies on the assumption that the timing of the wave as it reaches superficial tissue near the ribs on the subject’s back closely reflects that of the wave as it traverses the descending thoracic aorta. However, this study aimed to validate the NCMAC device against simultaneous measurements of carotid radial PWV using Doppler ultrasound to detect the pulse wave. The arm was chosen as a test location as the radial artery is larger and more superficial than the intercostal arteries.

Methods

We recruited 61 healthy volunteers (37 male, 24 female) between the ages of 18 and 30. Images of the medial aspect of the right forearm were captured by an infra-red camera (Eosens CL, Mikrotron, Unterschleissheim, Germany), for 30 seconds at a frame rate of 500Hz and analysed offline with custom Matlab software. This allowed the PPG signal to be extracted from individual or groups of pixels a known distance apart, from which the time delay and hence the PWV was calculated. The Doppler signals (MD2, Huntleigh Healthcare, Cardiff, UK) were recorded from the same arm shortly thereafter with the probes placed a known distance apart at the elbow and wrist.

Results

We found a weak but statistically non-significant correlation ($r = 0.045, p=0.73$) between NCMAC and Doppler PWVs. A Bland-Altman plot confirmed a lack of agreement between the methods, with a mean bias of -74.91m/s. Excluding NCMAC data clearly outside the normal physiological range (due to poor signal to noise ratio), gave a stronger and statistically significant correlation ($r=0.37$, $p=0.04$). The Bland-Altman plot confirmed the stronger relationship between the two methods with a mean bias of -6.978m/s. However, due to the wide limits of agreement we conclude that, in its current form, the NCMAC does not produce PWV estimates that are reliably and consistently close to their Doppler derived counterparts.

Conclusion

The NCMAC device failed in measuring PWV in the relatively simple vascular anatomy of the arm. The poor results may be attributed to limitations in sensitivity of the imaging process and the ability of the software to extract a pulsatile PPG signal. Future improvements in these areas will be directed at increasing the accuracy of the device. Initially, experimental investigations and numerical modelling should be focussed on the behaviour of light as it passes through the skin and underlying tissue and interactions with the pulsating blood vessels therein.

PS16.005 - Developing a Quantitative Performance Assurance Risk Classification Model within a Generalized Risk Scoring System
Author(s): Vishvek Babbar1, Agustina Krivoy2, Petr Kresta2, Michael Moore1, Tidimogo Gaamangwe1
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Risk classification is an essential process for various medical device management systems, e.g. performance assurance (PA). Several quantitative risk classification models have been developed but there is no standardized model because investigators may apply different rules to determine risk factors and risk categories. Most quantitative models also seem to assume that the distribution function for all the risk factors is the same. Therefore, the purpose of this work was to develop quantitative risk classification models within a generalized risk scoring system, taking into account the possible difference in the distribution functions. Example models, and applications are presented. The significance of the generalized system will be discussed.

Empirical rules were used to assign risk factor weights and risk category scores. The risk scores were applied to 134 devices randomly selected from the regional medical device inventory. Two models, linear and exponential, were developed to transform the assigned scores to actual risk scores. The actual risk scores were then normalized to a [0,1] range. After scoring, devices were assigned to either Low, Medium or High risk levels. The distribution of the inventory between risk levels was compared with the American Society of Healthcare Engineering (ASHE) distribution for similar devices.

Figure 1 shows that the inventory distribution between risk levels is model dependent. Comparison of this distribution with ASHE (Figure
2) shows that the exponential model seems to be in better agreement with ASHE system. The results suggest model difference in sensitivity between low and medium but relatively similar for high risk devices. The significance of the model differences on applications such as PA prioritization and setting completion targets will be discussed. The next step of combining risk level with retrospective factors, such as repair history and number of missed inspections, is being explored for refined inspection prioritization.

**Figure 1.** Percentage of devices assigned to each risk level based on the proposed models

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Linear</th>
<th>Exponential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>32%</td>
<td>24%</td>
</tr>
<tr>
<td>Medium</td>
<td>44%</td>
<td>12%</td>
</tr>
<tr>
<td>High</td>
<td>76%</td>
<td>12%</td>
</tr>
</tbody>
</table>

**PS16.006 - Project Management for Clinical Engineering – Considerations in the evaluation and acquisition of medical equipment for health services in Brazil**

**Authors:** Cleber S. Alves, Marilia M.F. Gomes, Lourdes M. Brasil

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The public health system in Brazil must provide the population, comprehensive care and with wide availability of resources. However, the actual conditions demonstrate that available resources are not sufficient to give full attention to required health. With regard to medical devices, it is observed that its acquisition is often done without adhesion to technical criteria aiming to support the technology throughout its life cycle. The project management processes enables the clinical engineer to join the assessment team of technology to be acquired proactively analyzing the acquisition of medical equipment throughout its life cycle. The research presented involved the search for articles that deal with the project management in state of the art applied to the evaluation of medical devices focused on the incorporation of these technologies in the health care environment, addressing an adapted model of the project management processes proposed by the Project Management Institute to the activities of clinical engineer.

**PS16.007 - Human Factors for Health Technology Safety: A new book on incorporating Human Factors into the work of biomedical technology professionals**

**Authors:** Andrea Cassano-Piche1, Patricia Trbovich2, Melissa Griffin1, Ying Ling Lin1, Anthony Easty2

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In healthcare, adverse events involving medical technology failures have traditionally been the primary concern of biomedical technology professionals. In contrast, incidents involving the context of use (generally classified as “use errors”) have been left to clinical managers. Considering the high number of health technology-related adverse events caused by use-error, and the effectiveness of applying human factors principles to improve the design and safety of medical technologies, it follows that human factors methods should also be applied to technology development, evaluation, selection, implementation, training and the review of incidents, to support safe technology use.

While having a human factors professional as an integrated staff member of a healthcare facility is ideal, in reality, human factors professionals are not well established in this manner. Biomedical technology professionals, however, are well integrated within most healthcare facilities, routinely participating in evaluation, implementation, training and incident investigation related to health technologies. These responsibilities, when augmented by human factors methods, can improve the fit between a health technology and its context of use, which will lead to more effective, efficient, and safer use.

This presentation will introduce a new book, Human Factors for Health Technology Safety, aimed at providing biomedical technology and other professionals with the guidance required to integrate human factors methods into their tasks; acknowledging the familiar constraints of time and resources, and the complexity of the healthcare environment. The history of its development and structure of the document will be described and one or more case studies from the text will be shared to illustrate how the book can be used by biomedical technology professionals.

The text has been written based on what biomedical technology professionals know and do as core aspects of their profession. Each human factors principle and method is explained in the context of the biomedical technology professional’s core activities. Human fac-
tors methods are presented in sufficient detail so the depth and nuances of the discipline are not lost, but in an accessible manner so that non-human factors professionals do not become overwhelmed. Also, recognizing that biomedical technology professionals work in health care facilities world-wide, the book is written to be applicable and adaptable to audiences with varying levels of resources.

Other guidance documents about incorporating human factors into the design of new health technology exist, and are used widely by health technology manufacturers, but very little hands-on guidance exists about applying human factors methods in a healthcare setting. This book serves to bridge this gap and expand the practice of human factors in healthcare facilities, so that staff and patients can experience safer and more efficient healthcare.

Human Factors for Health Technology Safety was commissioned by the Clinical Engineering Division of the International Federation for Medical & Biological Engineering and was written by members of HumanEra. HumanEra’s core focus is on the application of human factors methods and principles to improve healthcare safety, while taking into account health care technologies, practices, and environments of use.

PS16.008 - Politics, value and risk: a system to allocate medical equipment funding
Author(s): Peter Cook, Keith Ison
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Healthcare providers seek to provide the best possible patient care, using the most appropriate medical equipment. Yet there is never enough money to go round. How does an organisation get the most from the funding it has available? What guides its purchasing priorities between replacing old equipment, buying extra items or bringing in new technology?

This poster presents a purchase prioritisation process which has been developed over 20 years and used at two large and one specialist hospital in London. This process encourages the active involvement of clinical departments, makes equipment requirements clearer and better coordinates purchasing. Although originally aimed at allocating funds to medical equipment costing over £5,000GBP, the process is easily scaleable. It supports the adoption of more elaborate systems needed to respond to economic and regulatory pressures in UK hospitals.

Important lessons learned in developing the process have included how to use risk alongside value for money in prioritisation; and the necessity of including ‘soft’ issues such as user preference and strategic and organisational impact alongside ‘hard’ measures such as return on investment and the degree of equipment standardisation.

Bids are collected from clinical departments before being checked and assessed. Purchase recommendations are drawn up, based on the relative risk of not getting equipment and/or the financial benefits of the investment and limited by available funding. These recommendations are considered by a group chaired by the hospital Medical Director that consists of several clinicians from different clinical disciplines, the senior operational manager and representatives from Finance, Estates, IT and Clinical Engineering. This group can adjust purchasing priorities in the light of clinical need and organisational strategy, with the outcome being formally approved by the relevant organisational Board committee.

A simplified flow diagram of the process is shown below. The process does not capture all bids, such as business cases for large infrastructure developments such as a new MR scanner. An amount of money is kept back each year as a contingency fund to replace equipment which fails in year; the amount spent gives some indication on how well the bidding process prevents potential service disruption. Analysis of the outcome for over 10 years of data suggests any bias in the allocation of funds is small and feedback from clinical groups has been positive.

PS16.009 - Magnetic Resonance system configuration and editing tools
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Magnetic Resonance (MR) technologies play a fundamental role in medical diagnosis systems and scientific research due to their powerful versatility and non destructive characteristics.

Current devices and methods require sophisticated tools not available for scientists who work with the equipment outside the manufacturer’s realm. A limited number of studies, as ODIN (Object Oriented Development Interface for NMR) and DAMARIS (Darmstadt MAGnetic Resonance Instrument Software) has provided trials for meeting scientist’s expectations.

This study describes tools for programming methods and MR systems. It includes a library – PyMR, an Application Programming Interface (API) and an Integrated Development Environment (IDE) with a graphical sequence editor.

The implementation of our system uses the state-of-the-art of computing technology and user’s requirements. The structure includes PyMR, which acts as a front-end that generalizes its configuration and access. The API supplies the hardware-specific configuration and the IDE provides an easy way for the creation and management of MR sequences. The project was developed in Python along with PySide framework for the graphical user interface.

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PS16.010 - The Unintentional Irradiation of a Live Human Fetus During a CT Scan: a case study

**Author(s):** Jeff Frimeth¹, Eduardo Galiano-Riveros², Marcelo Godin³

¹Aspect Inc., Toronto/CANADA, ²Laurentian University, Sudbury/CANADA, ³Hospital del Cancer, Asuncion/PARAGUAY

**Purpose:** The purpose of this work was to calculate the dose accidentally absorbed by a live fetus during a diagnostic CT procedure to a pregnant patient, and to assess the likelihood that the premature termination of the pregnancy was radiation-induced.

**Methods:** A patient underwent a diagnostic CT procedure as part of her initial clinical work up for a FIGO stage II cervical cancer. At the time of imaging - and unbeknownst to the staff – the patient was found to be 12 weeks pregnant. Approximately two weeks later, the fetus became non-viable and was surgically removed. Following established institutional procedures, the case was referred to the Physics Department for further dosimetric evaluation to determine what role - if any - the fetal dose played in the premature termination of the pregnancy. The fetal dose was determined using Wagner’s CTDI Phantom Dose Reference Model method. The manufacturer’s Abdomen Baby protocol was used to base the CTDIvol on, with appropriate corrections taking into account the actual scan parameters.

**Results:** Our estimated absorbed dose to the fetus was 19.3 mGy. Further, we estimate that the rotation of the fetus through an approximate 90º angle along the caudo-cephalic axis during imaging had no clinically relevant effect on the calculated absorbed dose.

**Conclusions:** The fetal dose was well below the consensus levels for negligible risk of abnormalities (50–150 mGy). At the time of exposure, the fetus was beyond the period of preimplantation; the most radiosensitive stage of pregnancy for a radiation-induced lethality. We conclude that the premature termination of this pregnancy is most unlikely to be of radiological etiology.

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PS16.011 - Device reconditioning service for home-based assistance. How to choose the right approach.

**Author(s):** Roberta Chiarizia¹, Roberto Miniati², Ernesto Iadanza³

¹Clinical Engineering Department, ASUR Marche, ANCONA/ITALY, ²Department Of Information Engineering, University of Florence, Florence/ITALY

The home-based system’s target is to give opportune responses to the problems which affect an increasing part of population. The aim of the service is to guarantee higher environmental performances and to maximize the effectiveness of these services. Starting from this, our experience was to show and suggest a method to deal with the difficulties on the management of a part of home-based service, called devices reconditioning service and identifying the best procedure to suite the needs. The critical elements and the different types of approach found, “in house” and “in outsourcing”, in this health management system, were compared through Break Even Analysis. From an economical point of view this methodology points out which one, between the two presented management solutions, is the best according to collected data.

**PS16.012 - Approach to the management of infusion systems in hospitals**

**Author(s):** Roberta Chiarizia¹, Roberto Miniati², Ernesto Iadanza³

¹Clinical Engineering Department, ASUR Marche, ANCONA/ITALY, ²Department Of Information Engineering, University of Florence, Florence/ITALY

Drugs administration is the distinguishing feature of the infusion systems. They represent fundamental instruments in controlling clinical risk and in the improvement of the health care assistance. Using infusion systems allows the continuous drugs administration, resulting in the reduction of concentration fluctuation, and, keeping the appropriate speed infusion, is the way to guarantee the desired therapeutic effect. The study presented in this paper allowed us to analyze and describe some critical points in the management of infusion systems, volumetric and syringe pumps, inside a subarea of Azienda Unica Regionale Sanitaria delle Marche (ASUR Marche). Some management solutions have been suggested such as supplementary services, in order to keep the functional continuity of the medical units, ready-to-use extra devices and their traceability. These services would allow to have extra devices in case of breakdown or in emergency situations; extra devices would belong to the so called infusion library and their handling can be both free or with a penalty. In order to decide the proper quantity of infusion systems, from the one hand, and from the other assuring the full service of the available devices, a mathematical reasoning has been done using real data from medical units. In our view this would guarantee to the hospital to save money and to get the most from the devices. In the end we suggest for the introduction of the closed-circuits for
increasing the safety of the operator during the infusion of cancer therapy.

PS16.013 - A Basic Study on the Measurement of Electromagnetic Fields in a New University Hospital Building Before and After the Hospital Opened

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It is well-documented that establishing electromagnetic compatibility (EMC) is important for using medical equipment and communication devices in hospitals. To evaluate the basic electromagnetic environment, measurements should be conducted over 2 periods (before and after the opening of the hospital). We measured the electric field intensity induced by electromagnetic radiation in the broadcasting spectra coming from outside the hospital at 73 locations in our new hospital building in February 2014 (before any patients came into the hospital for the very first time) and August 2014 (6 months after the opening of the hospital). Frequency modulated radio signals, ultra-high frequency television signals, aeronautical radios, community wireless systems, and cellular phone system base stations were strongly detected at the windows of the upper floors. There was no great difference in measured levels between before and after the opening of the hospital. There were no cellular phone unit signals before the hospital opened its doors to patients, but were very strongly detected 6 months thereafter. In this study, the maximum electrical intensity was 0.28 V/m from cellular phone system base stations (2.1 GHz) observed on the south end of the 4th floor before the hospital first opened. This value was lower than the EMC marginal value of the general electronic medical equipment specified in IEC 60601-2-2 (3 V/m). Therefore, electromagnetic interference with medical equipment was extremely improbable in this situation. However, there were no cellular phone system base station signals in the elevator hall, in a portion of the corridor (located in the center of the hospital), and in the hemodialysis unit. Measurements 6 months after the opening of the hospital revealed very strong cellular phone unit radio waves in the hospital. To promote greater EMC safety, the hospital should prepare countermeasures to improve these conditions, e.g., installing an interior cellular phone system base station.

PS16.014 - IAEA database of national dosimetry audit networks for radiotherapy

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Recently, the IAEA has undertaken a task to review the coverage and operations of national and international dosimetry audit networks (DAN) for radiotherapy. The aim was to organize the global database describing the activities of dosimetry audit networks across the world. A dosimetry audit questionnaire has been designed including information on different aspects of the dosimetry audit, such as the audit framework and resources, its coverage and scope, the dosimetry system used and the mode of audit operation, i.e. remotely and through on–site visits. In 2010, 2011 and 2013, the IAEA questionnaire was circulated to numerous institutions known for having operated dosimetry audits for radiotherapy in their countries or internationally, including members of the IAEA/WHO Network of Secondary Standards Dosimetry Laboratories.

In response to the IAEA surveys, 54 institutions in 45 countries confirm they operate dosimetry audit services for radiotherapy. The participation in audits is voluntary for a radiotherapy centre in 2/3 of responder countries and it is mandatory in the remaining. In general, audits are carried out regularly, with the frequency depending on the local circumstances; however, some organizations operate audits only by request. Most programmes verify megavoltage photon and electron beams, but some extend the audit scope to orthovoltage X rays, brachytherapy or radiosurgery. Few offer audits of tomotherapy and proton facilities. All organizations include the basic dose audit in the reference conditions in their programmes. Audits are also conducted for non-reference conditions, and for complex beam geometries, using semi- and/or anthropomorphic phantoms. Most clinical beams (85%) are checked through remote audits. Globally, approximately 2/3 of radiotherapy centres registered in the IAEA Directory of Radiotherapy Centres (DIRAC) have received some level of the dosimetry audit. However, better availability of the dosimetry audit is necessary for improving dosimetry practices in radiotherapy and for increasing safety of cancer patients undergoing radiation treatments.

The DAN database is located and maintained at the IAEA. The data from the 2010, 2011 and 2013 IAEA surveys were used to initially populate the database. When publicly available, this database can be used to provide information to international community on the availability of dosimetry audits in radiotherapy and the status of DAN activities across the world. At the same time, the information on participation in audits will be available to clinical trial organizations so that radiotherapy centres that are audited nationally and pass the national criteria are recognized as being competent to participate in international clinical trials as part of a global harmonization of clinical trial QA activities.

A concept for a DAN database was further developed to include a framework for international recognition system for national DANs activities. The introduction of such a system will be advantageous for comparing the auditing work between the various countries and regions, and to ensure that the national networks operate to the consistent internationally accepted standards and levels.


PS16.015 - Telehealth - Achieving its Promise in 2015

Author(s): Thomas M. Judd

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Telehealth is achieving its promise in 2015. This will be demonstrated through three current case studies in which the presenter is participating:

1. US government HHS/HRSA study on evidence-based medical (EBM) tele-emergency care for rural locations
2. NGO EBM pilot for tele-neonatology between the national Children’s and OB Hospitals (and their key referral hospitals) based out of Skopje, Macedonia and Northside Hospital System Neonatology group in Atlanta, Georgia USA
3. NGO EBM tele-OB/Gyn and tele-neonatology as part of country-wide teaching and referral hospital development for Haiti; will bring together all parts of country as well as real-time e-consults with relevant specialists from all North America

The presentation will assess how clinical engineers can play a vital role in creating relevant solutions for use cases, partnering with other experts, such as these for and in developing countries.
PS16.016 - The New Japanese Guidelines for Use of Mobile Phones in Hospitals
Author(s): Takashi Kano¹, Eisuke Hanada², Minoru Hirose³, Hidenao Atarashi⁴
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The new version of “Guidelines for Use of Mobile Phones and Other Devices in Hospitals” has been published by the Electromagnetic Compatibility Conference Japan (EMCC) in August, 2014.

The Japanese hospitals have been setting their own rules for using mobile phones at their facilities, taking into account the guidelines published in 1997 by EMCC and public manners in a comprehensive way.

In the meantime, we have seen drastic changes in pertinent circumstances, such as the penetration of mobile phones into daily life, the abolishment of second-generation mobile-phone services, and the improvement of medical electrical equipment for electromagnetic immunity.

These Guidelines have been created in consideration of the above circumstances through a review by experts, medical associations, wireless service providers, and relevant ministries and agencies in order to use mobile phones and other wireless communication devices more securely and safely in hospitals.

As mobile handsets (which hereinafter mean to include smartphones and tablets with a built-in cell-phone function) have become increasingly essential to daily life in recent years, it is desirable to allow the use of mobile handsets by patients and hospital visitors in hospitals to the extent possible for improvement of convenience and QOL for patients. On the other hand, while medical electrical equipment is required to have a certain level of immunity for electromagnetic fields, their operation may be affected by mobile handsets when they are used in close proximity. Another concern is public manners, such as sounds made during phone calls, of ringtones, of incoming mail tones, of operation, and of watching TV (hereinafter called “Calls”). Therefore, it is necessary to place certain restrictions on the use of mobile handsets in hospitals and establish proper rules for using them.

Since the kinds of medical electrical equipment, the need for using mobile handsets, and the need for consideration of others appear to differ greatly among specific areas in hospitals, they need to set area-specific rules. For the areas where the use of mobile handsets is allowed, they also need to set up the conditions for use (e.g., separations, precautions for use).

It’s also necessary to set rules specifically targeted at hospital staff when hospitals establish rules for using mobile handsets at their facilities. Considering that the use of mobile handsets for medical practice contributes to the swift and optimum operation of medical services, the use thereof, including Calls, may be allowed in principle, on the condition that hospital staff is fully educated about the prevention of interference with medical electrical equipment.

By establishing rules for using mobile handsets by reference to these Guidelines, hospitals are more capable to properly manage and operate wireless communication devices in their facilities. To make wireless communication devices available more safely and securely along with further development of ICT for medical services, hospitals need to pay more attention to the management of the EMC environment by reference to these Guidelines.

The English version of “Guidelines for Use of Mobile Phones and Other Devices in Hospitals” has been published in EMCC URL (http://www.emcc-info.net/info/pubcom2/2608_5.pdf).

PS16.017 - Study on Medical Equipment Location Systems that use RFID Technology
Author(s): Manabu Kawabe, Yasuyuki Miwa, Takashi Kano
School Of Biomedical Engineering, Facculy Of Health & Medical Care, Saitama Medical University, Saitama/JAPAN

(To protect the property of the hospital and periodically check medical equipment, it is important that the hospital staff can locate medical equipment used at various places in the hospital. Therefore, we have developed a location management system for medical equipment using RFID (Radio-Frequency Identification Device) technology.)

These Guidelines have been created in consideration of the above circumstances through a review by experts, medical associations, wireless service providers, and relevant ministries and agencies in order to use mobile phones and other wireless communication devices more securely and safely in hospitals.

As mobile handsets (which hereinafter mean to include smartphones and tablets with a built-in cell-phone function) have become increasingly essential to daily life in recent years, it is desirable to allow the use of mobile handsets by patients and hospital visitors in hospitals to the extent possible for improvement of convenience and QOL for patients. On the other hand, while medical electrical equipment is required to have a certain level of immunity for electromagnetic fields, their operation may be affected by mobile handsets when they are used in close proximity. Another concern is public manners, such as sounds made during phone calls, of ringtones, of incoming mail tones, of operation, and of watching TV (hereinafter called “Calls”). Therefore, it is necessary to place certain restrictions on the use of mobile handsets in hospitals and establish proper rules for using them.

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The English version of “Guidelines for Use of Mobile Phones and Other Devices in Hospitals” has been published in EMCC URL (http://www.emcc-info.net/info/pubcom2/2608_5.pdf).

PS16.018 - Development of a Regional Prioritization Process for Diagnostic Imaging Equipment Replacements
Author(s): Rebecca Austman, Petr Kresta
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Prioritization of Diagnostic Imaging (DI) equipment for replacement in the Winnipeg Regional Health Authority (WRHA) is completed through a separate process than for other types of medical equipment. DI systems are first prioritized at the regional level, and then by a provincial committee against imaging systems throughout the province. Historically, the equipment prioritization approach within
WRHA has been through a largely qualitative and subjective voting process. As a result, the final prioritization depended on how well the manager of each site/program could sell their needs. Previous studies have developed various quantitative methods for prioritizing other types of medical equipment, but no known studies have developed a method targeted for DI equipment.

The purpose of this study was to develop a quantitative prioritization method by assigning points to selected criteria, or Prioritization Factors, that should be used when considering a piece of DI equipment for replacement. Based on a literature review, four Prioritization Factors were identified that were both relevant to DI equipment and easily obtainable: Remaining Useful Life, Support Status, Condition, and Clinical Capability. Each prioritization factor was assigned a weighted score (Table 1). Determining the relative weights for each of the factors involved input from managers from each of the DI sites, using a comparative process and involving some aspects of a previously established Analytical Hierarchy Process. Each Prioritization Factor had several categories within it (Table 1), from which the managers of the site/program had to select from on their request form. The form then automatically converted the selections into a corresponding score. The sum of the scores from the four Prioritization Factors was presented as the Priority Score. Other mitigating factors could also be written in the request justification, but were not assigned a score.

This method was applied during this year’s replacement prioritization exercise. The numerical scores acted as a guide to aid decision-making for the managers during the regional voting process, as well as for prioritizing the equipment within their sites. Overall, the feedback received from the users of the new system was positive, and it has been well accepted. It ensured that relevant factors such as age, condition, supportability, and capability were all considered when submitting the equipment requests, so that systems could be compared more objectively. Future work includes further refining the factors and scores based on the initial experience, as well as expanding this method to be used during the province-wide prioritization.

PS16.019 - Implantable Medical Devices: more Safety with Traceability and Surveillance

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Background
Medical Devices (MD) market produces an annual turnover of about €100 billion in Europe: 70% is produced in Germany, France, United Kingdom, Italy and Spain. Small and medium enterprises cover 95% of MD field composed by 25 thousand industries. For these reasons, there is an increasing attention to this sector in Europe. European Directives 93/42/CEE, 90/385/CEE and 98/79/CE order the main rules for the MD commercialization in Member States. The European Database on Medical Devices (EUDAMED) was instituted by European Directive 98/79/CEE in order to strengthen supervision operations and to increase market transparency.

In Italy, MD market is about €13.5 millions, with an annual growth rate of 4.7% in the period 2004-2012 and high innovation level. Italy is one of the few European Countries to create by law a MD List and to start a new data flow of MD consumption from healthcare facilities.

Objective
The aim of our work is to suggest some way to use these precious informations, already available through data flows, in order to obtain a traceability of Implantable Medical Devices. HTA analysis as well as better control on manufacturer warnings are possible too.

Methods
All official flow are analysed, identifying data and each database. Italian hospitals costs in MD are monitored through Consumption Flow. Different data flow connect patient data to implantable MD data. In Lombardy Region, for example, the Patient Data Base is interfaced with the flow from the Hospital Discharge Forms. The implantable MD data are related to hospitalization codes. Therefore it is possible: a) to identify univocally the patient, tracing the National Insurance Number; b) to trace the whole clinic history after the implant; c) to carry out extremely detailed analyses.

Conclusions
Nowadays the major attention is about the economic and regulatory aspects of MD sector; for patient safety we correlate implantable MD with clinical events. This process could be useful for healthcare facilities (patient clinical issues and HTA) and for companies and competent authorities (post-market supervision and medical device surveillance).

PS16.020 - Using standard test methods to ensure quality and maximize supply of personal protective equipment in a time of global emergency response

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The rapid spread of 2014’s Ebola outbreak, in West Africa, required a stable and adequate supply of personal protective equipment (PPE) to protect healthcare workers caring for patients with suspected or confirmed haemorrhagic fever. There quickly emerged an urgent need for off-the-shelf PPE traditionally destined for much different industrial applications to meet this health care service delivery demand. Clear and specific minimum standard performance criteria for each type of protective item had to be defined within a short period of time so that countries affected by Ebola infections could procure necessary PPE, put in place procedures and prepare staff to do their work in high risk environments. In the field, there was much variability in material performance and final item construction therefore, it was necessary to choose only the most relevant performance requirements and ensure an explicit minimum standard of quality, in order to simplify procurement of complex design PPE and to maximize its quantity from major manufacturers to priority countries. However, limited studies had been found to guide recommendations of these complex items and their combinations. Technical information was combined from industrial standards with practical input from clinical teams, field logisticians, global
procurement information and researchers of major manufacturers. These evolving minimum performance standards and combinations thereof, became more stringent as supply of products to priority countries stabilized. Also, the challenging combinations of performance criteria shaped the future design need for PPE items more suitable to current demands and preparation for future outbreaks. Indeed, the USA launched “Fighting Ebola: A Grand Challenge for Development. Fighting Ebola”, a design competition to address, among other themes, the specific design issues of commercial PPE. The initiation and evolution of a small and highly technical component of a greater relief effort will be presented.

PS16.021 - Creation of a system for the coding of medical devices
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Medical devices have different nomenclatures for their classification. Some of the most significant nomenclatures are the Universal Medical Device Nomenclature System (UMDNS) and the Global Medical Device Nomenclature (GMDN) by the Emergency Care Research Institute (ECRI). In Italy the main are CIVAB and “Classificazione Nazionale Dispositivi Medici” (National Classification for Medical Devices – CND). The aim of this study is to create a system to automatically decode several device models from CIVAB to UMDNS code. All medical devices are coded with a table which is based on their definitions presented in these nomenclatures. The coding is lastly applied to a list of models of medical devices, developed by different companies.

PS16.022 - Establishment of Radiation Qualities for Radiodiagnostics in LCR/UEJR According to IEC 61267 and TRS 457
Author(s): Luis Magalhaes
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The main goal of this work is to establish the radiation qualities of the Laboratório de Ciências Radiológicas (LCR) conventional X-ray equipment for calibrations in radiodiagnostics according to the recommendations of IEC 61267 and TRS 457. Tests were conducted to evaluate the homogeneity of the radiation field, high voltage applied to the X-ray tube, scattering, half-value layers (HVL) and homogeneity coefficients. The results obtained that characterize the radiation field, satisfy the conditions required by TRS 457. Invasive high voltage measures presented results compatible with the requirements of this standard. The HVL measures showed that for the first HVL the tolerance limits of IEC 61267, and the values for the homogeneity coefficients were within the limits established. The quality tests performed in this work were highly satisfactory in meeting the standard requirements. Thus, the main goal was achieved, and the methodology can be used by other similar X-ray systems.

PS16.023 - A Healthcare Facilities Qualitative and Multivariate Quantitative Assessment Methodology for Mongolia
Author(s): Claudio I. Meirovich1, Adiya Bold2
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A qualitative analysis, multivariate analysis and a scoring system is proposed as the methodology to evaluate a healthcare infrastructure and technology city network. The methodology requires visiting each facility; interviewing the staff; completing an infrastructure checklist; assessing each room including area measurements; making pictures of each room, all the installations and all the major infrastructure elements, making a full equipment inventory including the working conditions of the equipment; identifying the exact location of all the inpatient beds of each facility and writing an evaluation report. The collected information is then cleaned to do a multivariate analysis with “R”. The assessment of each facility is focused on 4 areas (dimensions): infrastructure, installations, support services and equipment. A compound score is calculated using weights for each component that builds each dimension. The weights are defined by a group of experts. The resulting scores for each dimension of each facility are then evaluated and crosschecked with the pictures and the evaluation (qualitative) report. The level of confidence of the collected information is also rated. The proposed methodology was used to assess 33 healthcare facilities of Ulaanbaatar City in Mongolia: 9 specialized hospitals, 5 District Health Alliances, 6 district hospitals, 6 secondary general hospitals, 3 maternity hospitals and 4 Village Hospitals. The obtained results were used to prioritize new investments for the health sector over the next years. Further work is required in order to adjust the proposed methodology to better identify or classify a facility’s conditions, adding more answer options and including more experts in the weight definition stage.

PS16.024 - Practice of HB-HTA on the Study of HIFU Technology for the Treatment of Prostate Cancer and Uterine Fibroma
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1Information Engineering, University of Florence, Florence/ITALY, 2School Of Human Health, University of Florence, Florence/ITALY

The aim of the study has been the development of a Hospital Based – Health Technology Assessment, study directed to analyze the clinical, social and financial aspects derived from the use of the HIFU method for the treatment of prostate cancer and uterine fibroma in comparison with the traditional therapeutic approaches.

A systematic literature review was carried out inspecting the treatment of prostate cancer through the use of HIFU technology as well as its use for the treatment of uterine fibroma. At a later stage, clinical, social and financial indicators (gathered from EUnefHTA Core Model as well as from scientific literature) were defined and evaluated and a single benefit index was drawn in the end to have a rapid and direct comparison among the various treatment methods.

For the treatment of prostate cancer, HIFU reaches good results in the clinical setting obtaining 78% of negative biopsy results post-surgery and a 68% disease-free survival rate at 5 years. It also proves efficient in the social setting and equal to traditional surgeries. For the treatment of uterine fibroma, HIFU presents an improvement of post-surgery symptomology in 80% of cases, revealing a good clinical efficacy and showing particularly convenient in the patient quality of life.

Even though the traditional techniques represent the current gold standard, the initial results for the treatment of prostate cancer, exclusive to low risk of illness, and of uterine fibroma through the use of HIFU appear positive and, therefore, encouraging for the immediate future even though it remains fundamental to have greater availability of evidence especially in the long run.

PS16.025 - A Simulation Based Model for Planning Operating Theater Activity in Complex Hospitals: Case Study in Orthopedics
Author(s): Francesco Frosini1, Roberto Miniati1, Paolo Avezzano1, Fabrizio Dori1, Duccio Cocchi1, Ernesto Iadanza1, Sheila Belli2, Maria Teresa Mechi2, Vega Ceccherini4, Andrea Belardinelli5
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Operating theaters (OT) in hospitals represent some of the highest sources of economic expenditures since their high complexity in terms of technology equipment (integration of different complex devices and specific technical requirements), organization (multi-personnel area with complex patients flow) and usage (optimum planning between regular activity and emergency management). For the above reasons, it is essential to understand and plan the whole surgical path (patient and personnel) by avoiding foreseeable inefficiencies, delays and risks.

Hence, the aim of this study is fully modeling a generic orthopedics OT in order to support hospital decision makers in OT design and activity planning for both regular and emergency scenarios.

In order to do that and due to the complexity of the OT system, a simulation approach is fundamental for properly understanding the whole process and for clearly controlling and analyzing all the factors involved (surgical durations, types, working times and rooms availability, etc.). Discrete event models have been found reliable and accurate to simulate complex health systems (e.g. emergency management, beds management, logistic and assets estimation, etc.).

Finally, after selecting the most appropriate type of model, and using past surgical data and experts' opinions from the hospital for its development and implementation, a more precise and reliable clinical validation of the model is currently in progress, by concluding a data verification that needs a period of on-site data collection.

**PS16.028 - Risk management tool in the application HFMEA in purge sector on the Material and Sterilization Centers.**

**Author(s):** Sérgio S. Mühlen¹, Michele C.A. Sousa¹, Maria Isabel P. Freitas²

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Introduction: Material and Sterilization Centers in healthcare facilities should ensure the quality of medical instruments for safe patient care. For the sterilization process to be carried out properly, it is essential that the article to be sterilized is free from organic matter and some inorganic substances. If the activities of receiving, cleaning, rinsing and drying of surgical instruments, located in the Cleaning sector, are incomplete or inadequate for being performed quickly, they can compromise the cleanup. These failures may have diverse origins and they determine important factors to be identified for qualifying the work process. Objective: To assess critical points in processes and identify areas for improvement in the activities undertaken in the cleaning sector. Healthcare Failure Mode and Effect Analysis (HFMEA) technique was applied to the procedures performed in that sector. Methods: The HFMEA is a tool that provides a systematic evaluation of the critical points in processes by classifying them according to the severity of the potential effects of their failures and to their probability of occurrence, allowing the prioritization of the risks to be controlled. For its implementation a multidisciplinary team was formed, the process was mapped, the risk analysis was executed and the failure modes related to the process were evaluated. Results: 89 failure modes involving the cleaning and drying of instrumentation were found, and 262 potential causes associated with these failure modes were identified. Of this total, 131 potential causes (50 %) were selected and analyzed to propose measures and actions for improvement. A guide was prepared for to help implement the proposed improvement measures. Conclusion: The application of the HFMEA tool provided a diagnosis of the critical points of the process and resulted in the proposition of improvement solutions that have been condensed into a guide action and measures that can aid the team managers of CME in incorporating safer routines in the execution of their activities and patient care.

**PS16.029 - Generate health and wealth by innovation**

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Innovation, health and wealth – hospitals have a unique capability in these three areas. Hospitals always strive to give the best health to patients, but innovation and wealth are often a lower priority, or lack the relevant infrastructure to carve out the aspects from clinicians and standard healthcare facilities. On a positive note, there are plenty of unexplored opportunities waiting to be exploited.

An ideal way for hospitals to adopt innovation and increase participation in research is to collaborate more with industry and universities. This arrangement can be used to exploit health and wealth in hospitals through innovation.

“Innovation” is often interpreted as discovering a new technology or method and confused with inventions. Innovation often results from the integration of known elements, directed towards a change in service, process, text, modification, development or research. Invention may not be required, rather benefits can occur from creatively redeploying our existing knowledge and assets in a new way to deliver the best healthcare services to patients, whilst meeting the wealth agenda at the same time. Such assets may not always reside within the same organisation and a more open approach, enabled through collaboration with the right set of organisations, can result in optimising the contributions from each party enabling innovative solutions to be created, and more importantly, deployed in relatively short timescales.

There are numerous ways to align health with wealth by first recognizing, and then making use of existing assets and resources with hospitals. Some examples are:

1) Facilities re-use: There are plenty of sophisticated devices and services in hospitals that when not in use, could be used by device and drug manufacturers to carry out research, safety or performance testing. Imaging systems and clinical laboratories are such examples.

2) Collaboration with industry by providing consulting service: Clinicians, scientists, physicists and engineers working within the healthcare services are valuable resources for requirements definition, design and development of medical devices - Usability & human factors, Imaging systems and clinical laboratories, and Clinical Trials & investigations

3) Implementation of innovative methods: There are numerous services in the healthcare services that can be altered with minimal expenses which can result in greater savings and efficient functioning. Some examples are Medical equipment library, standardisation of medical devices in hospitals and effective management of medical device maintenance contracts.

Obvious questions that come to our mind are: how can hospitals generate more health & wealth by exploiting such resources? Why do such centres not exist or are not well known? How much more can hospitals innovate whilst not losing its core function to deliver...
patient care?

The healthcare services require the right framework, expertise and skills to find & develop such opportunities. Medical Physics departments, being a centre of these facilities and having capabilities, provide a resource to identify initiatives to explore these opportunities.

PS16.030 - Validating and comparing Methods for testing Endothelial Function
Author(s): Ruga Prakash Ratnakumaran, Steve Greenwald, Delran Anandkumar
Blizard Institute Of Cell And Molecular Science Pathology Group, Barts and the London School Of Medicine and Dentistry, London/
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Background- Impaired endothelial function (EF) is strong predictor for the subsequent development of cardiovascular disease. Current EF testing involves using an expensive and technically difficult method known as Flow-mediated dilation (FMD). We are testing a simpler and more robust method known as the finger-tip endothelial function (FTEF) test, which measures the time difference between the arrival of the pulse at the middle finger of each hand (ΔPAT) before and after hyperaemic flow. As a preliminary validation of this new approach, we have compared the magnitude of the pulse arrival time difference with the maximum change in pulse wave velocity (measured in the radial and brachial arteries by Doppler ultrasound). We have also compared the time taken to return to baseline for the two methods and the area under the ΔPAT- or PWV- elapsed time curves.

Method- 48 healthy volunteers (31 male, 17 female) between the ages of 18 and 40 with no previous or current medical conditions were recruited. FTEF and the Doppler PWV measurements were performed simultaneously. Baseline data were recorded for 1 minute followed by hyperaemia induced in the left arm by 5-minute occlusion with a sphygomonanometer cuff. The response after cuff release was recorded for another 5 minutes.

Results- There was a statistically significant positive correlation when comparing relative/absolute difference in PWV against absolute difference in ΔPAT (p=0.0168/p=0.0487). A statistically significant positive correlation between the FTEF and Doppler PWV methods was observed when comparing time taken to return to baseline (p=0.0264). However, on average, ΔPAT returned to baseline significantly later than PWV (P=0.0003). A statistically significant correlation was also seen when comparing area under the magnitude time curve (p=0.0187).

Discussion- The FTEF test and Doppler PWV method of assessing EF demonstrated a correlated maximum effect, time course and difference observed in ΔPAT is due to changes in brachial-radial PWV. FTEF proves to be a potentially simple and useful method for assessing EF. Comparison of FTEF with the gold standard (ultrasound FMD) is in progress to further validate the FTEF technique.

PS16.031 - Reliability Indicators in the Medical Equipment Management
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This paper presents a study which uses reliability indicators for medical equipment management. There are considered corrective and preventive maintenance records to calculate the mean time between failures and the mean time to repair. The application of this method, the maintenance records collected refer to anesthesia equipments used in operating rooms of five health care facilities in the public network of Santa Catarina state, Brazil. The analysis of the indicators was made according brands and date of installation of anesthesia equipments. The mean time between failures of the equipment under analysis is acceptable and was 16 months for brand A and 10 months for brand B. However, it was not possible to conclude whether the periodicity of preventive maintenance performed is being effective or not for the containment of failures. It is concluded that the analysis of indicators if not describes the operational context of use and may lead to a finding of reliability of precipitated brands, not being trusted to reality.

PS16.032 - Methodology for Safety Movement of Clinical Facilities Focused in Oncology
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The National Cancer Institute in Mexico City is the leader in critical cares on Oncology, it sets the policies and programs for the cancer control in all the country. For 40 years it was hold in a space of 1.5 hectares for its operation, and in 2011 the construction of a new facility began which provides more space and safety operations to patients, visitor and medical staff.

The transfer process of 10 clinical and diagnostic services to the new facility started in 2013. The Biomedical Engineering department implemented a process for time and motion, as well as risk analysis, to perform the movement with the least impact for patients and users, delaying the minimum diagnostic studies and treatment and the minimal effects in their activities.

The services in which this methodology was implemented were: Imaging, Nuclear Medicine, Clinical Laboratory, Pathology, Emergency, Operating Rooms, Intensive Care Unit, Recovery Room, Sterilization Facility and Inpatient Units.

Moving the Imaging and Nuclear Medicine departments represented the translation of approximately $ 20 million dollars in medical equipment, among which stand out: 1 PET-CT, 1 SPECT-CT, 1 Gamma-camera, 1 MRI 1.5 T, 1 Dual CT Scan, 1 Angiography System, 2 Digital Radiographic System and 1 Digital Fluoroscopy System, 4 Digital Mammographic and 1 Stereotactic System, 1 Digital Orthopantomograph, 1 Densitometer, 7 Ultrasound, 2 complete PACS-RIS systems with 15 diagnostic stations. The total time for transfer of both departments was 40 days and studies and services were not suspended or delayed for patients, with the exception of MRI and PET-CT, for which required support from neighboring hospitals to be done.

Clinical Laboratory moved eight laboratories: Hematology, Clinical Chemistry, Urinanalysis, Bacterology, Tumor Markers, Molecular Biology, Coagulation and section sample distribution. The running time was 4 weeks.

The change in Clinical Pathology and its various services required 3 weeks for Cytopathology, Molecular Pathology, Immunohistochemistry, Histopathology and Inclusion.

In addition, eight Operating Rooms, 15 Recovery Rooms, 9 Intensive Care Rooms, 135 Inpatient beds and Sterilization facility were moved. For their flow operation and transcendence movement took place in two days each service with a strict control of the risks. All the movements were designed, documented and analyzed for a team of women biomedical engineers.
The implemented methodology allowed us to conduct the transfer of the above mentioned clinical, diagnostic and treatment services with minimal impact and control risks on patient care, considering services were not suspended or delayed, their safety was always verified, the safety for the users and the 643 medical equipment as well. No device was damaged or required major repair and working properly on hospital care and equipment.

PS16.033 - Design of a remote use ECG with an Optical Communication System (FSO) for Telemedicine Applications

Author(s): Raul Rodriguez-Aleman, Yair Vazquez-Lopez, Gerardo S. Romo-Cardenas
School Of Engineering, Montemorelos University, Montemorelos/MEXICO

This paper expose the current work in the development of an ECG of 12 derivations with the capability of connection through an optical communication system. Prior investigation shows that attention provided in the first minutes of a heart problem it’s essential. The ECG signals are going to be transmitted into laser beam through the atmosphere to establish communication between the ECG and the medical center, Capable to analyze the signals and give a proper diagnosis. There are a few challenges to this project; Multiplexing ECG signals into a laser Diode and effectively transmitting those signals through the atmosphere to a receptor. This through an optical communication system which refers to the transmission of a laser beam modulated through the atmosphere to communicate between the scene to a medical center where a specialist doctor can analyze the ECG information, rate and blood pressure patient. Because the optical communication system are in recent exploration. Several techniques have not been investigated, capabilities and limitations in various scenarios and applications. An exploration of optical communication systems audio and video was performed to analyze their performance in the propagation in open space. Experiments were designed to simulate optical effects of transmission in the atmosphere by means of a base of gelatin, likewise absorption experiments and polarization of the beam is designed to better understand its operation, advantages and limitations of these communications systems. According to the Beer-Lambert law, the beam can be absorbed into the path to follow in the atmosphere having different effects on the propagation of the beam and the information is conveyed. Likewise the polarization effects generated in the intensity of the transmitted signal.

PS16.034 - Adverse events and death related to the use of the MRI equipment

Author(s): Ricardo A.M. Sá, Walter V. Mendes
1Gerência De Engenharia Clínica, SECRETARIA DE ESTADO DA SAÚDE DE GOIÁS - SESGO, GOIANIA/BRAZIL, 2Escola Nacional De Saúde Pública Sérgio Arouca, Fundação Oswaldo Cruz, Rio de Janeiro/BRAZIL

Objectives: The aim of this work was identify the occurence of adverse events (AE) and the death related to the use of the MRI equipment informed in incident notification system.

Background: The World Health Organization (WHO) recommends that health care systems should be able to identify, report and recalls all incidents, especially AE. A few authors have developed a generic system risk model to search and to analyse the root causes of AE. This system can be useful for identifying these causes and improve the protection of the health and safety of patients and users by disseminating information and to prevent the occurrence of AE.

Methods: MRI is “a diagnostic technique that uses a magnetic field and radio waves to produce a detailed image of the organs, tissues and bones within body”. The AE notifications were collected from the Manufacturer and User Facility Device Experience Database (MAUDE). The AEs were classified based on Shepherd’s model (The Systems Risk Model). The concept of AE used in this study was “events that produce, or potentially may produce unexpected or unwanted outcomes that affect the safety of patients, users or others”.

Results: We found 1487 AE related to the MRI equipment in the last 10 years (period from 01/01/2004 to 12/31/2013), being 12 related to death, and 774 of them were related to injury, 295 reports were related to “malfunction”, 349 reports related to “others” and 51 reports related to “No Answer Provided”. We analyzed the 12 deaths occurred. Three cases were excluded because they are repeated. From the remaining 09 reports, 07 AEs were deaths of patients and 02 AEs were deaths of professional maintenance. The causes of deaths of patients were heart attack (03 cases), respiratory arrest due to disconnection or malfunction of the anesthesia machine (02 cases), collision with ferromagnetic objects (01 case) and diagnostic error (01 case). The causes of deaths to maintenance professionals were asphyxia (01 case) and collision with the magnet (01 case).

Conclusion: We think that Shepherd model is very useful to identify causes and assess the risks of AE surveyed. For future studies, we propose to use the Shepherd’s model to evaluate the AE related to the use of radiology equipment like digital x-ray and mammography.


Sá RAM, Mendes W. Assessment Of adverse events related to the use of the Computed Tomography Equipment. Abstract accepted in ISQua 2012.

Sá RAM, Mendes W. Assessment Of Adverse Events Related To The Computed Tomography. Abstract accepted in HTAi 2012.

PS16.035 - Adverse events and injuries related to the use of the MRI equipment

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Background: The World Health Organization (WHO) recommends that health care systems should be able to identify, report and recalls all incidents, especially AE. A few authors have developed a generic system risk model to search and to analyze the root causes of AE.

Objectives: The aim of this work was identify the occurrence of adverse events (AE) and injuries related to the use of the magnetic resonance imaging (MRI) equipment informed in incident notification system and to classify them accordingly to their causes following the Shepherd’s model.

Methods: The AE notifications were collected from the Manufacturer and User Facility Device Experience Database (MAUDE). The AEs were classified based on Shepherd’s model (The Systems Risk Model - SRM). The concept of AE used in this study was “events that produce, or potentially may produce unexpected or unwanted outcomes that affect the safety of patients, users or others”.

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**ABSTRACTS | IUPESM 2015 WORLD CONGRESS ON MEDICAL PHYSICS & BIOMEDICAL ENGINEERING**

**Results:** We analyzed 91 AEs related to injury occurred in the last year (period from 01/01/2014 to 12/31/2014). Three cases were excluded because they are repeated. From the remaining 88 cases, the study showed that 71 AEs were related an injuries in patients (80.7%), 11 EAs were related an injuries in MRI technicians (12.5%), 05 EAS were related an injuries in MRI professional maintenance (5.7%) and 01 EA was related only to damage of device (1.1%). The causes of injuries in patients were burn skin, the most frequent one (61 cases, 69.3%), collision with ferromagnetic objects (4 cases, 4.6%), and mechanical chock between patient and magnetic to (3 cases, 3.4%), and others (3 cases, 3.4%). The causes of injuries in MRI technicians were mechanical chock between operator and MRI table (7 cases, 8.0%), collision with ferromagnetic objects (3 cases, 3.4%) and fall of the technologist (1 case, 1.1%). The causes of injuries in MRI professional maintenance were collision with ferromagnetic objects (4 cases, 4.6%) and helium gas escape (1 case, 1.1%). Our work classified the AEs based on Shepherd’s model, being the operator component the most frequent to the direct cause (46 cases, 52.3%) and all 46 cases were related to the education/training sub-component, the root cause. Of these AEs, 27 (30.7%) could not be analyzed because of the limited information provided in the MAUDE.

**Conclusion:** We think that Shepherd’s model is very useful to identify causes and assess the risks of AE surveyed. For future studies, we propose to use this model to evaluate the AE related to the use of radiology equipment like digital x-ray and mammography.


Sá RAM, Mendes W. Assessment of adverse events (AE) related to the use of the Computed Tomography Equipment. Abstract accepted in ISQua 2012.

Sá RAM, Mendes W. Adverse Events And Death Related To The Use Of The Magnetic Resonance Equipment. Abstract accepted in ISQua 2014.

**PS16.036 - Investigation on solar aging in sunglasses by developing of automated prototype for sun exposure of lenses**

**Author(s):** Leonardo M. Gomes\(^1\), Homero Schiabel\(^2\), Liliane Ventura\(^2\)

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The first Brazilian standard for UV protection sunglasses, NBR15111, was drafted and published in 2003, hitherto a faithful copy (mirror) of European, BSEN1836 standard. From 2010 to 2013, the School of Engineering of São Carlos (USP) made contribution in the review and drafting of this standard and the main change so far is on the extension of the UV range analysis for protection of sunglasses, i.e. from 280 - 380nm to 280-400nm and the resistance to irradiation test increased from 25h to 50h. In previous studies, there are indications that ultraviolet protection degrades with use and exposure of sunglasses to natural ultraviolet radiation. Thus, this project aims to build a prototype for irradiating sunglasses lenses, where one of the spectacles will be submitted to the solar simulator; and the other to the prototype. This prototype consists of a box for protecting mechanical and electronic systems, an automatic lid and a laser cut acrylic panel, which houses 100 lenses arranged in the use position and which will be irradiated by the sun from sunrise until sunset. The lid opens automatically; the panel is ejected by a mechanical system from inside the box and should turn towards the sun, so that the lens will always be irradiated from the front by the sun. The data about azimuthal angular position of the Sun for the city where the prototype is located is previously calculated and recorded on the memory of the prototype. Sensors will be installed to close the cover and protect the glasses of undesirable weather conditions and to determine the ultraviolet index to which the lenses are being subjected to. The exposure time and UV index will be recorded and automatic opening or closing the lid may also be interfered by a PC by online software. Previously to the lenses being placed on the panel, spectroscopy will be performed, in the range of 280nm - 2000nm, at 5 different positions imposed by the standard at 3 different temperatures: 230C; 50C; 350C; also polarization measurements of the lenses will be performed; as well as the flammability and resistance to impact tests. Just sunglasses in compliance with the standards will be subject of the study. All these tests will be performed over again after every 30 days of exposure. Figure 1 shows the prototype's mechanical design and how it should operate. Mechanical parts are being fabricated following the illustrated design.

**PS16.037 - Integral clearance of medical rooms based on the type of medical treatment ensures a safe environment upon first use**

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Medische Technologie, Medisch Spectrum Twente, Enschede/NETHERLANDS

**Aim**

Patient and medical staff safety can only be guaranteed in a medical environment that is safe in terms of electricity, (ionizing/non-ionizing/thermal) radiation, liquids, gases and particles. The specifics of each type of medical treatment, e.g. invasiveness of treatment or nature of radiation, define which safety measures are required to provide a safe environment in a medical room. As all different types of safety measures have to act simultaneously, we propose an integral and multidisciplinary approach for acceptance testing of medical rooms.

**Current situation**

Our institute is building a new hospital. All new medical rooms have been built over a period of five years since the first sketches and initial determination of the requirements. For several rooms the intended types of medical treatment have changed during the construction period due to advancing methods of treatments or new medical equipment. Sometime these changes require additional safety measures. We also noticed that end users and supporting staff have an incomplete overview of aspects of newly constructed rooms that have to be validated. Additionally, responsibilities but also technical documentation of medical rooms are scattered among various officers and departments within the hospital. This lack of overview of all safety measures for each single room makes it impossible for the physician or head of department to take responsibility for a safe medical procedure upon first use. In order to ensure a safe environment upon first use, but also creating a solid base to handle future changes in types of medical treatment in a room, we have used an integral and multidisciplinary approach for acceptance testing of our newly built medical rooms.
New procedure

Our procedure to check the safety measures in medical rooms is based on the intended types of medical treatment, including the used medical equipment. The intended types of medical treatment (defined by answering questions such as "Is medical electrical equipment intended to be used in direct contact with the patient?") must be agreed on by both the responsible physician and the head of the department in the initial phase of the construction period. During construction, changes in intended use are checked against the safety measures. After building the responsible officer (e.g. the radiation protection officer) must confirm that the safety measures taken in the room indeed match the intended use. The intended types of medical treatment and all checked safety measures are presented in one integral overview. Finally, the head of the department and the responsible physician share responsibility for final acceptance of the medical room based on the intended types of medical treatments.

Conclusions

Current methods for acceptance testing of medical rooms do not guarantee the safety of patients and staff. By introducing a procedure of integral and multidisciplinary acceptance testing of medical rooms based on the type of medical treatments, a safe environment upon first use is ensured. Our next steps will focus on the implementation of a change management procedure for medical rooms to guarantee the safety of a room during its life cycle.

PS16.038 - Real-Time Posture Classification and Correction based on a Neuro-Fuzzy Control System

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Sitting position is one of the most common postures found in an office environments leading to long periods of time in that position. Assuming a poor posture in a sitting position during these long periods can even set this situation to worsen conditions, as this can lead to several health problems, namely back, shoulder and neck pain. To support the efforts in reducing such ailments, intelligent chairs are being developed in order to detect and correct poor sitting postures and alert the users to prolonged sitting behaviours. Here we describe the development of a chair prototype equipped with air bladders in the chair’s seat-pad and backrest, a pneumatic circuit composed of air and vacuum pumps to respectively inflate and deflate said bladders and piezoelectric gauge pressure sensor to measure the internal bladder pressure (Figure 1). The air bladders, which were previously manually manufactured, are now industrially assembled to improve reproducibility. We use a machine learning approach by using an Artificial Neural Network Algorithm (using 15 neurons, 1 hidden layer, tansig as the transfer function, and resilient backpropagation as the training function) to classify 12 standard sitting postures (Seated postures used in the experiments and their respective class label: seated upright, leaning forward, leaning back, leaning back with no lumbar support, leaning left, leaning right, right leg crossed, right leg crossed, leaning left, left leg crossed, left leg crossed, leaning right, left leg over right, right leg over left,) with an overall score of 81%. We optimized the classification to around 87% using Decision trees and the anthropometric information of the user, such as height and weight. Fuzzy Logic was introduced to the existing Algorithm by using as input the Centre of Pressure, the Posture Adoption Time and the Posture Output from the existing Neural Network Algorithm. This new Neuro-Fuzzy Algorithm now takes into account intermediate postures between the previous standard and the time period adopted in each posture, prompting the development of a Fuzzy Control System that inflates and deflates each bladder during a specific period of time according to the Fuzzy Output.

Figure 1: A – Placement of the pneumatic control modules in the back rest; B – Placement of the pneumatic control modules in the seat pad; C – Placement of the air bladders in the inside the padings of the chair. D – Industrial design of the air bladders from the second prototype

PS16.039 - Management of electromagnetic interferences in healthcare facilities - A Review

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Management of electromagnetic interference has become a major issue in Quebec hospitals. Several discussions on this issue have been held between managers of medical technologies departments. Some hospitals tend to allow more widespread use of wireless technologies while others continue to formally ban them. As a contribution, we present a review of literature on devices that may transmit frequencies that can interfere with medical devices, such as pagers, cordless phones, cell phones, tablets, portable radio transceivers, tracking devices, laptop computers, telecommunications antennas and medical equipment. Because of its wide availability, portability and accessibility, cell phone is the most popular wireless technology. The greatest distance of immunity known to date is 6 m, excluding the combination effect of the agglomeration of several electromagnetic sources in the same area. From our literature review it is safe to allow cell phones in a health facility if the usage is made out of a nursing unit, regardless of the vocation (critical or general Medicine) or outside of a diagnostic or medical department (medical imaging and laboratories). By cons, for medical imaging technologists carrying a pocket dosimeter (immunity of 38 cm), the use of cell phones might be banned while still carrying the dosimeter. The nuisance caused by cell phones, their need for regular disinfection by their owners and the protection of privacy should be considered by healthcare facilities in preparation of regulations, procedures or policies on health and safety at work. A subsequent study should
analyze electromagnetic interference of medical equipment between them. Hospitals that have already authorized the use of cell phones on the care units would benefit requiring phones with Flight mode enabled, pending the development of a Hospital mode that inhibits, in addition, sound recording, video camera and forces the phone ring mode to vibration.

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Despite the presence of policies and procedures regarding the regulation of the use of wireless devices in hospitals, they are hard to make effective for employees, patients and visitors. Considering many concerns related to electromagnetic interferences and patient privacy, we suggest a more realistic approach based on the design of a Hospital Mode in smartphones and tablets. Hospital Mode manages electromagnetic interference, noise nuisance, protection of privacy, sound level and inhibits video camera and forces the phone ring mode to vibration in non-clinical area. A key aspect of Hospital mode resides on its ability to switch automatically the smartphone or tablet ON and OFF depending on the area of the hospital. We recommend a regulation towards smart building integrating dedicated frequencies bandwidth to manage Hospital Mode for any compliant wireless technology.

**PS17 - TRACK 17: EDUCATIONAL AND PROFESSIONAL ACTIVITIES**

**PS17.001 - A discipline about Human Factors Engineering and Usability applied to Medical Devices for under graduation courses using Active Learning techniques**  
**Author(s):** Renata A.R. Custódio¹, Ana P.S.S. Almeida², Rodrigo M.A. Almeida³, José A. Ferreira Filho³, Alexandre C.B. Ramos¹  
¹Institute Of Mathematics And Computer Science, Federal University of Itajubá, Itajubá/BRAZIL, ²Institute Of Industrial Engineering, Federal University of Itajubá, Itajubá/BRAZIL, ³Institute Of Systems Engineering And Information Technology, Federal University of Itajubá, Itajubá/BRAZIL

This paper proposes a new discipline with hybrid methodology mixing traditional approach and Project Based Learning, using some active learning techniques as peer instruction to teach Human Factors and Usability focused on Medical Devices. This course will be offered in Federal University of Itajuba for undergrad students in Computer Sciences, Information System, Computer Engineering, Control and Automation Engineering, Electronic Engineering and Industrial Engineering. The dynamics of the classes will be guided by working in teams of students and tutoring in the proposed Project Based Learning themes. Some formal lectures about specific concepts and methods throughout the development and analysis of the proposed problems will also be held. It is expected to have a greater conceptual gain with a higher engagement by students. To evaluate the student achievement, an assessment will be applied to the end of the course, targeting both the knowledge gain and the student’s motivation.

**PS17.002 - The medical equipment management inside the accreditation process: a comparison with the Brazilian accredited hospitals**  
**Author(s):** João E. Côrrea¹, Rodrigo M.A. Almeida², João B. Turrioni³  
¹Institute Of Industrial Engineering, Federal University of Itajubá, Itajubá/MG/BRAZIL, ²Institute Of Systems Engineering And Information Technology, Federal University of Itajubá, Itajubá/BRAZIL

This work aims to analyze the process of management of medical equipment in hospitals and compare the views of JCI, QMENTUM and ONA, a Brazilian accreditation model, on this topic. To the date these three accreditation models are the ones being used in Brazil. The survey results showed that for the Brazilian hospitals the accreditation model ONA becomes more efficient since it more in line with the reality of Brazilian hospitals.

**PS17.003 - The Medical Physics M.Sc. program at the National University of Mexico: Results and lessons learned after 100+ graduates**  
**Author(s):** María-Ester Brandan  
Instituto De Física, Universidad Nacional Autónoma de México UNAM, Mexico City/MEXICO

The M.Sc. (Medical Physics) program at the National Autonomous University of Mexico (UNAM) is one of two in the country. After 17 years of activities, it has graduated more than 100 students who mostly work (60%) in clinical activities. A large fraction (26%) of the graduates is presently studying, or has already completed a Ph.D. in medical physics. 8% of our former students work in non-clinical activities related to medical physics. The academic program has been revised in 3 occasions (the original 1997 curriculum, and 2003 and 2009 revisions). Accumulated experience, increased available human resources, and recently published international recommendations for educating medical physicists have determined the curricu-
lar changes. The most visible operational changes have been higher entrance requirements and promotion of a more efficient use of the time during the thesis project execution. The main obstacle for a rapid graduation has always been the thesis completion. Thanks to various strategies, graduation time including the thesis defense, has decreased from almost 4 years at the start to 2.7 years now. The areas for the required thesis have always been relatively wide and continue to expand as medical and biological physics develop in the country. Former students who get a doctorate and join Mexican universities are having an impact in the development of new research groups. Currently, the UNAM Physical Sciences Graduate program considers establishing the medical and biological physics fields of knowledge as academic options within its Ph.D. in Physics.

**PS17.004 - An Experience on the dosimetry of HDR Brachytherapy Treatment Planning of Cervical Carcinoma at BPKM Cancer Hospital, Nepal**

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**Propose:** To identify the status of Brachytherapy planning by evaluating the bladder and rectum dose of cervical carcinoma patients those undergone HRD brachytherapy for six years.

**Methods and materials:** Fifteen hundreds and ten patients, from 2005 to 2010, were taken for this study. In total four thousands five hundreds and thirty treatment plans were done to complete all patients' treatment. The Fletcher Suit Delclos FSD types of applicators, orthogonal radiographs were used for dosimetry. Radio opaque dye and rectal probe is used to identify bladder and rectum location respectively.

**Results:** 1510 patients completed all three cycle of treatments. Maximum patients, 1055 (69.87%), have received bladder dose less than 4 gray per fraction. Less than five percent patients have received bladder dose more than 71 % of prescribed dose per fraction. Similarly; in case of rectum dose, total 1324 (87.68%) pts has received rectal dose less than 57 % per cycle. 1324 (87.68%) pts have received dose less than four gray per fraction.

**Conclusions:** Maximum patients were treated with bladder and rectal dose less than 60 Percentages of point A dose with satisfactory pear shape. Normal organ dose should minimise, however, it should not produce a significant reduction in disease control.

Keywords: HDR Brachytherapy, Remote after loading, ICRU38, cervical carcinoma patients.

**PS17.005 - Health IT Education for Clinical Engineers**

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Relevant Health IT education content and opportunities for Clinical Engineers (CE) and health technology management (HTM) leaders, both in developed and developing countries, will be explored through three case studies:

1. the US Veterans Administration (VA) HTM Health IT education program in 2015
2. a global program developed by ACCE and IFMBE-CED in 2015

The need for the training and continuing professional development (CPD) of medical radiation physicists in Russia and CIS countries has dramatically increased lately due to the activation of the purchases of the state-of-the-art equipment and cutting-edge technologies for the modernization and reconstruction of radiation therapy departments. The efficiency of radiotherapy treatment for cancer patients and use of the state-of-the-art accelerator facilities highly depends on the qualification and number of medical physicists. There is currently an acute shortage of medical physicists in the CIS region. The qualitative professional training of medical physicists is the priority task in these countries. The fulfilment of this task has become possible due to the cooperation between the IAEA, Rosatom and Association of medical physicists in Russia (AMPR) who initiated and launched two IAEA Technical Cooperation (IAEA TC) Projects on Building Capacity for Medical Physics in Radiation Oncology for the Commonwealth of Independent States. The International Training Centre (ITC) of the Association of medical physicists in Russia based at the N.N. Blokhin Russian Cancer Research Centre is the main counterpart in the 2012-2015 IAEA TC Projects designed for the Russian-speaking medical physicists of the CIS countries to improve their knowledge and skills in the radiotherapy physics. The objective of the regional projects is to level differences in radiation oncology among CIS countries through education and training of medical physicists. ITC plays a key role in the implementation of the Projects by hosting trainees and executing training courses and practical sessions. During three years (2012-2014) of the IAEA TC projects 10 regional courses of 1-3 week duration were conducted. A 3-month group fellowship on practical aspects of medical radiation physics in radiotherapy was organized for 5 fellows from Kazakhstan, Kyrgyzstan, Moldova, Tajikistan and Uzbekistan. A total of 197 medical physicists were trained from 10 CIS Countries (Azerbaijan, Armenia, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Uzbekistan, Ukraine) and Lithuania. The table below shows the number of trainees from each country:

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of trainees</th>
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<tbody>
<tr>
<td>Azerbaijan</td>
<td>6</td>
</tr>
<tr>
<td>Armenia</td>
<td>6</td>
</tr>
<tr>
<td>Belarus</td>
<td>21</td>
</tr>
<tr>
<td>Kazakhstan</td>
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<td>Kyrgyzstan</td>
<td>5</td>
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<tr>
<td>Moldova</td>
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</tr>
<tr>
<td>Russia</td>
<td>67</td>
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<tr>
<td>Tajikistan</td>
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<td>Uzbekistan</td>
<td>3</td>
</tr>
<tr>
<td>Ukraine</td>
<td>30</td>
</tr>
<tr>
<td>Lithuania</td>
<td>9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>197</strong></td>
</tr>
</tbody>
</table>
PS17.007 - Assistive Technologies in Biomedical Engineering Education
Author(s): Lenka Lhotská1, Tatjana Welzer2
1Department Of Cybernetics, Czech Technical University in Prague, Prague /CZECH REPUBLIC, 2University of Maribor, Maribor/SLOVENIA

At present the need for interdisciplinary education supporting development and practical application of assistive technologies (AT) is continuously growing. It is given by development of demographic and age structure of the population and the need to ensure support and safety of elderly and handicapped people with increased health and other risks. Currently there is lack of graduates having interdisciplinary theoretical education in the fields of electronics and information and communication technologies and simultaneously focusing on the whole complex of practical needs of applications related to assistive technologies (AT). When we started developing courses in this area we realized that the closest and already established study program is Biomedical Engineering. The students get required courses in electronics, information and communication technologies and physiology. Thus we can relatively easily extend the curricula with new topics needed for managing the area of assistive technologies.

We are also well aware of the fact that the universities try to support education of students with special needs as much as possible. However, the requirements on support range from very simple tools up to very sophisticated systems. This area is not yet mapped very well and needs more elaborate review.

Although this area is very challenging it also offers opportunities for direct involvement of students with special needs into research projects focused on development of assistive technologies because they know the problems very well and as team members they can contribute to successful development of new more advanced tools, devices and systems.

Although it seems that all new technologies are somehow covered by existing courses in electronics, informatics, telecommunications, etc., we see and the practice proves it frequently that these courses are not properly interconnected. Nowadays we educate engineers specialized in electronics, or telecommunications, or informatics. But many of them are lacking the system view on an interdisciplinary problem. They often understand a narrow area very deeply but they do not see its connections to other neighboring fields that are necessary when developing a complex system.

In addition to purely technical courses there must be introduced courses that cover problems of handicapped people (for example their sensing limitations linked with necessity of having different computer or device interfaces, movement limitations – different design of equipment). The students must acquire knowledge about different types of handicaps and means how to compensate them. Further they must be educated in the design of tools and devices with respect to cognitive impairments, vision and hearing problems, supported communication, supported mobility; assessment and requirement analysis, and related topics. Another large area of interest is eAccessibility, namely improvement of access of handicapped people to electronic resources, including Internet. And last, but not least the legal, ethical and social issues must be considered since we are working with sensitive data similarly to medical domain.

In the paper we present examples of courses on AT and involvement of students and/or users with special needs.

PS17.008 - Future-Proofing Physics and Engineering in Medicine
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Medical physicists and biomedical engineers have played a pivotal role in the development of new technologies that have revolutionized the way medicine is practiced today. They have been transforming scientific advances in research laboratories to improving the quality of life for patients. Indeed innovations such as computed tomography, positron emission tomography, magnetic resonance imaging, linear accelerators, artificial hearts, robotic surgery and bionic limbs have collectively improved the medical outcomes for millions of people. The emergence of precision medicine exemplifies the potential of emerging science to improve patient outcomes and support efficient health delivery. The multi-disciplinary and cross disciplinary nature lends them an edge in research innovation. However, current emphasis tends to only enhance the specific skill development and competency at the expense of future roles and opportunities. This emphasis is largely driven by financial and political pressures for optimizing limited resources in health care. This has raised serious concern on the ability of the next generation to innovate and lead the development of new technologies. The use of nanoparticles to treat tumours, targeted radionuclide therapy, high-intensity focused ultrasound, electromagnetic wave ablation and image-guided surgery are just some areas challenging the old paradigm. We should venture into and explore non-traditional and blurred boundaries between various medical disciplines from diagnosis to treatment.

How do we future-proof the next generation? We must reform the existing curriculum by embracing contemporary sciences such as molecular biology, systems biology, nanotechnology, advanced materials, bioinformatics, spectroscopy, etc. We should encourage collaboration and interchange of ideas between medical and non-medical physicists; biomedical and non-biomedical engineers. The next-generation must be able to work or lead effectively as part of a collaborative multidisciplinary team. They should be able to participate in intelligent discussions with surgeons, neurologists, cardiologists, imaging specialists, pharmacologists, technologists, statisticians, computer scientists, spectroscopists and biologists to various extent. Furthermore, they must also engage with the public on their role in healthcare and research activities. With the right approach, the next generation will then look forward to making continued and significant contributions to the “new world” medicine. As it is, various global health challenges await the ingenuity, versatility and curiosity of medical physicists and biomedical engineers.

PS17.009 - Nuclear and Radiological Emergencies - First IAEA Training Course for Medical Physicists
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The role of the medical physicist in preparedness and response to nuclear and radiological emergencies (NRE) has been discussed at previous joint IOMP-IAEA-WHO workshops (WC-2012, ICMP-2013). There was broad agreement that by virtue of their academic education and clinical training Medical Physicists with their expertise in radiation protection (e.g. radiation dosimetry, dose measurement, etc.) may be an added value of the workforce dealing with NRE. Most current medical physics curricula include topics relevant for NRE, like radiation dosimetry, handling radioactive materials and assessment of exposure, instrumentation, radiation monitoring, shielding, etc. However, specific training is essential – particularly in countries with no adequate emergency preparedness infrastructure - to enable a clinical medical physicist to be fully prepared to
respond efficiently in an event of NRE, within a national or local emergency response plan. To improve preparedness of the clinical medical physicists for events of NRE and to set a standard for knowledge acquisition, the IAEA developed a specific training package for medical radiation physicists. The training package consists of 14 modules, which can be delivered through a one-week Workshop. Additionally to the above topics, the course program includes specific training on protection strategies, medical management, psycho-social effects, impacts on mental health and effective risk communication. The 1st Workshop to be held shortly after the WC2015 will be organized by the IAEA and hosted by the University of Fukushima, in co-operation with the National Institute of Radiological Science (NIRS). The purpose of the Workshop is to provide the participants with a good understanding of their potential complementary roles in NRE situations, and to prepare them to contribute effectively to support the response to an NRE situation as identified in emergency preparedness plans. This pilot Workshop will target trainers who have the potential to train other medical physicists in their countries as well as other health care professionals in the response to NRE situations. Replication of this Workshop in due time is expected in order to increase the number of medical physicists who will be fully prepared to support NRE worldwide.

PS17.010 - Academic Real Time Digital Medical Image Processing Environment
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In this work we developed an academic tool for teaching Digital Medical Image Processing in a Graphical interface using functions developed in Matlab. This platform makes possible the visualization of histograms, Fourier Spectra and the image in real time, with their modifications occurring as long as the user alter the image. We included the following functions in the software: brightness control, contrast control, contrast enhancement, histogram equalization, image inverse, image normalization, exponential transformation, gradient filter, logarithmic filter, Sobel filter, sum with original image, arithmetic average, geometrical average, Gaussian filter, median, maximum, minimum. We also included some noise options: exponential noise, gama noise, Gaussian noise, ReyLeight noise, Pepper noise, Salt noise, pepper and salt noise, white noise. Another interesting possibility is the comparison between the processed image and its original version besides the histogram and Fourier Spectra. A threshold tool is available to create binary images from the processing image. This process is possible anytime in the processing flow. It is possible to visualize the entire processing flow in an action log and save the image, histogram or Fourier Spectra in commercial image formats, such as .jpg or .tif. In addition, both common format images and DICOM are available in the software. In digital image processing classes in Federal University of Uberlândia, professors are already using the tool to show how some image processing functions work, besides a student who is developing his final undergraduate thesis in Biomedical Engineering in our system.

PS17.011 - Detection of Eye Movement; possibility how to control world
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Electrooculography is one way how to detect eye movement. Nowadays represents this method a possible compromise between the price and accuracy of equipment. Development of this method also benefits from the contemporary trend of miniaturization when electrode can be attached e.g. to the goggles. It is not necessary to have the electrodes attached on your face. Hardware solution of electrooculography and visualization software is presented. Furthermore mathematical dependency output voltage on input eye movement is determined. This work also brings the electrooculography method and principles to the awareness of students.

PS17.013 - Career Progression for Medical Physicists
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Some clinical medical physicists are employed under negotiated national/state/provincial employment awards or contracts. These may be specific to medical physicists, or they may cover other clinical scientific professions as well. These awards often inherently define a career path for the physicists. In most countries a career path is not defined in any way, and in some countries a medical physics is not even recognised as a profession despite it being listed as such by the International Labour Organization.

But most medical physicists are not under an employment award, so they do not have a recognized career path to follow. Awards often provide guidance as to how a medical physicist’s career is progressing and they often define the level of responsibility and expertise required at each stage of the structure. This provides certainty to the physicists as to what they can achieve career-wise and what they must do to progress.

A survey of existing employment structures and awards for medical physicists was carried out in early 2014. In some cases these were found to be little more than pay scales, but in some cases the documents are very detailed and run to dozens of pages. The more detailed documents define multi-level career structures with the degree of responsibility expected at each level and what must be achieved to advance through from one level to the next being explicitly defined. The more detailed awards inherently define how a medical physicist’s career should progress and to offer guidance to those who employ medical physicists as to how they can develop career structures that will enable their employees to optimise their career and performance.

A well-designed award will also define minimum education and training requirements, require employers to make provision for the physicists’ continuing professional development, deal with issues that arise when a physicist leaves the workforce for a period of time and wishes to re-enter it, and encourage and provide for joint clinical and academic appointments.

While regional medical physics societies are professional and not industrial organizations, they should all have career progression policies in place to offer guidance to both clinical medical physicists and their employers to ensure that the members of the clinical physics workforce can develop to their full potential. This will lead to improved medical physics professional standards and improved health care delivery.

PS17.014 - IOMP-W – the International Organization for Medical Physics Women Subcommittee
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The objective of the Used Equipment Donation Program (UEDP) of the American Association of Physicists in Medicine (AAPM) and the International Organization for Medical Physics (IOMP) is to help developing countries acquire used equipment in good working condition through donations of used equipment made through AAPM/IOMP. The UEDP insists that the used equipment donated is in good working condition and verifies as far as possible that it meets the need of the recipient developing country (DC). The guidance in the ‘WHO Guidelines for Healthcare Equipment Donations’ (WHO, 2000) is adhered to and relevant regulations are followed. Technical assistance is given, if need in installation or training is needed. The recipient pays for the handling and shipping and some financial help is available in special cases. UEDP reports are published in the IOMP publication Medical Physics World (MPW).

The International Organization for Medical Physics Women Subcommittee (IOMP-W) has been recently established to meet the demands of the women in our professional society for an official representation in the governing body.

The objective of IOMP-W is in compliance with the main IOMP mission and directives to advance medical physics practice worldwide by disseminating scientific and technical information, fostering the educational and professional development of medical physicists, and promoting the highest quality medical services for patients.

IOMP-W Functions:

Develop, implement and coordinate tasks and projects related to the role of females in medical physics scientific, educational and practical aspects.

To disseminate the experiences, good practice and learning within IOMP NMOs and other relevant accessible areas/across the globe.

Popularize the role of the women in medical physics and encourage female medical physicist to advance in the profession.

Organize international cooperation in medical physics and related specialties.

Provide regular status/progress updates to the IOMP on all tasks and projects related to the IOMP Female Group.

IOMP-W has currently focused on various dissemination activities to popularize the committee among the professional society. The major dissemination activities are directed toward the development of IOMP-W section under the main IOMP website, various advertising materials, participation in scientific and professional events, establishing and strengthening our relations with other organizations. Parallel to these dissemination activities IOMP-W took a leading role in a worldwide survey to access the role of the women in the field of medical physics.

IOMP-W is also turning to the past to memorize and honor the women that contributed towards the development of Medical Physics. Special posters have been developed to present the work of Marie Curie, Irène Joliot-Curie, Goeppert-Mayer, Rosalyn S. Yallow, Harriet Brooks, Chien-Shiung Wu.

IOMP-W are planning to extend these activities to a larger scale to cover IOMP Regional societies and NMO’s to popularize the role of women MP’s and contribute towards the improvement of our profession worldwide.
**PS18 - TRACK 18: GENDER, SCIENCE AND TECHNOLOGY**

**PS18.001 - Bone density measurements in strontium-rich bone-mimicking phantoms using quantitative ultrasound**  
**Author(s):** Bisma Rizvi, Eric D. Silva, Jahan Tavakkoli, Ana Pejovic-Milic  
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**Objectives:** Osteoporosis is a disease characterized by decreasing bone density and microarchitectural deterioration of bone tissue, which enhances bone fragility and fracture risk. Strontium renenate, is reported to promote bone formation and inhibit bone resorption, thus maintaining and increasing the bone mineral density (BMD) of osteoporotic individuals. Consumption of the strontium renenate for more than six months affects BMD scores, as assessed by dual energy X-ray absorptiometry (DEXA). Such DEXA-determined BMD scores often present a positive bias. Self-administration of strontium-based supplements, which is becoming prevalent, is expected to have the same impact on bone density measurements as strontium renenate.

The objectives of this work are: (1) to develop novel bone-mimicking phantoms containing different concentrations of strontium, and (2) to investigate the effect of bone strontium content on bone mineral density (BMD) obtained by a bench-top transmission-through-quantitative ultrasound (QUS) system.

**Materials and Methods:** Preliminary investigation was performed using the bench-top QUS beam on a new generation of bone-mimicking phantoms composed of hydroxyapatite and gelatin in an airtight container with dimensions of 2.5×6.5×6.5 cm³. These bone-mimicking phantoms contained different concentrations of strontium and/or with a varying bone density. Using the bench-top QUS system, the broadband ultrasound attenuation (BUA) and speed of sound (SOS) of the phantoms were measured in an ultrasound frequency range of 0.5-1.3 MHz.

**Results:** Measurements using the bench-top QUS system showed a strong dependency of the BUA with the BMD ($p < 0.001$). On the other hand, dependency between the SOS and the BMD was not statistically significant ($p = 0.095$). Moreover, increasing bone strontium concentrations up to 3 mol% strontium showed no effect on the BUA ($p = 0.749$) or the SOS ($p = 0.862$) values measured in this study.

**Conclusions:** The results obtained in this study suggest that the QUS is a promising diagnostic tool capable of providing BMD scores independent of bone strontium content. This could be relevant in QUS evaluations using commercially available clinical systems in individuals who are being treated for osteoporosis using strontium-based drugs or through self-supplementation with various strontium compounds.

**PS19 - TRACK 19: BIOPHYSICS AND MODELLING**

**PS19.001 - Numerical Modeling Of The Electrical Impedance Method Of Peripheral Veins Localization**  
**Author(s):** Muheb B. Al-Harosh, Sergey I. Shchukin  
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Veins in biological tissue produce electrical impedance to the alternating current passes through it. Bio-impedance method based on measuring this electrical impedance value using an array of surface electrodes has the capability of detecting peripheral veins. This paper presents the theoretical and experimental studies, reflecting the possibility of impedance method of peripheral veins localization. Mathematical model has been proposed to calculate the resistivity anomalies of vein in soft tissues and reflects the electrical impedance characteristic, depending on the location of the electrode system and the vein. A system electrode has been designed to be attached to the body in order to measure the electrical impedance value. The data obtained will determine the capabilities of the method. Experimental studies confirm the adequacy of the proposed mathematical model.

**PS19.002 - Modeling current density maps in the heart**  
**Author(s):** Mohammadali Beheshti, Farbod H. Foomany, Karl Magtibay, Stephane Masse, David A. Jaffray, Kumaraswamy Nanthakumar, Sridhar Krishnan, Karthi Umapathy  
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[Fig1: a) Geometry of modeled heart, b) simulated diffusive current in z direction in a chosen slice for reentrant scenario, c) simulated diffusive current in z direction in a chosen slice for normal scenario, d) and e) simulated activation in the chosen slice at two different time steps for reentrant scenario (red represents active and dark blue represents cells at rest, the values are dimensionless based on Aliev-Panfilov model) ]
Background:
The electrophysiological state of the heart is known to vary in different heart conditions. However it is hard to measure electrical activity inside the heart tissue. Magnetic Resonance Imaging (MRI) based Current Density Imaging (CDI) is able to provide a three-dimensional map of current pathways inside the tissue. However due to the experimental setup and logistics issues it is difficult to perform CDI either in ex-vivo or in-vivo hearts. Therefore generating a model that simulates CDI maps for the purpose of studying cardiac electrical activity could improve the understanding of current distributions in various heart conditions.

Method:
The current density maps are simulated using Aliev-Panfilov electrophysiological model. The averaged diffusive current in the mathematical model is related to the current density and the diffusion tensor representing heart structure is extracted from Diffusion Tensor Imaging (DTI). A single source of excitation mimicking the Sinoatrial Node (small sphere in Fig1.a) is considered and two electrodes simulate the CDI electrodes (Fig 1.a). Three different heart conditions are considered for both cases of presence and absence of injected current. The condition “dead” (D) represents excitable cells while there is no natural excitation in the heart, “reentrant” (R) is created by blocking ion channels in a cubic area temporarily (Figs 1.b.d and e), and “normal” (N) in which there is natural excitation without any block.

Results & Conclusion:
Averaged diffusive current density patterns generated from the theoretical model shows the difference between states (Figs 1.b, and 1.c). Figs 1.d and 1.e show the activation maps at two time instances for reentrant scenario, the results are shown for a chosen slice. Histograms of the results (Fig 2) show the possibility of detecting various states using averaged diffusive current. This demonstrates high potential of CDI as a tool to study various heart states.

PS19.003 - Finite Element Modeling of Gelatin Phantom from Measured Impedance Spectra
Author(s): Douglas Dutra1, Ana M.R. Pinto1, Pedro Bertemes-Filho2, Aleksander S. Paterno2
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Gelatin has been used as a phantom in different medical applications, as in electrical impedance spectroscopy. In this paper, the measured spectra of resistance and reactance of three gelatins with different concentrations of salt are presented. The Cole-Cole equation and the Debye model were used to fit the data by using a script written in MATLAB. The best set of these parameters offers the lower least square error when compared to the measured ones. The complex permittivity is then calculated as a function of frequency by using a software developed in finite element modeling (FEM), which solved the governing equations for the electrical field and potential. The measured and simulated data from FEM showed closer spectra than fitted one. It can be concluded that the FEM technique can be used to predict the impedance spectrum of gelatins as a tissue phantom. This might be a useful tool for modeling materials in biomedical, pharmaceutical and cosmetic applications.

PS19.004 - Prediction of radiation induced direct and indirect cellular damage using a novel ionisation spatial clustering algorithm
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Aim:
It is accepted that clusters of DNA DSBs lead to cell death rather than individual DSBs following irradiation. Consequently, the total number of ionisation events/DSBs does not directly correlate with cell survival. A novel clustering algorithm was developed in this work to group spatially correlated ionisation events from radiation tracks to predict DSB formation.

Methods:
The Monte Carlo particle interaction code RiTRACKS was used to simulate ionisation track structures of various heavy ions and the corresponding production/diffusion of free radicals in water medium. A spatial clustering algorithm was developed based on a hierarchical clustering function in Matlab to group ionisation events into DSBs to predict radiation induced cell death. The definition of a DSB according to (Stewart,2001) is two or more ionisation events located on the DNA double helix within a distance of 20 base pairs (bp), corresponding to a distance of 6.8 nm. Using this DSB definition, an original ionisation clustering algorithm was applied to predict the formation of DSB clusters in a cell. It was also used to determine the relative contribution from direct and indirect radiation damage to DSB formation as a function of the LET and atomic number of the ion.

Results and Conclusions:
Figure 1 illustrates how the complexity of radiation induced DNA DSBs change with particle LET. While higher energy protons produce more ionisation events per track, the complexity of the radiation damages they produce is less compared to low energy protons.

Figure 2 shows the relative contribution from indirect radiation damage (% as compared with direct damages) with increasing particle LET. The indirect damage decreases exponentially with increasing LET. The indirect contribution from heavy ions can be as high as 70% for photons, 50% for carbon ions and 30% for iron ions in the LET range investigated.
membrane under the ultrasonic excitation is obtained through the acoustical theory and biological knowledge. Provided that the cell membrane is a thin slice which is completely soft and has the same thickness. It further assumes that the cell membrane suffers uniform tension along any direction and the tension is so strong that the fluctuation of tension induced by the small deflection can be negligible in the course of vibration. Then according to the deduction of Ritz method, the vibration equation of cell membrane with ultrasonic excitation is obtained. The parameters included in the equation are the semi-major axis and semi-minor axis of ellipse, angular frequency, acceleration of gravity, surface tension and surface density. These parameters can be determined by experimental method, then the angular frequency is calculated through the equation and the resonance frequency is obtained. When the frequency of acoustic wave reaches the resonance frequency of cell membrane, it will make the cell membrane resonance and enhance the permeability of cell membrane. The vibration amplitude at this time is the largest, which makes ultrasonic energy enter the cell to the biggest extend and result in a series of biophysical effects. The conclusion of this paper is applied to the cells of gynostemma seeds and the theoretical value is found to coincide with the experiment value, thus confirming that this theoretical model has certain correctness.

PS19.006 - The Effect of Applied Force on Arterial Pulse with a New Flexible Pressure Sensor
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Arterial pulse has always been considered as an important signal containing abundant information of human body. Thanks to the recent advancement of high sensitivity flexible pressure sensors, which are small, light-weighted and more adaptable to human skin, pulse signals can now be detected from radial or carotid artery over the skin unobtrusively and continuously. The flexible sensors can be worn on skin not only for the monitoring of health status but also for the possible early prediction of cardiovascular acute events in real time. One of the key issues regarding practical applications is to understand the interaction and adaptation of the sensors to human skin. In this work we used a resistive flexible pressure sensor made in our own research Lab to measure arterial radial pulse at wrist and studied the effects of external force applied over the flexible sensor on the measured arterial pulse signals. The signals were recorded from 10 healthy subjects under 13 increasing magnitudes of applied force (0.1-1.8N) with duration of 2 minutes for each trial. The following figure shows the normalized pulse amplitude (the amplitude of AC component of the detected arterial pulse signal) under different levels of applied force. It is observed from this study that 1) as applied force increased, the pulse amplitude of all subjects shared a same tendency-first increase and then decrease; 2) the force where the pulse amplitude reached its maxima varied among different subjects. Our experimental findings suggest that the effect of applied force should be carefully examined when applying the flexible device for physiological signal measurements. Based on this study, we are currently recruiting patients for a clinical trial and developing a model for the unobtrusive real time monitoring of the internal arterial pressure with the ultimate goal of predicting cardiovascular diseases at the early possible stage.

PS19.005 - Research on Vibration of Cell Membrane of Plant Seed with Ultrasonic Excitation
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Ultrasonic radiation for plant seed can enhance the permeability of cell membrane, which is mainly related to the mechanical effect of ultrasound. Enhancing the permeability of cell membrane improves the germination rate and production of plant seed. The shape of plant cell wall is approximately like ellipse and cell membrane as the boundary of cell is usually close to the cell wall. The elastic vibration induced by ultrasound is mainly the vibration of cell membrane from the perspective of structure and substance of cell wall and cell membrane, as cell wall can’t vibrate elastically. Considering the complicated effect of cell wall and cytoplasm on the whole vibration system, it assumes that the effect can be ignored temporarily for simplifying calculation. So the cell membrane is studied as a single rectangular membrane and the frequency equation of cell
and hemodynamics boundary conditions are required for a realistic numerical flow simulation. Flow can impact AAAs in several ways; here transient transport topology will be studied in the lumen. To correlate transport with morphological growth, simulations will be carried during the longitudinal study of patients with more than 4 follow-up CTA.

Methods Lumen and thrombus geometry extraction from all follow-up CTAs, volume computation and AAA growth estimation (i). Numerical simulation of the flow using FVM validated towards 4D MRI (ii). Simulation conditions: polyhedral mesh, Newtonian viscosity, transient mass flow inlet and 0D pressure outlet. Computation of the Finite Time Lyapunov Exponents (FTLE) of the flow (iii). The FTLE field is able to capture transport boundaries using data from a whole cardiac cycle. Extraction and volume computation of enclosed stagnations zones and analysis of their progression over time, from AAA diagnosis to repair (iv).

Results Simulated flow topology showed a correspondence with MRI velocimetry experimental data. AAA lumen segmentation on seven patients over a cardiac pulse confirmed the hypothesis of a rigid wall condition on elderly patients. The transport study method allowed the isolation of stagnation zones from the circulating ones reproducibly. The volume of stagnation zones is highly correlated \( r=0.98 \) and \( 0.93 \), resp. red and green) with AAA growth while circulation zone›s remains stable.

Discussion We present a numerical approach for the quantification of stagnation zones in AAAs. It takes into account the highly transient dynamics of the flow and offers a scalar Eulerian field representing a Lagrangian phenomenon. Stagnation zones are known for promoting the advection of shear-stress activated platelets to the wall leading to the apparition of ILT. More patients will be added to the study in order to better understand the relationship between transport, and AAA growth and thrombus formation. This could also give a better insight on the dynamics of the AAA growth, a step toward predicting!

Figure: Example of the evolution over time (left to right: 2006, 2009 and 2012) and stagnation zones in a AAA. This patient presented two zones isolated in the flow.

PS19.007 - The Art of Engineering Medicine: A New Fast Non-Invasive Method to Directly Assess Ischemia in Human Diseased Coronary Arteries

Author(s): Iyad Fayssal, Fadl Moukalled, Samir Alam, Robert Habib, Hussain Ismaeel
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Fractional flow reserve (FFR) is a traditional indicatory index used to assess functional stenosis severity and determine whether a stenosis causes ischemia or not. Invasively measured FFR values \( \leq 0.8 \) indicate that the downstream heart tissue perfused by this vessel is at risk for ischemia. Currently, measuring FFR is an invasive procedure that is expensive, time consuming, not widely available, and not without complications. Recently, comprehensive predictive techniques involving numerical methods have gained attention. In specific, the use of computational fluid dynamics (CFD) methodologies combined with patient specific data allows computing in-vivo FFR. However, these non-invasive methods are associated with high computational cost and require high performance computing technology. This study focuses on the development of new strategies to reduce computational run time of solution prediction. The first strategy is based on isolating the diseased artery and simulating it separately without implicitly integrating other arterial segments while retrieving the accuracy of in-vivo hemodynamic significance of the stenosis. Special treatment of boundary conditions at the truncated domain was done via an in-house developed methodology, allowing to directly estimating ischemia in the stenosed artery. The second strategy is based on replacing a full transient simulation by a steady state one performed under mean conditions. The value of the developed strategies lies in their potential to (i) replace the experimental method which is based on intrusive processes and (ii) be performed with low computational cost. The latter advantage can significantly impact the applicability of this method in clinical practice at large.

PS19.008 - Influence of the alteration of the flow topology during the abdominal aortic aneurysm growth.

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Introduction The Abdominal Aortic Aneurysm (AAA) is the 13th cause of death in the USA. Patient specific AAA growth prediction and rupture risk remains challenging but rests upon the sole measure of its maximal diameter. In order to update current diagnosis criteria, influence of the blood flow on growth mechanics should be taken into account. Knowledge of the patient geometry and hemodynamics boundary conditions are required for a realistic numerical flow simulation. Flow can impact AAAs in several ways; here transient transport topology will be studied in the lumen. To correlate transport with morphological growth, simulations will be carried during the longitudinal study of patients with more than 4 follow-up CTA.
PS19.009 - Using the DDST to Train and Test Anthropomorphic Robotic Children
Author(s): Paul Frenger
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Normal childhood growth and development (G&D) causes anxiety for parents, who want health care providers to examine their children, recording their progress against standards to facilitate early intervention if problems arise. The Denver Developmental Screening Test (DDST, 1967) can be utilized by doctors, nurses, teachers or other professionals with minimal G&D training. Along with its updated version (DDST II, 1992) it is the most widely used G&D measurement tool. The DDST was validated on normal children in Denver, Colorado, in the areas of gross motor, fine motor-adaptive, language and personal-social. Entries on the test sheets are organized by chronological age; i.e.: child “plays ball” at 10-12 months.

Recently, research into pediatric G&D led to models of robot-artificial intelligence (A.I.) that mimic child maturation processes. One example is the European iCub (2004-2010, Figure 1). The author’s ANNIE humanoid robot-A.I. (2000-present) predated iCub by four years. Regrettably, there is no standard training and evaluation methodology to uniformly compare techniques and outcomes between robots, or between the robot models and actual children. The author is attempting to fill this gap by using the DDST as a tool to accomplish these goals, with ANNIE the test subject.

ANNIE’s hardware and software have been described in detail at bioengineering and computer conferences, including CMBES. Its software relies on the Forth-language variant IEEE 1275-1994 (Open Firmware), a plug-and-play networking system. Its hardware includes analog artificial neuron circuits for its emotion engine and optical character recognition (OCR). The A.I. embeds a “subject-verb-object” format, compatible with DDST entries, in its schema-script system.

During training, modified DDST milestones in each of the four categories are input to the A.I. compiler. When ANNIE encounters objects not already known, (like “ball” or “raisin”) the compiler creates a blank database entry for each via Forth’s error-handling mechanisms. These unpopulated object entries are filled-in later as training progresses, including images taken from ANNIE’s machine vision eyes, sounds from its microphone-ears, and text from OCR and other sources.

During testing, each DDST challenge is presented to the robot (tests are input by keyboard rather than by ANNIE’s speech recognition system). The robot responds by attempting to demonstrate mastery of the test.

Result: with sufficient training, ANNIE performed every milestone except: walking, dressing, balancing, hopping-jumping (for which the robot is not yet equipped). The missing gross motor functions will be added in the future.

Figure 1: iCub plays ball (courtesy Wikimedia Commons).

PS19.010 - The new low-cost metaphase finder for biological dosimetry
Author(s): Akira Furukawa
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Biological dosimetry is to estimate one’s dose by biological phenomena. Most popular and “gold standard” phenomenon is the appearance of dicentric chromosomes in one’s metaphase cells among white blood cells. Metaphase finder is a tool for biological dosimetry that finds metaphase cells on slide glasses. It consists of automated microscope, auto-focus system, X-Y stage, camera and computer. It does the image diagnosis of the microscopic images of the slide glasses, and displays the positions of metaphase cells. A metaphase finder is used for the personnel worked at Fukushima nuclear plant to know how much dose they irradiated.

The author and colleagues have already reported a low-cost metaphase finder system, using commercially-available products (1). Its software was application of mathematical morphology. But the system was a combination of multiple manufacturers and then it requires much knowledge and skill to the resellers and users. This system was more compact and less price than commercial products. The system would be another choice for resellers and users, but its speed was needed to faster.

Then, the author has collaborated with a software company to start new project to make another system. This system is using new special software is expected to be faster than non-custom made system. We used Nikon Eclipse Ni-E microscope with motorized X-Y stage, 4x objective lens and 1920 x 1024 pixels color camera for hardware. The software added the new function to compare the color of the image. The new system was also compact and low-price.

Now, the system was completed and we tested its speed. It was 13 minutes and 56 seconds per one slide, while capturing 1,333 images. We accomplished the aim of the project. The dicentric-dose curve will be shown in this presentation.

This research is supported by The Japan Science and Technology Agency.

(1) Akira Furukawa, Masako Minamihisamatsu, and Isamu Hayata: Low-cost metaphase finder system, Health Physics, Volume 98, Number 2, 2010.
PS19.011 - Concentrated photoactivation: focusing light through scattering

**Author(s):** Ana Teresa Gabriel\(^1\), Jorge Machado\(^1\), Ricardo Gomes\(^2\), João Coelho\(^3\), Catarina Silva\(^4\), Cataria Reis\(^5\), José Paulo Santos\(^1\), Pedro Vieira\(^1\)

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Light has long being used in medicine; however, the high scattering of biological tissues always hindered its use. The aim of this work is the development of methodologies to focus light inside biological tissues. Geant4/GAMOS Monte Carlo platform was used to simulate the possibility of parameterize the time delay of multiple sources of external light, offset in time, as a function of the interest region position in order to create constructive interferences in a breast sample. A computational model was implemented and the platform was configured in order to perform these simulations. Preliminary results using a single light source were performed. It was concluded that scattering in adipose tissue is very high which is consistent with previous studies.

PS19.012 - Steered Molecular Dynamic Simulation Approaches for computing the Blood Brain Barrier (BBB) Diffusion Coefficient

**Author(s):** Maysam Pedram\(^1\), Amir Shamloo\(^2\), Aria Alasti\(^2\), Ebrahim Ghafr Zadeh\(^2\)

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In the recent years a great amount of research deals with different physical and biological aspects of the BBB structure, a robust shield that separates the blood and brain, a recent research held by the authors of this paper has focused on figuring out computing the diffusion coefficient of endothelial cell membrane. In this study, the major efforts have been concentrated on calculating a standardized measure for the amount of permeability and diffusion of this barrier. As a result, this work is dedicated to molecular dynamics (MD) simulation of calculating the interaction force between nano-particle and BBB membrane. data is recorded by using steered molecular dynamics simulation and crossing nano-particles with constant velocity for many times on both sides of the membrane. This data help to find diffusion coefficient in order it can convert the discrete medium simulation into continuum medium.

PS19.013 - The study of the relationship between the scatterer particle size of soft tissue in ultrasonic focal region and the frequency offset of backscattered signal

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The traditional B mode ultrasonic imaging equipment utilizes the information of amplitude envelope of ultrasonic backscattered RF signal to construct the soft tissue image, while other information such as frequency and phase is not fully utilized which is related to the microstructure of tissue. When the biological soft tissue have some pathological changes, its attenuation coefficient\(\tau_w\)elastic properties, particle size or concentration (the number of scatterers per unit volume) of ultrasonic feature scatterers will be changed accordingly. The power spectrum of ultrasonic backscattered RF signal of the soft tissue is related to the particle size, geometric shape, concentration and elastic properties of ultrasonic feature scatterers.

Based on the ultrasound propagation property in biological soft tissues, it was studied that the relevance between the central frequency offset of ultrasonic backscattered RF signal and the particle size of ultrasonic feature scatterer. The interreaction of attenuation coefficient of tissue in the focal region of ultrasonic transducer, concentration of ultrasonic feature scatterer, as well as the central frequency, bandwidth and focusing properties of ultrasonic transducer on the central frequency offset was explored by means of the computer simulation.

Four experimental imitations with different particle sizes of scatterer were made, and the frequency characteristics of these three types of ultrasonic backscattered signals were studied by the statistical signal process method. Experimental imitation was made by gelatin, glass bead, glycerin, distilled water, anti-septic and glutaraldehyde. The glass beads are special solid glass beads of 2#・3#・4# provided by Qinhuangdao QinHuang glass beads Co. Ltd. Their average effective scatter radii are 36.25 mm, 47 mm, 55.25 mm and 64.25 mm, respectively.

The results of computer simulations reveal that the frequency shift of ultrasonic backscattered signal of soft tissues would increase with the particle size of ultrasonic feature scatterer increasing, and approximately shows a linear growth relationship. The frequency offsets is different with the different parameter of transducer such as the central frequency, bandwidth and focusing property, and the number concentration of ultrasonic feature scatterer and focusing property of transducer have not significant effect on the frequency offset.

The results of imitation experiments indicate that, with the increase of the effective scatter radius of ultrasonic feature scatterer, the central frequency of ultrasonic backscattered RF signals of experimental imitation would shift to the low frequency and is more and more close to the central frequency of ultrasonic exciting signal.

It can be concluded that the information of frequency and phase of ultrasonic backscattered RF echo signal may be used to study the microstructure characteristics of soft tissue and explore the application of ultrasonic diagnosis technology in the physiological pathology diagnosis of biological tissue.

PS19.014 - Dynamic Model for Shear Stress-Dependent NO and Purine Nucleotide Production from Endothelial Cells

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We developed a dynamic mass transport model for a parallel-plate flow chamber apparatus that predicts concentrations of nitric oxide (NO) and purine nucleotides (ATP, ADP) produced by cultured endothelial cells (ECs). The flow chamber, which was designed and fabricated in our laboratory, permits real time in vitro measurements of NO produced by ECs at different levels of wall shear stress \((\tau_w)\) (Andrews et al., Nitric Oxide, 23(4):335-42, 2010). From steady-state NO measurements with bovine aortic ECs cultured in this chamber, Andrews et al. (2010) found that a hyperbolic function provided the best fit for the \(\tau_w\)-dependent rate of NO production \((R_{NO})\).

\[ R_{NO} = R_{max} + \frac{R_{max}(\tau_w/A) \cdot \tau_w}{(\tau_w/A) + 1} \]

More recent studies with this flow chamber (Andrews et al., Cellular and Molecular Bioengineering, 7(4):S10-20, 2014) investigated the role of \(\tau_w\)-dependent release of ATP in modulating \(R_{NO}\). In order to analyze data from these studies, we modified a previous model that characterizes the spatial distribution of NO in the chamber (Fadel
et al., Annals of Biomedical Engineering, 37(5):943–54, 2009). The modified model predicts how the net release rates and mass transport for NO, ATP, and ADP vary with changes in \( \tau_w \). Two previous models in the literature for ATP release and ADP formation were implemented. The first model (John and Barakat, Annals of Biomedical Engineering, 29(9):740–51, 2001) predicts a rapid rise in ATP and ADP to steady-state values within a few sec. The second model (Qin et al., Biomechanics and Modeling in Mechanobiology, 7(5):345–53, 2008) predicts a slower increase, reaching peak ATP and ADP values at different \( \tau_w \) followed by a slow decline in concentration, attributed to “receptor desensitization” (a reduction in the response with a longer stimulus).

Experimental data obtained after altering ATP and ADP concentrations with apyrase (Andrews et al., 2014) were analyzed to quantify changes in \( R_{\text{cyt}} \) using this model. Apyrase is a calcium activated plasma membrane-bound enzyme that catalyzes the conversion of ATP to ADP, followed by conversion of ADP to AMP and inorganic phosphate. A reduction in \( \tau_w \)-dependent \( R_{\text{cyt}} \) was found when 1 Unit/mL apyrase was added to the media in the chamber, presumably due to lower ATP and ADP at the EC cell surface. The 2 ATP release models were used to predict effects of different isoenzymes of apyrase on ATP and ADP concentrations in the chamber, although the exact composition of apyrase used experimentally was uncertain. We explored different functional relationships to describe experimental changes in \( R_{\text{cyt}} \) with \( \tau_w \) due to changes in ATP and ADP. A reasonable fit was found with an apyrase isofrom of Desiree which predicts the largest decrease in ATP and ADP. Further experimental data is required to validate the model and obtain better estimates for the model parameters. The dynamic model simulations provide a greater understanding of experimental results obtained with parallel-plate flow chambers and allows quantitative analysis of the relationship between \( \tau_w \), purine nucleotide concentrations, and NO produced by ECs.

**PS19.016 - Cancer stem cells in a hierarchical model of tumour regrowth in five head and neck carcinomas**

**Author(s):** Loredana G. Marcu\(^1\), David Marcu\(^2\), Sanda M. Filip\(^2\)

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**Introduction:** Locally advanced head and neck carcinomas (HNC) are aggressive due to several tumour-related factors such as: hypoxia, elevated levels of the endothelial growth factor receptor and tumour repopulation during treatment. There is a growing body of evidence towards the existence of cancer stem cells (CSC), which represent a subpopulation of tumour cells that hold the ability to proliferate indefinitely, are tumorigenic and also more quiescent than non-cancer stem cells. Due to their ability to respond to triggers these cells are considered to be accountable for treatment resistance and failure, as well as tumour recurrence. However, there is insufficient quantitative information in the literature regarding the kinetics and behaviour of CSCs in order to assess their impact on tumour control. The aim of this work is to simulate the possible mechanisms behind CSC generation and contribution to tumour regrowth during treatment on five virtual HNC with different growth kinetic parameters.

**Methods:** A hierarchical model of HNC has been grown using probabilistic methods starting from one tumour-initiating cell. The model written in C++ has generated a virtual tumour of 10⁷ cells having biologically real parameters. The radiation software module kills cells according to surviving fractions defined for each phase of the cycle. A fraction of 20% cells are recruited after irradiation as CSCs (which proliferate via symmetrical division) or non-CSCs (asymmetrical division). The fraction of CSCs is limited to 25% of total cells.

**Results:** The model has shown that tumours growing with different kinetic parameters (mean cell cycle time, volume doubling time) respond differently to conventional radiotherapy. Due to the repopulation ability of CSCs, tumours with shorter mean cycle times (20h – 40h) cannot be cured with 70Gy given in 2Gy/fraction, 5 days a week, over 7 weeks (see figure). A typical HNC with 33h mean cycle time would need an additional 26Gy, or a 6 day/week treatment to be cured, considering that the tumour is non-hypoxic. Tumours with mean cycle time of 20h exhibit a drastic resistance through repopulation, as the interfraction interval (24h) is larger than the time for cell division.

**Conclusions:** Differences in treatment response of various HNC models due to CSCs and their interplay with growth kinetics show the importance of CSC identification within the tumour. The need for accurate markers for CSC labelling is therefore imminent. Both quantitative and qualitative knowledge on CSC are needed to describe the resistant subpopulation and to design treatment regimens accordingly.

**PS19.015 - Mechanism of Phospholipase as a Potential Anti-Bacterial Drug Revealed by Nonlinear Spectroscopy**

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Lipids play a fundamental role in diverse biological processes for energy storage, compartmentalization, and signaling, etc. In this respect, it is of great importance to understand the pathways and mechanisms of lipid metastasis triggered by phospholipase. Recently, it was found that the local enrichment of negatively charged lipids into biomembrane domains can lead to high activity of phospholipase A\(_2\) (PLA\(_2\)), suggesting a potential anti-bacterial application of PLA\(_2\) [1]. Here, we apply the 2\(^{nd}\)-order nonlinear optical spectroscopy – sum frequency generation vibrational spectroscopy [2] to investigate the hydrolysis process of model lipid biomembranes catalyzed by PLA\(_2\). Two types of phospholipases and two types of phospholipids were used including secretory human phospholipase A\(_2\) type IIA (PLA2-IIA), venom PLA\(_2\), 1,2-dipalmitoyl-sn-glycero-3-phospho-(1′-rac-glycerol) (sodium salt) (DPPG, negatively charged) and 1,2-dipalmitoyl-sn-glycero-3-phosphocholine (DPPC, neutraly charged). Nonlinear spectroscopic results indicate, compared to PLA\(_2\), PLA2-IIA can strongly bind to the negatively charged DPPG biomembrane with certain specific orientation and trigger the fast hydrolysis process, confirming its anti-bacterial function.


PS19.017 - Effects of interaction with electromagnetic field on cell culture of Saccharomyces cerevisiae

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Saccharomyces cerevisiae has been regarded as a convenient target for investigating effects of electromagnetic fields, such as cell proliferation, given that it has wide applicability in industry. At the same time, the relationship between cell growth and form culture could be an indicator of the conditions of their environment where it is growing. In this work, we studied the change in the rate of cell reproduction and changes in the pattern of growing of a cell culture of Saccharomyces cerevisiae when it’s stimulated magnetically. The magnetic field used for stimulation was generated with a Rodin coil in the range of approximately 1 to 4 mT, at frequencies of 60, 100, 800, 1500 and 2450 Hz. The yeast was grown in liquid medium YPD, and stimulated for 8 hrs. For frequencies of 60 and 800 Hz the cell culture was a decrease in the rate of cell proliferation, relative to the control sample. The frequencies of 100 and 1500 showed an increase in the rate of cell proliferation, while the stimulated sample to 2450 didn’t show a significant change. For the study about changes in the pattern of growth, it was performed a fractal analysis of the growing culture. Samples of Saccharomyces cerevisiae in YPD medium, was stimulated for 8 hours with the same Rodin coil at frequencies of 100, 800 and 1500 Hz. The observation was performed by a microscope and the fractal dimension analysis was performed during the first two hours after stimulation. The box counting method was used for the determination of the fractal dimension. The results suggest that there are no changes in the pattern of crop growth.

![Graph](image)

**Fig. 1** The parameter values extracted from the LP model are shown: a) phantoms with increasing stenosis ($R_{\text{sta}}$), changes are significant (***, p<0.001) for a severe (70%) stenosis, b) phantoms with decreasing compliance ($C_{\text{sta}}$), changes are significant (***, p<0.001).

PS19.018 - Obstructive and Sclerotic Disorders affecting Carotid Blood Flow to the Brain

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Stroke remains one of the leading causes of death in North America. A large number of strokes are a direct result of carotid artery disease. Physiological and pathological changes in the carotid artery can result in obstructive and sclerotic disorders. The internal carotid artery (ICA), one of the branches of the common carotid artery (CCA), is a major route for blood supply to the brain. Thus, obstructive changes such as stenosis due to plaque development can impede blood supply to the brain. Sclerotic changes associated with the hardening of the artery result in changes to the pressure and flow relationship thus reducing blood supply to the brain.

An experimental in vitro flow loop was employed in combination with a lumped parameter (LP) model to study changes in blood supply to the brain as a result of obstructive or sclerotic disorders of the carotid artery. An LP model is an electrical analogue to the experimental in vitro flow loop, consisting of a pump supplied with an idealized carotid artery waveform. A family of carotid artery phantoms with varying compliances and stenosis severity were used. Simultaneous pressure and volumetric flow-rate waveforms were measured using flowmeters (EP620/625, Carolina Medical Inc.) and a pressure catheter (SPR 350S, Millar Inc.). The pressure waveform is as an input to the LP model to generate a predicted flow-rate waveform, which is then matched to the measured flow-rate waveform by varying the LP model parameters.

An LP model, specifically designed to match an in vitro flow loop, was validated and parameter values were extracted for five different phantoms by matching waveforms. The increased resistance associated with the stenosis and the differences in the phantom compliances are shown in Fig. 1. Mean flow rates through the ICA were calculated using the experimentally measured flow-rate waveforms. Obstructive disease had minimal impact on mean flow-rate up to a certain threshold (70% stenosis) before it became significant (p<0.05). A decrease in compliance on the other hand had a significant effect on mean ICA flow-rate (p<0.05). While obstructive disease does not directly have a large impact on blood supply, it is still considered important due to its role in the development of thrombotic events.

PS19.019 - Estimation of Tissue Temperature in Tumor Hyperthermia Using Ultrasonic Methods

**Author(s):** Xiao-Jian Wang, Xiao-Hui Qiu

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Estimation of tissue temperature in Tumor Hyperthermia is an extremely important assurance of therapeutic safety. In all kinds of measuring methods, ultrasonic nondestructive techniques are the safest and the most promising one. The main ultrasonic methods of temperature measurement are based on ultrasonic echo signal,
acoustic transmission signal, the characteristic parameters of ultrasonic image, theoretical model simulation and so on. The theories of various ultrasonic methods adopted for measuring tissue temperature are introduced in this paper with their application, limitation and research status analyzed respectively.

**PS19.020 - Modeling of a Photosensitizer Distribution Relevant to Photodynamic Therapy of Malignant Non-Pigmented and Pigmented Tumors**

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Photodynamic therapy (PDT) is a branch of phototherapy and it is among many available methods used in clinical practice to treat cancer. PDT is approved procedure for treatment of many types of cancer such as esophageal, lung and skin cancer. Research investigation show that the PDT technique can also be effective against melanoma. Generally speaking, three crucial elements in the PDT must cooperate to cause therapeutic effect of PDT: photosensitizer (PS), oxygen (O₂) and light. The PDT’s therapeutic effect depends on many factors involved in the PDT: accumulation of PS and oxygen availability in the treatment region, absorption of light by PS (activation) and efficiency of production of cytotoxic reactive oxygen species (ROS), mainly singlet oxygen (¹O₂). The main mechanism of cell death occurs by photogenerated ¹O₂ that attacks important parts of the cells (membranes) causing oxidative damages and cells death. To make the PDT a more effective treatment modality, an appropriate dosimetry is required. Two main factors must be controlled: PS accumulation within target tissue and optical penetration depth of light used (photon density). Because many of PS are fluorophores, monitoring PS fluorescence play significant role in localizing of PS and quantifying its concentration within tissue. The optical parameters of tissues (absorption and scattering properties) significantly influence both the intensity and shape of PS fluorescence, because the intensities of fluorescence excitation as well as emission light are modulated by the tissue. Additionally, melanin present in pigmented tumors strongly absorbs light, and it modifies both the propagation of excitation light and the resulting fluorescence emission. The goal of the present work is to model fluorescence measurements used for determining the PS concentration in non-pigmented and pigmented tissue. Monte Carlo (MC) method was used to simulate propagation of photons (exciting PS and emitting by PS) within tissue. The influence of melanin tissue concentration on distribution of the excitation and the emission light was estimated. Optical properties of tissue used in simulations are based on reported values for normal and pigmented skin. Computational model of skin consists of seven layers. The simulations were done for PS from porphyrin family since these compounds emit light at near 650 nm.

Spatial distribution of the fluorescence excitation and emission were simulated as functions of the tissues’ optical properties. It was demonstrated that the model is able to predict the spatial distribution of the porphyrin type PS fluorescence excitation/emission pattern within skin and PS concentration. The results of MC simulations were compared with the experimental images of skin fluorescence textures.
BMEE02 - MEDICAL DEVICE DEVELOPMENT AND COMMERCIALIZATION

BMEE02.1 - Med-Tech Commercialization – A Research Hospital’s Perspective
Author(s):

How do you define ‘success’ of your med-tech research? Seeing a commercialized product on the market available for use in patients around the world is arguably the most relevant, impactful and satisfying end-point for anyone in this field. However, the med-tech commercialization process is far from being a ‘cookie-cutter’ approach. What works in one field, falls short in others. What works at one institution, isn’t optimal for others. What works for one technology, completely misses the mark for another. How one industry partner prefers to work, is not uniform across all partners. It is a dynamic environment requiring flexibility and optimization of the various factors. A research hospital’s view on this exciting area will dive deep into the dynamics through a series of actual start-up and licensing examples demonstrating some of the approaches that have been implemented at the University Health Network, Toronto. A brief intellectual property primer will also be included to provide the attendee with a functional understanding of what is needed to succeed in some of the most common commercialization scenarios. How do you define ‘success’?


CONTINUING EDUCATION

BMEE01 - GENERAL BME EDUCATION

BMEE01.1 - Biomaterials - Cell-Material Interactions: Biochemistry & Physics
Author(s): Dennis E. Discher
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Tissue cells and implants all interact with the innate immune system, especially phagocytes that try to ‘eat’ everything. However, ‘Self’ cells are spared, and it turns out that a polypeptide found on all cells marks cells (as well as engineered particles and surfaces as ‘Self’), limiting their phagocytic interactions in vitro and in vivo [Rodriguez Science 2013]. If an injected cell thus survives and if it has stem-like properties, the tissue microenvironment can in principle influence its differentiation. We have focused on how matrix elasticity can direct stem cell lineage, recognizing that tissues can be very soft like fat and brain, or increasingly stiff like striated muscle and rigid like bone [Engler Cell 2006]. Stem cells feel and respond to such elasticity differences together with soluble factors [Discher Science 2009], and we now find such signaling propagates all the way into the nucleus, which adjusts its mechanics to tissue stresses but also feeds back on gene expression [Swift Science 2013]. What unifies these mechanisms of interest in immune recognition and in matrix-regulated stem cell differentiation is a convergence of decision-making pathways on cytoskeletal force generation.


BMEE01.2 - Radiology 101: Intro to X-Ray tubes (manufacture & maintenance)
Author(s): Phillip Bogolub, Cindy Friesen
xxx, xxx/UNITED KINGDOM

Dunlee presents, “X-Ray 101 & Working Together”

The presentation will begin with where X-ray tubes are used. This entails a brief overview of the different types of tubes.
We will then move onto what a tube does and what the outcome is.
The next section goes into detail of how an X-Ray and CT tube is made which includes the manufacturing process, the different varieties as well as the tube design itself.
We will show the anatomy of a tube and the various parts and what the specific functions of those parts are.
We will then go into the operation of the tube and what types of failures can be experienced.
We will also discuss why preventative maintenance and training is important.
We will conclude with questions and answer section.
What does it really take to manage a Digital Network consisting of DICOM and PACS? The objective of my talk will answer this question. Many of you may have already been exposed to the words “DICOM” and “PACS”. Although these words are normally used together, they are very different in achieving the goals they were designed for. Both technologies can exist together as well separate from each other.

Our conversation will begin with a short talk on the beginning, and continued evolution of “DICOM” and “PACS”. We will have a look at Conformance Statements and how to effectively use them.

Our conversation will then continue with how to effectively manage a Digital Network containing both DICOM and PACS. Throughout my experience, I have had the pleasure in being a part of successful executions of Digital Network management and as well as being part of projects that had “lessons learned”. The management of a DICOM and PACS Digital Network is continued work in progress that starts with Planning phase and ends with Decommissioning of the product. The topics we will explore to get a richer sense of what it takes to manage such Networks are:

Planning and Integration
Workflow considerations
A typical DICOM and PACS Network
People/Education
Scalability
Support Process
Disaster Recovery
Business Administration Challenges

Many biomaterials currently in clinical use were originally developed for engineering applications and surface modification is thus needed for their biomedical applications. The biomaterials specifically designed and developed for certain medical application(s) may require another set of surface characteristics that are suitable for the material to be used in another clinical environment; or surface modification is required for enhancing the clinical performance of the biomaterial in its targeted application(s). What our body “sees” and deals with when an implant is placed in our body is the surface of the implant. Therefore, surface properties of materials or biomaterials are of paramount importance, which can determine the success or failure of a material for its intended biomedical applications. Different types of biomaterials – metals, polymers, ceramics and composites – are now used in various biomedical applications. As these substrates are drastically different from each other, different coatings and surface modification techniques are used for implantable metals, biopolymers, bioceramics and biomedical composites (porous composite scaffolds in particular in recent years). And coatings themselves can be polymeric, metallic, ceramic or even composite in nature. Polymer coatings are very attractive for the surface modification of biomaterials because they provide great versatility in chemical groups on the surface for controlling the cell-biomaterial interactions. They are relatively easy to form/produce, using simple techniques such as dip-coating or solvent casting. Coatings can also be made via chemical grafting of molecules onto the biomaterial surface. Techniques/structures such as self-assembled monolayers (SAMs) and layer-by-layer (LBL) assembly are extensively investigated in the biomedical field due to their distinctive advantages. For example, PEGylated SAMs are formed for controlling the surface interaction of biomaterials with proteins, and drugs are incorporated in LBL-formed polymer coatings for their controlled release in vivo.

In the area of metal implants, NiTi shape memory alloys (SMAs) becomes a focus of research because they possess unique properties of shape memory and superelasticity. However, metals are bioinert and NiTi SMAs cause concerns over their long-term biocompatibility due to toxic ion release. Investigations have been performed to use the plasma immersion ion implantation and deposition technique to modify the NiTi SMA surface, yielding encouraging mechanical and biological results. For tissue regeneration, tissue engineering scaffolds play a crucial role but scaffold alone is not sufficient for regenerating functional body tissues. Growth factors are needed for prompting specific cell behaviors and functions. Additive manufacturing technologies such as selective laser sintering (SLS) may not be able to produce growth factor-incorporated scaffolds directly, but SLS-formed polymer scaffolds can be surface modified for incorporating growth factors for their controlled release later. One example is SLS-formed PHBV scaffolds with the surface modification of heparin onto which rhBMP-2 is incorporated. These advanced scaffolds have exhibited enhanced ability for bone tissue regeneration in vivo. This lecture will (1) briefly review clinical requirements (mainly surface requirements) for biomedical materials, (2) give an overview of coatings and surface modification techniques for different types of substrates, and (3) present and discuss the performance of some surface-modified biomaterials and indicate future trends.
BMEE07 - BIOINFORMATICS, TELEMEDICINE AND HOSPITAL INFORMATION SYSTEMS

BMEE07.1 - E-medicine and Remote Medical Consultations
Author(s): Gilad Epstein
OTN (Ontario Telemedicine Network), Toronto/CANADA

Learning objectives

- Overview of current Telemedicine programs
- Trends in virtual care
- Technology trends enabling new models of care
- Telemedicine is growing in popularity and is moving from a pioneering stage into mainstream.
- Innovative models of care leveraging technology are creating new opportunities in the healthcare industry.

In this session we will review the current state of Telemedicine in Ontario, and provide insights to future virtual care trends and the impact on patients and providers.

BMEE05 - CLINICAL ENGINEERING/TECHNOLOGY MANAGEMENT

BMEE05.1 - Introduction to Medical Technology Management (Clinical Engineering Practice)
Author(s): Saide Calil¹, Anthony Chan²
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The term “Management of Medical Technology” is widely used today but not many people really know its range. Some limit “Management” to maintenance services and consider only preventive maintenance and repair activities; some add other activities, such as technical training and quality control. The fact is many other activities can be added to “Medical Technology Management”, including risk management, cost assessment and control, equipment procurement, installation, discarding, and reporting to the hospital managers. The proposal here is to present and discuss:

1 – What activities are performed today by Clinical Engineers within what is called Management of Medical Technology?

2 – Which of these activities are really part of Management of Technology and which ones can be transferred to other subject such as: Financial Management

3 – Define what kind of knowledge is necessary for Technology Management to guide training courses on Clinical Engineering.
BMEE08 - GENERAL BME EDUCATION

BMEE08.1 - Biomechanics - Implant design
Author(s): Cheng-Kung Cheng
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Biomechanics - Implant Design

In order to reasonably assure the implant’s safety and effectiveness, the two major concerns of medical devices, computational models and biomechanical tests are conducted in the design phase. The computational models, including finite element model and kinematic model, are usually performed firstly because it is relative cost efficiency and easy to modify design parameters. In addition, using these models can quickly estimate the stress and strain distribution or kinematic performance of the implant. The biomechanical tests then take steps in to simulate the performance of implants under real-live mimic loading by following the ASTM and ISO standards. The research outcomes of the implants are essential for premarketing approval.

Although most of the orthopedic implants were initially developed in Europe and North America, the substantial differences between Asian and Western population should be considered for implant designs nowadays. Not only the bone quality, size, and geometry differences but also the epidemiology of disease and lifestyle can greatly affect the design concept. For example, the high prevalence of avascular necrosis of femoral in Asia leads to total hip arthroplasty while osteoarthritis in Western is the top indication of total hip arthroplasty. Furthermore, demands of high flexion is much more important for Asian patients after total knee arthroplasty for achieving activities like prayers kneeling, cross-legged sitting, and Japanese proper sitting. Therefore, understanding the discrepancies among different populations is beneficial in unique implant design to the target market.

Customized implant has become another growing category of implant design with the development of novel technology, which resolves the difficulties of manufacturing in the past and lowers the cost of production. The revolutionary 3D printing with metal material has elevated implant design from prototyping to practical scenario.

BMEE09 - BIOINFORMATICS, TELEMEDICINE AND HOSPITAL INFORMATION SYSTEMS

BMEE09.1 - Medical Device Network Connectivity
Author(s): Ryan Forde
Research And Development, Drager, Andover/UNITED STATES OF AMERICA

Medical device networks are becoming nearly ubiquitous in the developed world. These networks allow medical devices to share information with other devices, archive and store information for later access and warn caregivers about potentially hazardous situations before they occur. This talk will focus on patient monitoring networks and how they relate to hospital Information Technology networks and discuss some of the challenges of integrating the two. We will cover different communication technologies and when each might be used. Finally we will discuss some of the current efforts to create a standards landscape that will allow medical devices to interoperate and improve care for patients.

At the conclusion of the program, attendees will be able to:

1- Describe different communication protocols used by medical devices and explain what each might be used for.

2- Understand how patient monitoring networks can work with hospital IT networks and what some of the advantages, and challenges of connecting the two might be.

3- Understand the basic reasons why standardized medical device interoperability is important and how we might get there.
ABSTRACT

Multiscale Biomechanics in Deep Tissue Injury

BMEE10.1 - Arthur F. Mak
Division Of Biomedical Engineering, The Chinese University of Hong Kong, Shatin/HONG KONG

LEARNING OBJECTIVES

1) Acquire a basic understanding of the problem of deep tissue pressure ulcers;
2) Review the recent literatures on in-vivo and in-vitro studies related to deep tissue injuries
3) Learn how computational biomechanics can be applied to study the formation of deep tissue injuries and their propagation to become clinical ulcers

ABSTRACT

Damages occur when cells and tissues are subject to excessive physical stresses. Such damage thresholds depend on the exposure duration of these physical forces. Deep tissue injury due to prolonged excessive skin/skeletal loadings can lead to clinical pressure ulcers, affecting millions of persons with physical disability. In this short course, we will review recent literatures on (1) the transmission of skin/skeletal loadings to muscle tissues around bony prominences, (2) how mechanical stresses at tissue level invoke cellular damages, (3) the involvements of the vascular and lymphatic systems, (4) the effects of post-ischemic oxidative reperfusion might affect the load-carrying capacity of the involved tissues and their sub-cellular and molecular mechanisms, and (5) how damages in the deep muscles can propagate towards the skin, resulting in a clinical through-thickness ulcer. Relevant In-vitro, in-vivo, and in-silico studies will be summarized.

The application, knowledge and science of certification engineering and test for the evolving family of 60601 standards is now crossing the boundaries into the other 2 parts of the medical device regulatory processes – clinical and quality systems. All 3 processes have their separate requirements and roles in Regulatory approvals for sure. However, the trend is that a holistic approach in understanding all of the processes in the refinement and application of standards has the great ability to safely fast track innovation, advance safety and open global markets for med tech companies here and abroad.

A few of the substantial developments in the 60601 standards will be examined to illustrate the trend of evolving standards to improve safety and ultimately enabling better and safer patient care. For example, one of the most significant and challenging changes in 60601 standards is the use of the Risk Management process to facilitate rapid technology developments and clinical feature benefits. This is a knowledge area steeped in clinical applications and engineering, risk assessment, process design, and quality management.

Understanding these trends can enable healthcare and clinical engineering professionals to better to gage the safety and limitations that new medical technology will bring into their already sophisticated and evolving care environments.
BMEE11.2 - Quantitative Musculoskeletal Ultrasound

Author(s): Yong-Ping Zheng
Interdisciplinary Division Of Biomedical Engineering, The Hong Kong Polytechnic University, Hong Kong/CHINA

Learning Objectives:

1. To understand methods and applications of ultrasound elasticity measurement and imaging for musculoskeletal soft tissues
2. To understand what is sonomyography and its applications
3. To learn how to use 3D ultrasound imaging for musculoskeletal assessment, particularly for spinal deformity

This talk will introduce three different approaches for quantitative musculoskeletal assessment using ultrasound. Ultrasound imaging has been widely used for musculoskeletal tissue assessment, but mainly qualitatively and subjectively by operators. Only some simple parameters such as length and area may be obtained for static ultrasound images. Musculoskeletal ultrasound has been rapidly developed recently due to the reduced size and cost of ultrasound scanner, and a number of quantitative musculoskeletal ultrasound approaches have also been developed.

Elasticity and viscoelasticity of different musculoskeletal soft tissue plays a very important role in muscle contraction, motion, force transfer and load bearing. The change of elasticity may be associated with different diseases, such as osteoarthritis (cartilage tissues), spasticity and atrophy (muscle), diabetic foot (plantar tissue). Furthermore, muscle may changes its elasticity during contraction, making it a useful parameter to indicate muscle quality. Muscle elasticity cannot be measured but also imaged, thus it can be used to for diagnose some local tissue problems. In this study, different methods for the measurement and imaging of tissue elasticity will be introduced, including ultrasound indentation, acoustic radiation force impulse, supersonic shearwave imaging, etc. Applications for muscle, tendon, and articular cartilage assessment will be introduced.

The second quantitative musculoskeletal ultrasound method to be introduced is developed for muscle assessment, named as sonomyography (SMG), in relation to its counterpart electromyography (EMG). SMG is derived from real-time ultrasound images and represents the architectural changes of muscle during contraction. The architectural parameters include muscle thickness, cross-sectional area, pennation angle, fascicle length, etc. They are detected automatically from real-time ultrasound images continuously thus forming signals, which can then be used for muscle functional assessment as well as for control. In this talk, the development of this area will be introduced together with recent achievements by different groups.

3D ultrasound imaging has been commonly used for fetus assessment. The third topic is to introduce how to use 3D ultrasound imaging for quantitative musculoskeletal assessment, including how an 3D ultrasound image is form formed. The focus will be on the recent development of using 3D ultrasound for radiation-free assessment of spinal deformity, such as scoliosis. It has been demonstrated that 3D ultrasound is feasible to measure the spine curvature for scoliosis patient, including the lateral deformity as well as spinal rotation. 3D ultrasound imaging shows a promising future for scoliosis screening, monitoring for curve progression and assessment for treatment outcome. The potential applications of this new quantitative musculoskeletal ultrasound technique will be discussed.
Learning Objectives:

1) The attendee will be able to explain the need for certification of Biomedical Engineering Technologists (BMETs) and describe the basic steps involved to become certified in Canada.

2) The attendee will be able to explain the need for certification of clinical engineers (CEs) and describe the basic steps involved to become certified in the United States and Canada.

3) The attendee will be able to discuss the status of certification nationally and internationally.

BMEE12 - CLINICAL ENGINEERING/TECHNOLOGY MANAGEMENT

BMEE12.1 - Clinical Engineers & Biomedical Engineering Technologists Certification - International Perspective

Author(s): Larry Boyce¹, Petr Kresta²

¹Clinical Technology Management, Sodexo Canada, Woodstock/CANADA; ²Clinical Engineering, Winnipeg Regional Health Authority, Winnipeg/CANADA

Certification of Biomedical Engineering Technologists and Clinical Engineers – International Perspectives

Abstract

The session addresses contemporary issues in the certification of clinical engineers and biomedical engineering technologists through presentations and panel discussion with audience participation.

The need for certification of Biomedical Engineering Technologists and Technicians (BMET) is examined after 33 years of operating the Canadian Board of Examiners under the International Certification Commission (ICC). In that time little has changed, certification remains voluntary while a license to cut hair is mandatory in the province of Ontario. Currently in Canada there is no law or regulation that prevents the “talented maintenance mechanic” from maintaining medical equipment. The fundamental question is, “Is the public protected?” The current Canadian process is reviewed in an attempt to determine if it is working well enough to ensure that the public is protected. Should BMET certification be voluntary or mandatory? What are other countries doing?

The dissolution of the International Certification Commission in favour of the newly formed AAMI Credentials Institute (ACI) eliminated the International component of certification. Why this happened, the impact on technologists and the future of certification is examined?

Certification in Clinical Engineering is examined in several jurisdictions globally including the United States, Canada, and China. Responsibility for the Certification in Clinical Engineer program in the US and Canada shifted recently from the Healthcare Technology Foundation to the American College of Clinical Engineering. The current structure and status of the Certification Program is reviewed. The emergence of new clinical engineering related certification programs sponsored by the AAMI Credentials Institute, is examined and their potential impact discussed.

Clinical Engineering Division of the International Federation for Medical and Biological Engineering (CED/IFMBE) has been working for several years on a project looking at developing an international umbrella under the CED/IFMBE for the programs of certification in clinical engineering (CCE). Since the latest International Standard Classification of Occupations of the International Labor Organization explicitly considers biomedical/clinical engineers (CE) as an integral part of the health work force, it stands to reason that formal career paths of CE should be demanding similar, if not the same, as career paths of other health professionals with commensurate duration and level of university education.

The objective of this paper is to present current project status and activities, together with the proposal for CCE from the CED/IFMBE perspective. The CED/IFMBE, in cooperation with other interested parties, advocates the regulation of the CE profession and is currently establishing the mechanisms and structures for the CCE. IFMBE should ask all national governments to adopt and follow this model.
BMEE13 - CLINICAL ENGINEERING


Author(s): Michael Cheng¹, Saleh Altayyar², Hal Hilfi³, Julie Polisena⁴
¹Biomedical Engineering, Ottawa/ON/CANADA, ²King Saud University, Riyadh/SAUDI ARABIA, ³Biomedical Engineering, Ottawa/ON/CANADA, ⁴Canadian Agency for Drugs and Technologies in Health, Ottawa/CANADA

The stated purpose of medical device regulations is to ensure the safety and performance of medical devices. However, many health care professionals and users of medical devices may not know the scope and limitations of medical device regulations; often they have unrealistic expectations about the device regulators' ability to protect public health. While literature and guidelines on medical devices abound, they were written in different contexts by different medical device groups employing diverse terminologies. For a policy-maker or a health care worker, the task of navigating and digesting enormous amount of information becomes very difficult.

This session will present a simple, three-stage framework summarizing three essential steps (regulation, contextualized assessment, operation management) and the key elements in each step to ensure the ultimate patient safety and optimal performance for any medical device. This three-stage framework, which also reflects World Health Assembly Resolution WHA60.29, is useful for medical device policy and management planning; it can serve as a common reference framework among stakeholders for education, communication, and collaboration. Its components can be linked to all levels of activities in the lifespan of a medical device. Guidance on how to execute these three steps is available in the worldwide literature; one can search for details without losing the “big-picture” relevance, and then choose the right tools appropriate to one’s situation.

An insight from this framework is that, at present, medical device regulation, assessment, and management professionals tend to work in isolated groups; but the framework suggests a system with interconnecting components, through which there could be well-designed, functional interaction and collaborative activities among groups to enhance effective and efficient outcomes. Participants are encouraged to brainstorm on improving this situation.

At the conclusion of this presentation, attendees will be able to

1. know the unique difference between medical devices and drugs
2. clarify the differences between the general regulatory statement of “safety and Performance” and the ultimate healthcare objective of “patient safety and optimal performance” of medical devices
3. first do no harm.....identify the three essential steps to ensure patient safety with medical devices
4. expand the same three stages to include health technology assessment (HTA) and health technology acquisition and management (HTM) for optimal performance
5. know the basics of medical device regulations (HTR) and the essential elements for managing medical devices (HTM) (good management practices) in a healthcare facility
6. relate the widely available literature on medical devices to components of the big-picture holistic framework
7. use this simple three-stage as common framework to educate, communicate and collaborate with all stakeholders including the non-technical public as well as other healthcare professionals including the decision makers
8. hear the personal viewpoints on the importance of a holistic approach to medical device safety from the former Chair of the Asian Harmonization Working Party (http://www.AHWP.info , a medical device regulators’ forum of 24 countries/economies in Asia, Africa and South America).
9. your turn: questions, comments, suggestions
10. take home challenges in enhancing the outcome of medical device utilization in your local environments.
Prosthesis technology, such as dexterous upper limb, has advanced greatly in sophistication. Not only are the motor mechanisms advanced, capable of extensive dexterous manipulation, but the more advanced prostheses also possessing sensors for feedback. However, controlling the prostheses remains a significant challenge. Here the need and the challenge is the neural interface, whether to the peripheral or the central nervous system, and deriving or providing the information for motor control and sensory feedback respectively. This talk will present the current state of the art of neural interface for dexterous upper limb prosthesis and how neural control may be achieved. Neural interface technology may be noninvasive or invasive, and utilizes micro to macro electrodes for signal acquisition, and decodes spiking information from neurons and cortical rhythms from brain surface or the scalp. Sophisticated decoding of neural population and signal processing of EEG and Electrocor ticogram can derive information needed to control dexterous movement of the prosthesis. However, sensory information is not as readily relayed to the nerves or the brain and thus sensory prosthesis are not yet as advanced. Biologically inspired tactile sensors that take into consideration receptors and the nerve code may help achieve suitable sensory feedback via microstimulation of nerves or the brain of the amputee. Future research and development will achieve suitable sensory feedback via microstimulation of nerves that take into consideration receptors and the nerve code may help.

Biomechanical factors extensively participate the life activity of living organism. Mechanical environment involves the proliferation, differentiation and apoptosis of the cell, the growth and remodeling of the tissue, and the coordination of different physiological systems. Mechanical factors also play critical roles in the diseases and therapies. For example, wall shear stress participates the formation of atheromatous plaques; post-operative stress distribution affects the outcome of interventional surgery. The integration of biomechanics and microbiology has become the indispensable parts in the fields of physiology and medicine.
Computational simulation has been an important method for biomechanical investigation. Computational method can anticipate the irregular and complicated biological structure, predict and analyze the responses under extreme conditions. Despite that the simulations must follow by experimental validation and computational verification to ensure accuracy. We have conducted series of computational investigation in the areas of orthopedics, orthodontics, and injury prevention. These include:

1. The protective mechanism of woodpecker’s head for absorbing impacts was discovered. The special functions of beak and hyoid provided bionic insight in protective designs. (2) The finite element eyeball was simulated with an injury process, revealing the mechanism of amotio retinae. (3) Significant achievements on different orthopedic research and clinical application were also obtained, such as knee, cervical spine, wrist, fetal head, ankle, and osteoadaptation in space.

Computational technology has advanced the biomechanical researches in physiology and medicine. With the development of the computer technology and numerical algorithm, computational technology will continue to promote the interdiscipliinary and multiscale studies in biomechanics and mechanobiology.

Acknowledgment

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ABSTRACTS | IUPESM 2015 WORLD CONGRESS ON MEDICAL PHYSICS & BIOMEDICAL ENGINEERING

BMEE17 - MEDICAL DEVICE DEVELOPMENT AND COMMERCIALIZATION

BMEE17.1 - Technology Commercialization - Road Map and Precautions
Author(s):

This lecture will discuss the process of technology commercialization and provide cautionary advice to entrepreneurial scientists and engineers in bioengineering and medical physics. Technology commercialization begins by making sure scientists and engineers are aware of the opportunities afforded by commercialization and the requirement to have the intellectual property (IP) properly secured. Disclosing an invention or a trade secret in a public talk invalidates IP rights. Industrial contracts must carefully spell out the IP rights. University technology transfer offices only file patents that have a high likelihood of licensing. Existing corporations typically license technology with high reward and low risk. Startup companies are left with higher risk technology. The startup process is fraught with difficulties related to lack of skill of founders, inadequate governmental and investment funding, poor choice of corporate partners, and affordable experienced management. Offering the right product at the right time with excellent development, operations, marketing, sales, and service are the key factors to the success of startup companies.

BMEE18 - GENERAL BME EDUCATION

BMEE18.1 - BioMEMS - Microsensors; Microactuators; Microfluidics; Micro-Total Analysis Systems (e.g., Genomics and Proteomics)
Author(s): David Weitz
Physics & Seas, Harvard University, Cambridge/MA/UNITED STATES OF AMERICA

This talk will describe the use of drop-based microfluidics to perform very large numbers of experiments using small, picoliter-sized drops in an inert carrier fluid. This technology enables many new classes of experiments and applications. Both the underlying science and the applications will be described.
BMEE19 - BME TECHNICAL/SERVICE COURSES

BMEE19.1 - Rechargeable Batteries: Characteristics, Performance, and Maintenance
Author(s): Isidor Buchmann
Cadex, Richmond/CANADA

Topic As the reliance on the battery grows, so does the need for robust battery management standards and practices in healthcare. This is not happening uniformly and the Association for the Advancement of Medical Instrumentation (AAMI) rated battery management as one of the top 10 challenges for hospital’s biomedical departments. An US FDA survey says that “up to 50% of issues in hospitals are related to the battery.”

At a debriefing with the FDA at their Maryland HQ at which Mr. Buchmann participated, three shortcomings were identified with batteries in medical devices. Each of these will be discussed at the IUPESM World Congress, and are:

1. Deficiency in quality assurance in batteries by device manufacturers
2. Lack of understanding in battery system integration
3. Not knowing the end of battery life

Presentation Equipment manufacturers base the runtime of a device on a new battery, but this is a temporary state. Once rubber-stamped and approved by the authorities, the users are on their own. Little guidance is provided to assure continued performance and hints as to when to replace the battery.

A battery has a relatively short service life and will require several replacements during the life of the host device. Batteries are difficult to test and often escape the scrutiny of inspection. To assure reliability, a battery must be treated like any other serviceable part in a medical device.

When asking users of a battery-operated medical devices, “When should the battery be replaced?” no clear answers are given. Without a strategic management plan, a battery may stay in service too long, compromising reliability, but most are changed too early, increasing operational cost and stressing the environment.

Mr. Buchmann will give an overview of basic battery technology, discuss typical behaviors in healthcare, how their life can be optimized, pros and cons of a smart battery, when a battery should be replaced, and methods of analyzing batteries as part of maintenance systems.

Presenter Isidor Buchmann is the founder and CEO of Cadex Electronics Inc. and author of www.BatteryUniversity.com. For three decades, Buchmann has studied the behavior of rechargeable batteries in practical, everyday applications, has written award-winning articles including the best-selling book “Batteries in a Portable World,” now in its third edition.

Company Cadex Electronics specializes in the design and manufacture of battery chargers and analyzers, as well as advanced rapid-test and monitoring systems. Sold in over 100 countries, Cadex products are known for their robust design, reliable service and long product life. During the 30 years of operations, Cadex has secured several patents in the field of battery diagnostics and monitoring.

Battery University www.BatteryUniversity.com is an education website that addresses strengths and limitations of batteries in the hands of the everyday user. The papers evaluate different battery types and offer the best choice for an application. The information offers busy professionals a crash course on batteries; it helps engineers find a battery for a new product; students seeking answers for an academic project; and the everyday battery users wanting to prolong battery life.
2. Identify effective strategies for alarm management.  
3. Discuss attitudes and practices related to clinical alarms as revealed in the Healthcare Technology Foundation’s national surveys.

**Background**

The use of an instantaneous attention-getting feature, like an alarm, to improve management of a patient’s health condition has been used for many years. Alarm systems, ranging from simple alerts to complex alarm systems, are found on many medical devices. Alarms are intended to protect patients, however, they also contribute to noise, error, and the phenomenon of “alarm fatigue”, which can lead to adverse events.

Alarm fatigue results from staff being overwhelmed by a cacophony of non-actionable alarms, leading to a delayed response to the actionable alarms or to alarms being ignored or turned off. A high percentage of alarms are not actionable – they do not lead to changes in patient management.

Due to significant adverse events related to clinical alarms, the Healthcare Technology Foundation (HTF) began an initiative in 2004 to improve the management of alarms. A task force of clinical engineering professionals wrote a seminal white paper in 2007 summarizing the literature, adverse event data, and a national survey of 1,327 healthcare staff, which included observations and recommended improvements.

Between 2005 and 2009, the Food and Drug Administration received 566 reports of deaths related to alarms - over 100 deaths each year. The devices associated with the highest number of deaths were physiologic monitors and ventilators.

In 2011, the HTF administered a second national survey, to which 4,278 clinicians responded. The results of this survey were presented to the attendees at the 2011 AAMI Clinical Alarms Summit and distributed nationally. Little progress in alarm hazard reduction was found between the two surveys, with false alarms still comprising the most serious issue related to alarms. Almost 20% of the respondents reported that adverse events occurred in their hospital in the prior 2 years.

The ECRI Institute, an independent, non-profit health technology safety organization, identified alarm hazards as the #1 Health Technology Hazard for the past 4 years.

Effective January 1, 2014, the Joint Commission issued a National Patient Safety Goal (NPSG.06.01.01) requiring hospitals to establish alarm management as an organizational priority. Accordingly, organizations must design a systematic and coordinated approach to better manage this important safety issue. Policies, procedures, and education related to alarms will be required beginning in 2016.

**Deliverables**

This session will address quantitative and qualitative findings from the HTF alarm surveys. Results showed the impact of clinical alarms on patient safety, clinical perceptions of alarms, and alarm improvement efforts. Results of roundtables held at the 2015 AAMI annual meeting will be presented, along with current HTF activities, such as the development of an “Alarms 101” document for patients and families.

Care providers’ views of the issues and best practices for meeting patient management goals and the Joint Commission NPSG.06.01.01 will be discussed, including a case study. Also, the development of unique educational tools, including online clinical alarms orientation and training, will be covered.

**Objectives**

1. Describe the problem of alarm fatigue and its impact on patient safety.
BMEE21 - GENERAL BME EDUCATION

BMEE21.1 - Biomaterials - Cell-surface Interaction

Author(s): Caroline Loy, Diego Mantovani
Lab Biomaterials And Bioengineering, Laval University, A/QC/CANADA

Cell-Materials Interactions for the Replacement and the Regeneration of Tissue and Organs

Caroline Loy and Diego Mantovani
Canada Research Chair I for Biomaterials and Bioengineering for the Innovation in Surgery, Dept of Min-Met-Materials Engineering & Research Center, University Hospital Center, Laval University, Québec City, Canada

Over the last 50 years, biomaterials, prostheses and implants saved and prolonged the life of millions of humans around the globe. The main clinical complications for current biomaterials and artificial organs still reside in an interfacial mismatch between the synthetic surface and the natural living tissue surrounding it. Today, nanotechnology, nanomaterials and surface modifications provide a new insight to the current problem of biomaterial complications, and even allows us to envisage strategies for the organ shortage. Advanced tools and new paths towards the development of functional solutions for cardiovascular clinical applications are now available.

In this CE program, we are therefore proposing to present and discuss with English, French and Spanish speakers the past, present and future challenges of cell-material interactions. At the conclusion of this program, attendees will be able to:

1. Describe and discuss the principles of the host-response that any foreigner body generate when in contact with human cells and tissues;

2. Define and determine how to assess and predict in vitro the cell-materials interactions in the cardiac, vascular, neurological and orthopedic system, including those generated and the bone and blood interface;

3. Demistify the myth of the bionic man, and understand how diseased tissue and organs can be replaced, reconstructed or are envisaged to be regenerated.

BMEE21.2 - Biomaterials - Plasma Medicine

Author(s): David B. Graves¹, Michael Keidar²
¹Chemical And Biomolecular Engineering, University of California at Berkeley, Berkeley, CA/CA/UNITED STATES OF AMERICA, ²The George Washington University, Washington/UNITED STATES OF AMERICA

A new field of cold atmospheric plasma (CAP) processing associated with biomedicine has emerged in the last 5-10 years. [1] CAP can be used to shrink tumors, promote wound healing and sterilization, and treat dermatological and dental disease, among other things. This presentation will focus on the role of reactive oxygen species (ROS) and reactive nitrogen species (RNS). ROS and RNS (or RONS), in addition to a suite of other radical and non-radical reactive species, are essential actors in an important sub-field of aerobic biology termed ‘redox’ (or oxidation-reduction) biology. Evidence will be presented that RONS generated by plasmas are probably responsible for much their observed therapeutic effects. [2,3]

At the conclusion of the CE program, attendees will be able to:

1. Describe and discuss the emerging field of cold atmospheric plasma biomedicine.

2. Understand some of the physical and chemical characteristics of the plasma sources as well as typical tools used by plasma scientists to measure and compute key quantities.

3. Recognize some of the emerging connections between reactive species in aerobic biology and the therapeutic mechanisms of CAP.


**BMEE22 - GENERAL BME EDUCATION**

**BMEE22.1 - Biosensors and Signal Processing - Signal Analysis and Processing**

**Author(s):** Sri Krishnan

Electrical And Computer Engineering, Ryerson University, Toronto/Canada

**Abstract:**

In this talk the characteristics of biomedical (physiological) signals will be covered followed by the techniques and algorithms needed for processing, analysis and interpretation of these signals. Time-domain, frequency-domain, joint time and frequency domain, and sparse domain approaches will be covered in detail for applications related to body sounds’ signals, ECG, EMG and gait rhythm.

**Learning objectives:**

1) design of biomedical signal analysis system

2) interpretation and quantification of biomedical signals for various applications related to health ICT and emerging mobile health applications

3) algorithms for processing of biomedical signals

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**BMEE22.2 - Cellular and Biomolecular Engineering - Nanoparticles in Diagnostic Therapy**

**Author(s):** Mukesh Harisinghani

Radiology, Massachusetts General Hospital, Boston/MA/UNITED STATES OF AMERICA

Magnetic nanoparticles have been used for imaging oncologic and immune disorders as they provide a means of assessing macrophage activity. Conventional imaging in these areas is limited to anatomical depiction of abnormality, the use of magnetic nanoparticles provides the functional component and has been a poster child for bench to bedside application.

At the conclusion of the proposed program, attendees will be able to:

1. Understand the mechanism by which magnetic nanoparticles provide functional information on MRI

2. Understand the clinical utility of imaging with nanoparticles and how it could profoundly influence patient care

3. Understand what some of the technical challenges are when imaging with magnetic nanoparticles

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**BMEE23 - CLINICAL ENGINEERING/TECHNOLOGY MANAGEMENT**

**BMEE23.1 - Clinical Engineering Standards of Practice – Canadian New Edition and Other Countries**

**Author(s):** Anthony Chan¹, Bill Gentles²

¹Biomedical Engineering, British Columbia Institute of Technology, Burnaby/CANADA, ²Vice President, BT Medical Technology Consulting, Toronto/CANADA

**Learning Objectives:** At the conclusion of this session program, attendees will:

Understand the process of developing a Standard of Practice that is appropriate for their particular healthcare environment.

Understand the value of the discussions that take place during the development of a standard of practice.

Understand the main sections to include in a standard that is written to conform to ISO guidelines.

Understand how a standard of practice can be used as the basis of a peer review or accreditation process for Clinical Engineering services.

**Abstract**

Clinical engineering is one of several professional disciplines contributing to safe, effective and economical health care. The role and primary responsibility of a clinical engineering service is management of medical device technology, including adherence to recognized safety, quality, cost and efficiency standards.

The first Clinical Engineering Standards of Practice (CESOP) for Canada was published in 1998. The CESOP has since gone through 2 revisions, with the latest being published in 2014. Each revision was developed by a working group with broad representation from across the country. The working group for the 2014 revision met on a monthly basis for over a year, and produced 17 drafts before the final draft was presented to the membership for approval.

The CESOP is widely adopted by clinical engineering departments across Canada to establish scopes and practice; referenced by health care accreditation bodies; and used to formulate evaluation guidelines in peer review process.

Examples of standards of practice from other countries will be presented and compared to the Canadian standard.

**BMEE23.2 - Emerging Medical Technologies - What to Expect, How to Prepare for it**

**Author(s):**

Medical technologies are evolving at a rapid pace. This change is significantly impacting how healthcare organizations and their technology managers should plan for, procure, support, and update their technologies. This presentation will review new and emerging technologies that are expected to have the most impact on the healthcare technology management profession. It will also discuss the operational and mindset changes that healthcare technology management professionals must make to best prepare for their emerging and future roles. This discussion will include a review of the processes used by ECRI to assess and make judgments about new and emerging technologies with commentary on how these processes can be applied at healthcare organizations.

At the conclusion of this program attendees will be able to:
1. Describe important new and emerging trends in healthcare technologies
2. Discuss key operational changes that healthcare technology management programs should be making to prepare for new and emerging medical technologies
3. Develop a methodology for evaluating and planning for new and emerging medical technologies

BMEE24 - MEDICAL DEVICE DEVELOPMENT AND COMMERCIALIZATION

BMEE24.1 - The Product Development Cycle
Author(s): Lahav Gil
Ceo, Kangaroo Group, Toronto/CANADA

Learning objectives:

1. Understand the nomenclature of medical devices product development and how it correlates with the (business) language of commercialization of a medtech company
2. Understand the key steps of development that a clinical technology goes through, from technology-transfer all the way to commercial grade, validated and approved medical device, based on the FDA recommendations for product realization
3. Understand how to assess and evaluate technology rediness, and where it currently is on the product development map

Abstract:

The presentation will provide a clear map and the milestones of medical devices product development starting with requirements gathering and product definition and ending with a validated medical device ready to ship. We will cover each step and explain the content of the inputs and outputs along the progress path.

Some of the topics that will be covered, amongst others are: Business justification, requirements gathering and needs assessment, stakeholders analysis and value drivers, feasibility studies, user feedback, system SPECs and architecture, different kinds of prototypes, alpha prototype, preproduction build, design controls, serial manufacturing, V&V, DHF, DMR, DHR, NPI, ISO 13485 QMS, traceability matrix, labeling, change controls
BMEE25 - CLINICAL ENGINEERING/TECHNOLOGY MANAGEMENT

BMEE25.1 - Clinical Engineering Best Practice and Benchmarking

Author(s): Binseng Wang
Quality & Regulatory Affairs, Sundance Enterprises, Inc., White Plains/UNITED STATES OF AMERICA

While debated for over 30 years, productivity and efficiency (cost) measurements and benchmarking continue to be a challenging topic for the clinical engineering (CE) community. At the core of this challenge is the lack of reliable indicators substantiated by actual data. An attempt was made to evaluate some traditional and newer indicators using data collected from two distinct sources in the USA, each with >150 hospitals. Results confirm early concerns that worked hours self-entered by CE staff are subject to misuse and, thus, should be avoided as a productivity benchmark. Likewise, the cost-of-service ratio (COSR) is easily manipulated and, thus, not reliable as an efficiency benchmark. In contrast, good statistical correlation was found for both staffing and cost data with several hospital indicators that are consistently collected for reimbursement and financial reporting purposes. Good correlation with CE department indicators was more difficult to find, apparently due to the lack of reliable records and consistent accounting of all CE resources and expenditures. While no single, easy to measure and understand indicators emerged as replacements for the worked-to-paid-hours ratio and COSR, it was possible to build multi-dimensional models for both productivity and cost efficiency. However, these models, while accurate, are not precise, so the results need to be interpreted carefully. Furthermore, anecdotal data obtained from other countries showed that there are substantial differences in both staffing and efficiency metrics, even though there are numerous similarities in technical metrics. In essence, benchmarking of staffing and cost can be good starting points for a more detailed analysis of the differences among organizations that could reveal substantive causes such as service scope and strategy, organizational characteristics and geographical challenges as well as opportunities for major productivity improvements and cost reductions.

BMEE26 - CLINICAL ENGINEERING

BMEE26.1 - Collaboration on Healthcare Technology Decision-Making

Author(s): Julie Polisena1, Hal Hill2, Michael Cheng3
1Canadian Agency for Drugs and Technologies in Health, Ottawa/ON/CANADA, 2Biomedical Engineering, Ottawa/ON/CANADA, 3xxx, xxx/UNITED KINGDOM

This education session will discuss two types of collaboration on healthcare technology decision making, both of which emphasize a multidisciplinary approach. Firstly, we will briefly describe a simple checklist that guides the routine assessment of any request for the purchase of medical devices in a healthcare facility. Secondly, we will outline the application of formal HTA (health technology assessment) to support informed decision making for new technologies, a large scale technology acquisition and/or complex technologies. We shall devote a major part of this presentation to describe the collaboration of hospital-based HTA network to support informed healthcare technology decision making.

HTA is a form of analysis on health technologies that provides decision makers with information on their clinical effectiveness, safety, cost-effectiveness, and encompasses patient preferences, and ethical, societal, organizational and other considerations. It is a principle component of the holistic framework, (presented yesterday) to enhance the optimal performance associated with the use of medical devices. More specifically, we will elaborate on how HTA in a network of healthcare providers can assist in making decisions on the purchase, use and discontinued use of medical devices in their institution. In addition, we describe how local HTA units can collaborate to facilitate information sharing, avoid unnecessary duplication of effort, and provide equal access to timely evidence-based information to decision makers. This network of HTA producers would allow their work to contribute fully to ensure the sustainability at all levels of healthcare.

Many jurisdictions continue to face hospital budget cuts that force them to look at innovative ways to address these shortfalls, while still managing health care technologies. HTA at the hospital and regional levels is gaining recognition and importance in many parts of Canada and Europe given its potential for greater impact on hospital policies and clinical practice by involving the end-users in the assessment and decision-making. More could be achieved through effective collaboration or networking to combine efforts and experiences.

At the end of this education session, attendees will be able to:

1- learn more details of the Stage 2 (assessment function) of the Holistic Framework for Medical Devices presented yesterday (11 June 2015)

2 appreciate how multidisciplinary collaborations in healthcare technology decision making are crucial in contributing to the safety, quality, and sustainability at all levels of healthcare.

3- use a checklist to guide routine assessment on simple requests for the purchase of medical devices in a healthcare facility

4 understand how HTA for more complex cases can enhance the optimal performance on the use of medical devices

5- understand how an HTA collaborating network can facilitate information sharing on purchasing, implementing, managing, and decommissioning of medical devices.
BMEF01 - GESTION EN GÉNIE BIOMÉDICAL/CLINIQUE

BMEF01.1 - Exemples de Donnes Pratiques en Génie Clinique et Indicateurs

Objectifs d'apprentissage: A l’issue de ce programme de la session, les participants pourront:

1. Comprendre les éléments requis pour mettre en place une démarche qualité dans un service de génie clinique.
2. Comprendre les éléments requis pour mettre en place une stratégie d’entretien des équipements médicaux.
3. Identifier les éléments principaux d’une démarche de planification d’entretien préventif pour les équipements médicaux.
5. Identifier quelques indicateurs pertinents pour un service de génie clinique et les intégrer au sein d’un tableau de bord.

Exemples de bonnes pratiques en génie clinique et indicateurs

Le génie clinique est l’une des disciplines professionnelles qui contribuent à la sécurité et l’efficacité des systèmes de santé tout en contribuant à l’optimisation des coûts associés à l’utilisation des technologies. Le rôle et la responsabilité première d’un service de génie clinique est la gestion de la technologie des dispositifs médicaux, y compris le respect des normes de sécurité, de qualité, et les standards de gestion de coût et d’efficacité reconnus.

Cette session va présenter dans un premier temps les principaux éléments d’une démarche qualité pour un service de génie clinique. Cela nous permettra de constater que l’implantation d’une démarche qualité dans un service de génie biomédical ne constitue pas une fin en soi. C’est un outil pour améliorer l’efficacité de l’organisation d’un service de génie biomédical afin de répondre encore mieux aux attentes du personnel clinique, des patients et des administrateurs d’un établissement de santé. En utilisant les guides de pratiques reconnus dans le domaine du génie clinique, cette session présentera également des pistes pour revoir les principaux aspects de gestion des technologies de santé en hôpital tel que la stratégie d’entretien des équipements médicaux, la planification des entretiens préventifs des équipements, la gestion des projets d’acquisitions ou encore la mise en place d’indicateurs et de tableaux de bords.

ENGLISH

TITLE: Examples of standards of practices in clinical engineering, improvements and metrics - Exemples de bonnes pratiques en génie clinique, amélioration et indicateurs.

ABSTRACT: Clinical engineering is one of the professional disciplines that contribute to the safety and effectiveness of health systems and contribute to the optimization of costs associated with the use of technology. The role and primary responsibility of a clinical engineering department is the management of medical device technology, including compliance with safety standards, quality, and cost management recognized standards.

This session will present main elements of a quality system approach for clinical engineering departments. This will allow us to see that the implementation of a quality approach in a Clinical Engineering department is not an end in itself. It is a tool to improve the efficiency of the organization to better meet the needs of clinical staff, patients and administrators of a health facility.

Using standard recognized practices in the field of clinical engineering, this session will also present ways to review key aspects of healthcare technology management in health technology such as maintenance strategy of medical equipment, planning of preventive maintenance equipment, management of acquisition projects or the development of performance metrics and dashboards.

Learning Objectives:

At the end of the program of the session, participants will:

1. Understand the elements required to implement a quality approach in a clinical engineering department.
2. Understand the elements required to implement a maintenance strategy of medical equipment.
3. Identify the key elements of a preventive maintenance planning process for medical equipment.
4. Understand the main elements of a medical technology procurement project.
5. Identify some relevant indicators for clinical engineering services and integrate them within a dashboard.
BMEF02 - GESTION EN GÉNIE BIOMÉDICAL/CLINIQUE

BMEF02.1 - Clinical Engineering Standards of Practice – Normes de Pratique en Génie Clinique- Nouvelle Edition Canadienne en Français

Author(s): Mohcine El Garch1, Bill Gentles2
1Groupe Biomédical Montérégie, Agence de la Santé et des Services Sociaux de la Montérégie, Brossard/QC/CANADA, 2Vice President, BT Medical Technology Consulting, Toronto/CANADA

Le génie clinique est l'une des disciplines professionnelles qui contribuent à la sécurité et l'efficacité des systèmes de santé tout en contribuant à l'optimisation des coûts associés à l'utilisation des technologies. Le rôle et la responsabilité première d'un service de génie clinique est la gestion de la technologie des dispositifs médicaux, y compris le respect des normes de sécurité, de qualité, et les standards de gestion de coût et d'efficacité reconnus.

Le premier guide des pratiques en génie clinique (CESOP) pour le Canada a été publié en 1998. Le CESOP a depuis traversé deux révisions, la dernière ayant été publiée en 2014. Chaque révision a été développé par un groupe de travail avec une large représentation de partout au pays. Le groupe de travail pour la révision 2014 s’est rencontré sur une base mensuelle depuis plus d’un an, et a produit 17 avant-projets avant que le projet final soit présenté aux membres pour approbation.

Au cours de l’année 2015, le comité Bilingue du CMBES a entrepris la traduction du guide anglophone afin de pouvoir le partager avec la communauté en génie clinique francophone au Canada.

Le CESOP est largement adopté par les départements de génie clinique à travers le Canada pour établir les champs d'activité de la pratique professionnelle. Il est référencé par les organismes d'accréditation de soins de santé et il est également utilisé pour formuler les lignes directrices d'évaluation dans le processus d'examen des départements de génie clinique par les pairs.

Au cours de la session, des exemples de guides de pratiques d'autres pays seront présentés et comparés au référentiel canadien.

Objectifs d’apprentissage: A l’issue de ce programme de la session, les participants pourront:

1. Comprendre le processus d'élaboration d’un guide de pratiques qui est approprié pour leur environnement de soins de santé particulier.

2. Comprendre les principales sections du guide qui est rédigé en vue de se conformer aux lignes directrices de l'ISO.

3. Comprendre comment un guide de pratique peut être utilisé comme standard de base d’une revue du fonctionnement d’un service de génie clinique par les pairs ou dans le cadre d’un processus d’accréditation.

ENGLISH

Clinical engineering is one of the professional disciplines that contribute to the safety and effectiveness of health systems and contribute to the optimization of costs associated with the use of technology. The role and primary responsibility of a clinical engineering department is the management of medical device technology, including compliance with recognized safety standards, quality, and cost efficiency management standards.

The first Clinical Engineering Standards of Practices (CESOP) for Canada was published in 1998. The CESOP has since gone through two revisions, the latest having been published in 2014. Each revision was developed by a working group with broad representation across the country.

During 2015, the Bilingual Committee CMBES undertook the translation of the English-speaking guide in order to share it with the francophone clinical engineering community in Canada.

The CESOP is widely adopted by clinical engineering departments across Canada to establish the scopes of professional practice. It is referenced by the health care accreditation bodies and it is also used to formulate the assessment guidelines in the review process for clinical engineering departments peer.

The session will be an introduction to the CESOP French translation with some comparison with examples of other countries standards of practices.

Learning Objectives: At the end of the program of the session, participants will:

1. Understand the process of developing a practical guide that is appropriate for their particular health care environment.

2. Understand the major sections of the guide that is written in order to comply with ISO guidelines.

3. Understand how practice guidelines can be used as standard based on a review of the functioning of a clinical engineering department peer or as part of an accreditation process.
Objectifs:
1. Santé et sécurité au travail
2. Santé de la mère et du bébé
3. Outils pour se prémunir des effets néfastes de la technologie médicale sur l’humain
4. Prévention en milieu de travail pour les professionnels de la santé

Résumé:
L’environnement hospitalier comporte continuellement pour les employés différents risques selon la nature des tâches réalisées quotidiennement: proximité de patients infectés, exposition au bruit ambiant, exposition aux rayonnements ionisants, manipulation de produits chimiques ou biologiques, effort physique de manutention, risque d’éraflure ou de piqure accidentelle. Des mesures préventives et des directives appropriées permettent de minimiser ces divers risques et d’assurer aux employés des conditions de travail assez sécuritaires durant l’exercice de leur profession au sein de l’hôpital. Les dispositions mises en œuvre pour garantir une maternité sans danger ne sont pas appliquées de façon uniforme dans les établissements de santé, voire sur le même département. La présente formation est une mise à jour des connaissances qui a pour but de renseigner les professionnelles de la santé qui planifient d’être enceintes, qui le sont déjà, ou sont nouvellement mamans, sur les risques biologiques, chimiques et physiques induits par la proximité technologique ou les horaires de travail en milieu clinique. Des recommandations sont faites aux gestionnaires pour faciliter l’harmonisation des tâches et des congés connexes à la condition de grossesse ou d’allaitement chez la professionnelle exerçant en milieu clinique.

ENGLISH
Hospital environment has continuously presented different risks to the employees depending on the nature of the tasks performed daily: being close to infected patients, exposure to environmental noise or radiation, handling chemicals or biologicals, physical effort or ergonomics, risk of scratching or accidental needlestick injuries. Preventive measures and appropriate guidelines will minimize these various risks and ensure to employees fairly safe working conditions within the hospital. Procedures implemented to ensure safe motherhood at work are not applied consistently in health facilities or on the same department. This training is an update of knowledge which aims to inform health professionals who are planning to be pregnant, who already are, or are new moms. The risks studied here are related to biologicals, chemical and physical hazards induced by technological proximity or work shifts in clinical or medical areas. Recommendations are made to clinical and medical managers to facilitate the harmonization of tasks and optimize pregnancy or lactation leave conditions for female professionals working in a hospital.

Learning Objectives:
1. Occupational safety and health
2. Health of mother and baby
BMEF04 - GESTION EN GÉNIE BIOMÉDICAL/CLINIQUE

BMEF04.1 - La Gestion de Projets et de Portefeuille de Projets en Technologies de la Santé

Author(s): Mohcine El Garch
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L'objectif de ce cours est de donner des pistes de réflexion aux participants pour:

- Définir la gestion de projet dans un contexte hospitalier
- Réaliser la planification de leurs projets (petits ou grands)
- Établir la charge de travail du ou des professionnels
- Gérer la performance et les risques associés à un projet
- Communiquer de façon efficace l'avancement des projets
- Utiliser le logiciel MS Project pour réaliser la gestion d'un projet
- Partager des projets et des ressources en mode multi-projets avec MS Project

La gestion de projets et de portefeuille de projets en technologies de la santé.

Les activités du service de génie biomédical dans un hôpital sont plus souvent qu'autrement réalisées en mode projet. Travaillant seul ou en équipe, le professionnel est souvent amené à développer des outils lui permettant de suivre ces activités. Que ce soit dans le cadre de petits projets ou de projet de grande envergure, la connaissance des méthodes de projets et des outils pratiques sont un incontournable.

Ce cours présente les éléments principaux de la gestion de projet en général, les enjeux, les risques et les outils à mettre en place pour mieux gérer ses projets. Des exemples de projets et de situations rencontrées spécifiquement dans le domaine du génie clinique seront présentés et des outils pour gérer les projets et les portefeuilles de projets seront également abordés.

ENGLISH

TITLE: Project management and program in health technology projects - La gestion de projet et de portefeuille de projet en technologies de la santé

ABSTRACT: The activities of the Clinical Engineering department at a hospital are more often than not carried out in project mode. When working alone or in teams, the clinical engineer needs to develop tools to monitor these project activities. Knowledge of standard practices and tools of project management are a necessity in the context of large-scale project or even with the small projects.

This course presents the main elements of project management, issues, risks and tools to put in place to better manage its projects. Examples of specific projects and situations encountered in the field of Clinical Engineering will be presented and tools to manage projects and program will be discussed.

Learning objectives:
The objective of this course is to give food for thought to the participants to:
- Define project management in a clinical engineering perspective;
- Plan their projects (whether small or large);
- Establish workload for clinical engineers;
- Manage the performance and risks associated with a project;
- Communicate effectively the progress of projects;
- Use MS Project to achieve the project management;
- Share projects and resources in multi-mode projects with MS Project.
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BMEF05 - GESTION EN GÉNIE BIOMÉDICAL/CLINIQUE

BMEF05.1 - Implantation du Guide des Bonnes Pratiques de l'Ingénierie Biomédicale en Etablissement de Santé

Author(s): Fabienne Debiais1, Christine Lafontaine2

1Génie Biomédical, Hôpital général juif, Montréal/CANADA, 2Génie Biomédical, Haelys, Terrebonne/QC/CANADA

Résumé:

Cet atelier présentera le guide des bonnes pratiques de l'ingénierie biomédicale en établissement de santé et proposera une démarche d'implantation ainsi que des outils et méthodes pour y parvenir.

Cette session comportera un partage d'expériences variées provenant de plusieurs établissements de santé et faisant appel à diverses méthodologies (LEAN, ISO 9001 ...).

Objectif #1:

S'approprier le guide des bonnes pratiques de l'ingénierie biomédicale pour mieux le maîtriser et en tirer le maximum pour répondre aux exigences du milieu de la santé.

Objectif #2:

Découvrir différentes techniques de priorisation des bonnes pratiques de l'ingénierie biomédicale afin de maximiser l'impact des actions mises en œuvre.

Objectif #3:

S'initier à des méthodes de gestion de la qualité (LEAN, ISO 9001) en découvrant des projets concrets réalisés en milieu hospitalier.

ENGLISH

TITLE: IMPLEMENTATION OF BIOMEDICAL ENGINEERING BEST PRACTICE GUIDE IN HEALTHCARE INSTITUTIONS

ABSTRACT: This workshop will introduce the biomedical engineering best practice guide in healthcare institutions and will suggest an implementation process as well as tools and methods to achieve this. This session will include a sharing of varied experiences from several healthcare facilities and using various methodologies (Lean, ISO 9001 ...).

BMES01 - INTEROPERABILITY IN HEALTH TECHNOLOGY

BMES01.1 - Interoperability - Profiles - IHE

Author(s): Vladimir Quintero

Universidad Simao Bolivar, Barranquilla/COLOMBIA

Learning objectives

1- Why Interoperability is needed?
2- The role of IHE
3- Origin, purpose and use of Interoperability Profiles

ABSTRACT

The rapid advance of Information and Communications Technology, ICT, has produced, among other effects, the multiplication of data related to the health of a patient, data that is produced by the increasing amount of diagnosis, monitoring and treatment equipment available today to the medical science. Along with this development of technology-based data, models of care have evolved towards offering integrated services, often produced by different suppliers, with the consequent need for exchange and integration of clinical and financial information. Finally, the prioritization of patient-centered care has increased the number of actors, both users and producers of information in the processes of health care delivery.

The convergence of these three trends has exponentially increased the volume of data available for any patient, without simultaneously having developed a strategy to ensure that all such data, produced by different sources, can be seamlessly exchanged, integrated, processed, and used.

We have arrived to a paradoxical situation in which potential users of the information, like physicians, policymakers, researchers, and even the patients themselves, are surrounded by a sea of data, without being able to use it in an integrated and efficient way. What is needed is the implementation of interoperability between all those equipment, devices and systems.

According to HIMSS (Health Information Management Systems Society), in healthcare, interoperability is the Ability of different information technology systems and software applications to communicate, exchange data, and use the information that has been exchanged. Data exchange schema and standards should permit data to be shared across clinicians, lab, hospital, pharmacy, and patient regardless of the application or application vendor. Interoperability means the ability of health information systems to work together within and across organizational boundaries in order to advance the health status of, and the effective delivery of healthcare for, individuals and communities.

By the end of the 90's, the Radiology Society of North America, RSNA, the National Electric Manufacturer Association, NEMA and HIMSS came together to create a new organization to deal with this challenge of interoperability, the IHE: Integrating the Healthcare Enterprise.

IHE is an international initiative designed to encourage and promote the integration of medical devices and information systems that support the operation of modern health institutions. Its main objective is to ensure that in the care of patients, all required information for medical decisions is correct and available to healthcare professionals.

The strategy proposed by IHE articulates the needs of producers and users of equipment, devices and systems, from the viewpoint of Use Cases in which information exchange requirements are determined, and a solution that fits all participants needs is developed.
The methodology begins with the identification of priority situations of information exchange by users: Clinics and Hospitals, independent Doctors, research centers, etc. These requests are converted into use cases by a technical team of development engineers from major manufacturer of health equipment and systems in the world.

After identifying the particular characteristics of the exchange of information in each use case, they proceed to identify the most efficient standards for structuring this exchange (DICOM, HL7, ISO, IIEEE, etc.) and with them they design and build a profile of interoperability, which is then published and implemented in equipment and systems by those producers who participated in its development, and finally tested under real conditions during the massive testing event: the Connectathon, held annually in various countries.

This scheme collaborative competition ensures that the solutions offered by the interoperability profiles, integrated into ‘Technical Frameworks’ which are also published free of cost, have the widest possible coverage and can facilitate the exchange of information between the maximum number of equipment and systems, regardless of their origin.

Production of IHE is structured in 14 ‘Domains’ or thematic areas, to meet the different specialties and user needs. To date, the IHE has National Committees in 19 countries.

BMES02 - INTEROPERABILITY IN HEALTH TECHNOLOGY

BMES02.1 - Business Opportunities
Author(s): Mario Castañeda
Health Care Technology, Healthitek, San Rafael/CA/UNITED STATES OF AMERICA

The very existence of Health Care Technology departments, programs, and projects is at risk during times of organizational political and technical turmoil. Elections, reorganizations, austerity mandates, and disruptive technologies bring changes that impact the Health Care Technology leader. The leader’s ability to demonstrate added value during organizational transitions is vital. Successful designing, delivering, and sustaining programs during turmoil can be itself transformational and in line with the changes.

Our approach recasts the problem into an opportunity for economic growth. Under uncertainty, one of the major challenges is to design a program that motivates other key stakeholders to provide support. We designed a successful program in Colombia and will describe the factors that made this possible: 1) adopting the continuum of health model as a foundational framework, 2) building a coalition of public, private, and academic organizations for support, and 3) developing and implementing a new facilitation model to distill the ideas of 40 participant thought leaders from local business, industry, health care, and academia.

Learning objectives
The participant will

1) Identify opportunities brought about by organizational change, turmoil, and disruptive technologies.

2) Learn from the success of the Colombian Case study how to apply success factors to solve their own challenges.

3) Learn about how to identify opportunities for business, academia, and government to obtain support of their leaders.
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BMES03 - INTEROPERABILITY IN HEALTH TECHNOLOGY

BMES03.1 - Trends on IT and Health Technology
Author(s): Antonio Hernandez
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The healthcare sector has experienced fast evolution due to the convergence of information technologies and communications with the health technologies. We will present an overview of medical technology in healthcare facilities: standalone equipment, networks of medical devices (analog and digital), technology in public health servicing communities. Also, we will address the current trend in the use of mobile communication platforms for personal monitoring and auto management of health (people responsible for their own health). Parallel to this will be the evolution of epidemiological information systems, the clinical information systems and the information generated by mobile technologies. We will highlight some aspects of the integration and convergence of these technologies and the way they have impacted the workflow in healthcare facilities. This evolution brings benefits but also risks associated that are inherent to the use of technologies as well as some others made (intentionally or unintentionally) by the people. Also, this change of the healthcare delivery model gives more responsibility to the people in the management of their own health and well-being.

Topics include:
· The evolution and trend on healthcare technology
· The convergence of Health Technologies and Information and Communication Technologies

BMES03.2 - Healthcare Continuum
Author(s): Vladimir Quintero
Universidad Simon Bolivar, Barranquilla/COLOMBIA

Learning objectives
1- What is the Healthcare Continuum
2- Challenges and opportunities
3- Where Healthcare Continuum and Interoperability meets

ABSTRACT

Traditional health delivery is structured to meet patients’ specific and acute complications. It is focused on intervention and associated diagnoses. This system consolidates in the twentieth century in response to a large increase in demand for timely cure of diseases, especially infectious and viral. This business model requires companies able to make large investments in infrastructure and specialized equipment, as well as highly specialized personnel capable of performing complex surgeries. Therefore, it is a business that consumes a lot of resources (doctors, hospital beds, technology, medicine, etc.) contributing to increase the financial pressure on the health system. Besides being timely, it is a reactive health delivery to a patient’s need. In this sense, offered products and services are a response to a specific complication in the patient’s health. Therefore, consumers of products and health services that typically do not have such complications are not a target for companies in this business.

What is the necessary evolution of this way of delivering health given the significant changes in demand and environment? The need to provide a continuum of care to a population with further and further growing care needs is imposed. The aim of continuing care goes beyond the cure of a disease. It seeks to accompany the patient’s or consumer’s health throughout his/her life. In the continuous delivery of health intervention still exists, but is limited to what is necessary, the population most in need. That is only a small part of a much more complex whole, where prevention, early disease detection and remote monitoring of patients play a key role. The consumer (and no sickness or hospital) is the center of this business. On the one hand, it supports the value chain by sending data on their health through proactive use of mobile or remote technology. On the other hand, the consumer is the key element of the proposed value chain, which seeks to provide a “complete solution” for health, promoting the establishment of lasting (and not one-time) relationships over time.

The main differences between the traditional value chain of health delivery and that of continuous healthcare delivery are reflected in the benefits of this new way of looking at health:
· Increased business opportunities
· Better health for patients
· Optimization of costs for companies and the system

This paradigm shift in the delivery of health services brings a significant multiplication of the actors involved, of the offered services, and of the corresponding integration mechanisms.

Finally, all that change must be supported by information, which now more than ever must be standardized to ensure “the ability of different information technology systems and software applications to communicate, exchange data, and use the information that has been exchanged” which corresponds exactly to the definition of interoperability.
JT01.1 - SPECT and Gamma Camera State-Of-The-Art Technology and Current Research

**Author(s):** R Glenn Wells

Physics, Carleton University, Ottawa/Canada

Dedicated cardiac SPECT cameras were recently introduced into the market. These cameras represent a significant departure from traditional Anger-camera designs. They employ novel collimators and acquisition strategies, large numbers of detectors, and solid-state cadmium-zinc-telluride detectors. These features produce a 4-8 fold increase in camera sensitivity which can be used to significantly improve image quality, reduce acquisition times or reduce patient radiation exposure. Some of these systems are also quasi-stationary, opening the door to exciting future applications in dynamic imaging. This presentation will describe the design features of the more popular dedicated cameras, the DSPECT system (Spectrum Dynamics) and the Discovery NM530c (GE Healthcare) and highlight how the new cameras achieve their improvements in sensitivity. As with any new technology, there is a learning curve associated with its use; familiar artifacts like those from attenuation have changed their appearance and prevalence, and new concerns arise such as image truncation due to a limited field of view. Therefore, I will also discuss some of these and other limitations and challenges inherent in the designs and some implications for their integration into a clinical environment. I will present some of the evidence supporting the use of these systems to reduce acquisition times and patient exposures. Finally, I will discuss the use of these cameras for dynamic imaging. Once solely in the domain of Positron Emission Tomography (PET), the improved sensitivity and temporal resolution of the new cameras make it possible to acquire dynamic cardiac SPECT studies with clinically practical protocols. This will allow measurement of absolute myocardial blood flow which PET studies have shown will improve diagnostic and prognostic accuracy over standard relative perfusion imaging. I will describe some of the research being done by my group and others to bring these novel capabilities to the clinic.

At the conclusion of the CE program, attendees will be able to:

- Understand the novel features of these dedicated cardiac cameras and how they provide improved performance.
- Describe and discuss how these new cameras can be integrated into a clinical environment and how this may alter clinical protocols and workflow.
- Describe some of the novel capabilities of the new cameras and potential for future applications.

**JT01.2 - Magnetic Resonance Imaging State-Of-The-Art Technology and Current Research**

**Author(s):** Richard Frayne

Radiology and Clinical Neurosciences, University of Calgary, Calgary/AB/Canada

Magnetic resonance (MR) imaging continues to be a rapidly changing field, with a clear connection between technologic innovation and clinical imaging enhancement. MR technology has been in near constant evolution since before the installation of the first clinical MR imaging units. The first clinical MR images in Canada were obtained in 1982; since this time advancements have been made in all facets of clinical MR imaging. These advances can be conveniently divided into hardware and software developments.

MR hardware has seen increases in main magnetic field strength, improvements in gradient performance, and tremendous advances in imaging coil design. Today’s leading edge clinical systems operate at 3 T (with some centers now exploring systems operating at 7 T and higher), with gradient performance often limited to established physiological safety limits, and adoption of flexible multi-channel (32 or more) receive coils and, most recently, multi-channel transmission. These developments have been used to increase signal-to-noise in acquired images, improve patient throughput, and maturation of a wide range of application-specific imaging coils.

MR software has arguably seen an even more explosive growth in both new approaches and applications. Most clinical MR scanners have research environments that can be accessed by user at vendor-approved research sites. This access has allowed software-based innovations to occur not only at vendor R&D facilities; but also at ever increasing rates at universities and academic medical centers. Advanced approaches include ongoing development of fast imaging approaches (that are often coupled with clever under-sampling schemes and matching image reconstruction strategies), artifact suppression strategies (e.g., motion, fat), as well as new image contrast mechanisms. New MR applications have extended clinical MR imaging from purely anatomical/structural imaging to include the assessment of brain activation, diffusion, perfusion, relaxation rates, velocity and other functional/physiological parameters. Techniques are also under development to image molecular phenomena. An emerging concept, related to these new assessment methods, is the application of quantitative imaging techniques to patients.

At the conclusion of this presentation, participants will:

- Understand the historical pattern of advances in MR imaging and their impact on clinical care.
- Describe and discuss the relevance of state-of-the-art MR hardware advancements.
- Described and discuss the relevance of state-of-the-art in new MR software approaches and applications.
- Have an enhanced appreciation of the relationship between technologic innovation and clinical imaging enhancement.
JT02 - PROCUREMENT AND EQUIPMENT SELECTION

JT02.1 - UNICEF's Approach to Medical Device Selection and Procurement for Low-Resource Settings

Author(s): Shauna Mullally1, Ludo Scheerlinck2
1Health Technology Centre, UNICEF Supply Division, Copenhagen/DENMARK, 2Health Technology Centre, Medical Devices Unit, UNICEF Supply Division, Copenhagen/DENMARK

UNICEF works in over 190 countries to promote the rights of children and is a major source of health, nutrition, education, water and sanitation and child protection supplies in low-resource settings. In 2013, for example, UNICEF procured $2.8 billion worth of supplies for development programs and humanitarian emergencies in 130 different countries, of which approximately $142 million was medical devices and kits for maternal, newborn and child health (MNCH).

The medical devices team within UNICEF's supply headquarters in Copenhagen leads the selection and procurement of 800 medical and clinical laboratory devices that form our standard product portfolio. Many are stored in our supply warehouse where kits are packed for rapid response during emergencies and to facilitate distribution to end users. In addition to our standard device portfolio, we supply personal protective equipment, assistive health technologies for children with disabilities, and vocational training products for healthcare workers for MNCH interventions.

Our procurement is guided by UN and public procurement rules that ensure clear segregation of duties for technical and contracting staff during the tendering process. Quality assurance is also a critical aspect of the process, and is managed by an in-house team that runs a test laboratory and audits manufacturers' quality systems. We have developed quality policies for in-vitro diagnostics and medical devices, and work with the World Health Organization (WHO) on pre-qualification of rapid diagnostics tests.

In addition to managing medical device procurement, we advise on supply chain management and health technology management in-country, beginning with needs assessments. We work closely with the WHO and other partners to foster product innovation, produce guidance for medical device selection in low-resource settings and harmonize specifications for essential supplies for MNCH. We also conduct fit for purpose evaluations and research on the markets of our essential, strategic devices.

Some examples of our current work include:

- Strengthening MNCH services in the Democratic Republic of Congo through the supply of medical devices to equip 200 hospitals and 1,000 health centres nationwide
- Leading two projects to foster innovation for child wheelchair solutions for use in emergencies and for improved acute respiratory infection diagnosis for children in their communities
- Working with partners to evaluate new point of care HIV diagnostics in seven African countries
- Working with the WHO and UN partners on a list of essential medical devices for MNCH services at different levels of care
- Supplying a large percentage of the Ebola personal protective equipment to affected countries; developing technical specifications, leading an industry consultation and developing guidance

At the conclusion of the session, attendees will be able to:

- Describe and discuss UNICEF's approach to device selection and procurement and incorporate some principles of the approach into their own work
- Describe and discuss medical device selection and procurement challenges in low-resource settings and identify tools produced by UNICEF, the WHO and partners to address the challenges
- Provide examples of UNICEF's current medical device projects and identify opportunities for collaboration with UNICEF on medical device innovation, selection and procurement and health systems strengthening work

JT02.2 - Equipment Donation and Disposal - Goodwill vs. Risk

Author(s): Mario Ramirez1, Bill Gentles2
1Medical Engineering, The Hospital for Sick Children, Toronto/CANADA, 2Vice President, BT Medical Technology Consulting, Toronto/CANADA

Learning Objectives: At the conclusion of this session program, attendees will:

- Meet other participants who are involved in medical equipment donations and share contact information to promote further information sharing.
- Understand the reasons for the failure of donated medical equipment in developing countries.
- Understand the necessary 'best practices' related to people, processes, and metrics to most effectively donate medical equipment to developing countries.
- Understand the essential role of recipient organizations in improving the success rate of donations.

Abstract:

Previous studies conducted in the United States and Europe have shown that as much as 70% of medical equipment that is donated to low-income countries is never put into use in these countries[1]. As a result an unnecessary burden is created, and many of the recipients' equipment deficiencies remain unresolved.

Responses to natural disasters also generate a flood of donated medical equipment, which is often sent with a lack of understanding of what is really needed. A study of seven hospitals in Haiti found only 30 percent of the 115 pieces of medical equipment donated after the 2010 earthquake were working and 14 percent of the equipment could not be repaired. [2]

To address this ongoing problem, numerous articles and guidelines have been published. A recent guideline published in the UK includes a thorough examination of the reasons for the lack of success of medical equipment donations, and exhaustive recommendations to correct the problem. [3]

In this session we will review the current knowledge on the complexities of donating medical equipment to developing countries, and discuss possible approaches to improve the effectiveness of these donations.


JT03 - IMAGING

JT03.1 - CT State-Of-The-Art Technology and Current Research Topics
Author(s): Ting-Yim Lee¹, Aaron So², Esmaeil Enjilela²
¹Imaging, Lawson Health Research Institute, London/ON/CANADA, ²Imaging Research Laboratories, Robarts Research Institute, London, ON/CANADA

Learning Objectives

1. State-of-art technology in CT - wide detector cone beam, iterative reconstruction, dual energy

2. Research applications of dual energy

3. Research applications of dynamic contrast enhanced scanning - perfusion imaging in stroke, cancer and heart attack

Abstract

The advent of slip ring, dual energy, cone beam acquisition with wide detector array and iterative image reconstruction have revolutionized the applications of CT in both the clinical and research arena since the 1990’s. This presentation will discuss these different technological advancements and their implications in clinical and research applications. For clinical applications, examples will be drawn from dual energy material selective imaging, high resolution imaging and dose reduction. For research applications, perfusion imaging in stroke, cancer and heart attack and compressed sensing reconstruction for ultra-low dose perfusion imaging will be discussed.

JT03.2 - Review of PET State-Of-The-Art Technology and Current Research Topics, Including PET/CT and PET/MR
Author(s): Roger Lecomte
Sherbrooke Molecular Imaging Center, Research Center of CHUS (CRCHUS), Sherbrooke/CANADA

Positron emission tomography (PET) is a medical imaging modality using positron-emitting isotopes to investigate the fate of radio-labeled molecules in living organisms. By measuring the uptake, biodistribution and washout of the radiotracer, it is possible to obtain information about in vivo molecular processes involved in normal physiology, as well as in diseases such as cancer, neurological disorders, heart and cardiometabolic diseases. Major advances in PET technology have widened the range of applications of PET in both biomedical research and clinical diagnosis. Examples of these technological advances include very diverse and clever detector designs, sophisticated signal processing techniques, 3-dimensional imaging with iterative reconstruction algorithms, the introduction of time-of-flight measurement, and the combination of PET with X-ray computed tomography (CT) or magnetic resonance imaging (MRI). Whereas PET technology has made huge progress in the last decades, it has not reached its performance potential. This review will describe the basic principles, state-of-the-art technology and current developments of PET, including PET/CT and PET/MR dual-modality imaging. The overview will be concluded by detailing a few key research and clinical applications of PET imaging and by discussing some promising new ideas in the field.

At the conclusion of the CE program, attendees will be able to:

1- Describe and discuss PET imaging principles, technologies and applications used in diagnostic nuclear medicine and biomedical research.

2- Understand the underlying physical limitations and areas of potential advances of the PET imaging modality.
3. Explain the various advantages and limitations of different multi-modality imaging approaches.

JT04 - ETHICS

JT04.1 - Ethics for Biomedical Engineers and Medical Physicists Workshop

Author(s): Monique Frize¹, Jean-Pierre Bissonnette²

¹Systems And Computer Engineering, Carleton University, Ottawa/CANADA, ²Radiation Physics, Princess Margaret Cancer Centre, Toronto/CANADA

Learning objectives: (1) Become familiar with ethical theories, codes, and ethical decision-making; (2) learn the application process for obtaining ethics clearance for research projects; (3) explore various ethical dilemmas and how to deal with these.

Health professionals are concerned with a variety of questionable behavior and professional and ethical misconduct, especially when a patient's life is at stake. The workshop discusses the ethical decision-making process, including ethical theories and ethical codes, experimentation with humans and animals, clinical studies for prototype testing, and how to obtain ethics clearance for this type of research. The impact of technology and science on people, society, and the environment and means of minimizing harm are discussed. Ethics regarding gender and culture is also an important aspect to consider. For clinical practitioners, ethics regarding incident reporting, fairness, access to resources and skills, and educational practice are of concern. Ethics education and training is a must for anyone working in these two fields related to health care.

Format of the workshop:

The main ideas, concepts, and references will be presented (20 minutes). Groups of 4-5 persons will prepare an application to an Ethics Research Board for a research project of their choice; some ideas will be provided (30 minutes). Groups will review another group's application (20 minutes). Comments and ideas originating from participants will be collected and included in a report that follows the workshop (15 minutes). Although discussions will be conducted in English, groups preferring to submit their work in French will also be considered.
JT05 - LEADERSHIP

JT05.1 - What is Leadership? A Roundtable from Recognized Leaders

Authors: David Jaffray1, Kin-Yin Cheung2, Ratko Maširević3, Tony Easty4, Herbert Voigt5

1Ontario Cancer Institute / Princess Margaret Hospital, Toronto/CANADA, 2Medical Physics & Research Department, Hong Kong Sanatorium & Hospital, hong kong/HONG KONG, 3University of Zagreb Faculty of Electrical Engineering and Computing, Zagreb/CROATIA, 4University Health Network, Centre for Global eHealth Innovation, Toronto/CANADA, 5Biomedical Engineering, Boston University, Boston/UNITED STATES OF AMERICA

Leadership, and the dynamics of leadership, is one of the most complex topics in the workplace. Almost everyone has had the experience of being led by people they admired and respected and by people they did not. Since most leaders would prefer to be judged as belonging to the former group, it is useful to examine the attributes of a leader that engender admiration and respect and deconstruct them as a framework for us all to strive for.

In my opinion, very few people are natural leaders, and so for most of us, leadership takes work and effort. It is useful to regularly examine the ways in which we attempt to lead, to determine whether we are being effective. That said, what are some of the key attributes of effective leadership:

Knowledge where you are going: It is hard for team members to follow you if you yourself haven’t thought carefully about what you intend to achieve and how you intend to get there.

Communicate regularly: Most of us assume that those around us know more about our plans than they really do. It is easy to forget that key pieces of information have not been shared with team members, so try to make sure that this happens. It can be quite informal. It does not require endless memos and meetings.

Allow involvement and dissent: Not everyone agrees on how an issue should be tackled, and good leaders allow ideas to come forward from team members without fear of criticism or punishment. Ultimately, the leader may take the final decision on an approach, but the team is more likely to commit to it if it represents the collective talents and knowledge of the team. Good leaders should allow their ideas to be challenged and should be prepared to change if a team member proposes something better.

Provide support and encouragement: Sometimes things don’t go well, and it is important for a leader to be open about what is happening since everyone usually knows anyway, but at the same time encourage the team to see a way forward and do the best that it can in the circumstances.

Avoid playing favourites and public humiliation: Every team member deserves to feel needed and valued. If the leader has clear favourites, everyone will see that and the team dynamic is affected. Public humiliation of a team member for poor performance may be tempting but should be avoided. Even if the other team members agree that their performance is poor, they will not enjoy seeing a colleague be humiliated, and will wonder when it will be their turn for such treatment.

Try to make it fun: It seems like a cliché to speak of work as fun. Most people work to earn a living, after all. However, many jobs can provide great satisfaction when something goes well and there is a good outcome, even if there is no direct reward for the team.

**Learning Objectives:**

Presentation of the above attributes will stimulate discussion among participants, and provide a framework for considering leadership.

Participants will have the opportunity to comment on whether they agree with this list or identify other attributes as more relevant to their experience.

At the end of the session, participants will be able to take this material, enhanced with their own experiences and insights, and apply it in their own work environments.
JT06 - LEADERSHIP

JT06.1 - Hosting and Organizing an International Meeting
Author(s): For many professionals hosting an international meeting can elevate their career to a different level. Engagement in professional associations and organizations provides an excellent networking opportunity that helps support research and create general best practices. Attending an international conference, one sometimes wonders what it takes to run an international conference yourself and what you need in place in order to do so. In this session we will be exploring

- How to attract/bid on a scientific/medical conference
- Creation of a bid team and the necessary committees
- Financial investments and liabilities
- Planning process and time commitment
- Stakeholders and team members of successful conferences

The session is designed to give a comprehensive overview of the process involved based on practical examples such as the IUPESM World Conference and other meetings.

A special focus will be given to financial concerns and how to mitigate the risk of a meeting by involving professional groups and setting the conference up properly in a legal and tax-accounting matter. Finally there will be time for specific questions.

Learning Objectives:
- How to successfully bid on hosting a professional conference
- Designing a Continuing education programme that delivers value
- Properly assess financial risk and overall planning and budgeting for a professional conference

JT06.2 - Social Media in Science and Medicine
Author(s): Parminder Basran
Medical Physics, BC Cancer Agency- Vancouver Island Centre, Victoria/CANADA

The use of websites and applications that enable users to create, share, and discuss content is not new to medical physicists and biomedical engineers, but how one might adopt modern social media tools and technology for these purposes may well be. In this session, we explore social media in science in medicine with a particular focus towards medical physicists and biomedical engineers. We will explore how modern social media tools might be used in clinical activities, as a tool for research, as an educational tool, and as a means of public outreach.

Key learning objectives of this presentation are:
1. To provide a brief description of key social media channels and technology relevant to the medical sciences;
2. To provide some examples of how social media may be used in clinical, research, education and outreach activities;
3. To explore personal and institutional privacy concerns when using social media in a professional setting.

JT07 - HUMAN FACTORS AND MEDICAL DEVICE SAFETY

JT07.1 - FMEA and Root Cause Analysis
Author(s): Eric Ford
Department Of Radiation Oncology, University of Washington, Seattle/WA/UNITED STATES OF AMERICA

Of the systematic tools available for improving the safety and quality of care in radiation therapy, two have proven particularly useful: Failure Mode Effects Analysis (FMEA) and Root-Cause Analysis (RCA). These two techniques offer complimentary methods for analyzing error pathways. FMEA provides a method of quantifying hazards before they occur, while RCA offers a means understanding the drivers of error through in-depth analysis of events that have already occurred. Recent data demonstrates that these two tools are most effective when used in combination with one another. This presentation will provide an overview of FMEA and RCA with reference to the concepts and methods established in AAPM Task-Group 100 (FMEA) and the RO-ILS: Radiation Oncology Incident Learning System in the US. A series of case studies will be included which illustrate the practical operational aspects of both FMEA and RCA.

At the conclusion of the CE program, attendees will be able to:

Describe the fundamental concepts behind FMEA and RCA
Understand in detail the methods used for each
Incorporate each tool into the quality management program of their own clinic

JT07.2 - Human Factors and Usability Assessment
Author(s): Patricia Trbovich
Institute Of Biomaterials And Biomedical Engineering, University of Toronto, Toronto/CANADA

Learning Objectives:
At the end of the session participants will:

1. Appreciate the importance of understanding systems issues and intrinsic human limitations in improving patient safety
2. Understand Rasmussen’s model of migration to boundaries to explain the mechanism by which deviance occurs, stabilizes, regress, or progresses to harm. This model assesses how accidents occur and helps to understand the human and system contributions to adverse events
3. Have a general understanding of usability assessment and key concepts that help protect against dangerous errors that could lead to patient injury
4. Understand the “Hierarchy of Effectiveness” in developing solutions to safety problems

Healthcare organizations depend on human beings to perform safety critical tasks in complex work environments. Consequently, it is essential for these organizations to effectively address human factors and human performance considerations, to reliably achieve safe and successful outcomes. Human Factors (HF) is a discipline concerned with the study of how people interact physically and psychologically with products, tools, procedures, and processes. HF takes into account human capabilities, limitations, and characteristics and aims to make the environment function in a way that is safe and seems natural to people.

In this presentation, we will begin with a review of Human Factors and the relationship that exist between the high rate of preventable
adverse events in healthcare and the pace, and increase of new technology and approaches. We will discuss Rasmussen’s model of risk management in a dynamic society, which addresses the dynam-ic aspects of safety, and consequently is well suited to understand-ing current conditions in modern healthcare delivery and the way conditions may lead to accidents. When errors involving medical devices occur, people typically blame the users rather than investiga-te broader systems factors that are likely contributing, such as a poorly designed interface

between the medical device and the user, or inadequate user training. We will discuss how usability assessment can help fulfill the need to understand how to better ensure that (a) medical devices are designed for optimum capability and ease of use, and (b) clinician training is thorough and effective. Finally, we will discuss the crucial role that healthcare professionals, including biomedical technology professionals, play in selecting the appropriate strategy to reduce and remedy medical error. It is often not obvious nor clear, which error prevention tool to use, even when system-based causes have been identified. We will discuss various error prevention tools and their respective effectiveness for creating lasting changes in the healthcare system.

JT08 - SCIENCE AND RESEARCH

JT08.1 - How to get Grants: Tips for Success
Author(s): Aaron Fenster
Imaging Research Laboratories, Robarts Research Institute, London/ON/CANADA

Success for obtaining a grant for research is getting increasingly more difficult as the number of applicants is rising and funds for research is not keeping pace. Thus, for research grants to be successful, they must be outstanding, or at the very least, nearly outstanding. While the current state for research funding appears to be highly intimidating, complex, and with challenges that are over-whelming, the steps to produce a successful grant are highly logical and follows a regular pattern. Never-the-less, the current research funding environment causes many research applicants to avoid starting their grant until it is too late to produce the level of the grant that would make it successful.

The current research funding in Canada is quite complex with funding sources that include Federal, Provincial, disease-based foundations and private sources (e.g., philanthropists). Grants can be written for funding to support operating costs of research, equipment, infrastructure and individuals’ salaries. Details of the documents to be filled and submitted are usually different, requir-ing different types of information. However, the process for writing these grants follows the same steps: preparation, writing the grant, refinement, and submission of grant.

A successful grant writer would have these steps in mind and start their grant allowing sufficient time for each step. For example, while the most critical step is the preparation step, most researchers do not spend enough time or don’t quite understand what is needed. Specifically, this step requires substantial investments in time to generate the “idea” that would be considered transformative and/or meeting an unmet need that would have a significant impact on their field (e.g., significant impact on diagnosis, treatment or understanding of a disease). Since the “idea” generation is critical to success, the grant writer must steer away from ideas that are just “interesting”, “would be useful” or “somebody should do this”. The “idea” must be of significant importance to the community or field that it would evoke the comments such as “I wish I though of that” or “if the applicant can accomplish this task, it would change the way XXX would be done” or “if anyone in Canada (the world) can do this, this applicant has the best chance for accomplishing this goal”. Clearly, evoking these type of comments and reviews are difficult to achieve, so the question is how to generate the “idea” that would evoke these types of comments.

In this paper, I will describe the process for writing a successful grant and the steps and timelines needed to achieve this. The information that will be provided is based on a personal experience of writing successful and unsuccessful grants over the past 30 years as well as the experience and discussions with the scientists at the Robarts Imaging Research Laboratories in London.

Learning Objectives:

1) Planning steps used to write a successful grant.

2) How to allocate sufficient time to write a succesful grant.

3) What constitutes an “idea” that will be the basis of a succesful grant and how to achieve this.
Learning objectives:

1. To understand the basics of writing a scientific paper for submission to a peer-reviewed journal and the requirements of the journal.

2. To understand the importance of clear presentation of results for publication and how to achieve this.

3. To understand the reviewing process, to help in writing papers, as well as when/if invited to be a reviewer.

Publication of your work is necessary to move the research field forward, (and for your career!). Using our experience as authors, reviewers, editorial board members and editors, we summarize some observations on writing and reviewing scientific papers for a peer-reviewed journal.

i) For writing and submitting a paper: assuming the work is good as a starting point, the focus here is on what makes a clear paper. This is also likely to maximise the chance of it being acceptable. First, consider your main message and hence material selection and writing flow so that this is clear. Make the introduction relevant to where the work fits into the current state of related published research, going quickly from generalities to specifics. Even good well-presented work will not get into high-impact-factor journals unless it is clearly novel and/or significant. Methods should allow the work to be repeated; ask yourself if they are clear and complete. Explain acronyms. Results should clearly tie figures and tables to text. Conclusions should relate back to the key message and be sufficiently supported by results. Discussion and conclusions should not just be re-stated results!

Ask a colleague, unconnected with the work, to read the "final" draft paper and comment on clarity. If they can't understand it, neither will the referees! Re-read it yourself after a time gap. Check journal requirements and comply! Hastily prepared submissions are usually poorly prepared! Badly written papers, not complying with requirements and including mistakes, e.g. in references, give the impression that the work may also be poor. Work with experienced authors initially (e.g. supervisor). Look critically at papers you read and note what you think works well. New writers can learn good practice by example. Good luck!

ii) One area that needs really careful attention is the clear presentation of results in tables, graphs and figures and this is often not well done in submitted papers. Specific advice on this will be summarized.

iii) One potentially difficult issue regarding writing a paper is the question of "Who should be an author?" Various guidelines regarding this issue will be presented.

iv) For reviewing papers (important to think about for authors to help foresee potential issues that can be dealt with up front, as well as if invited to review), this summary will outline the review process at several major journals and discuss the role of the reviewer. The obvious central role is to ensure the scientific accuracy of the paper being reviewed and to ensure it properly situates the paper in the current state-of-the-art without becoming a review paper. It is also important to ensure the paper properly reports the results of others and to identify plagiarism if at all possible. The role is not to have the paper written the way the reviewer would write it, but to help the author make their paper clearer and unambiguous. The issue of a referee's potential conflict of interest will be addressed.
Quality

Quality control and assurance are becoming ever more important in light of the increasing complexity of modern devices that use ionizing radiation. In most large hospitals, a staff member is designated as the quality officer. Clinical audits are considered more effective than ISO 9001 audits, mostly because the auditing team is comprised of peers rather than administrative personnel. An emerging area is risk assessment, reporting and analysis of events. In the future, these obligations may take up a larger portion of the time available to medical physicists.

Radiation protection

Unlike other medical disciplines, regulations on the safety of medical uses of ionizing radiation are stricter. In many countries, this increases the burden on medical physicists to contribute to radiation protection.

Conclusion

Guidelines and actual staffing levels create not one but a number of workforce models that describe how many posts are associated with different aspects of medical diagnostics and therapy.

The model is constantly changing, although the ongoing trend is towards a diminishing share of direct clinical work, with more emphasis on supervisory, safety-related, and quality control/assurance tasks with a commensurate decrease in medical physics research.

MPE01.2 - International Educational Standards: Can We Define a Common Medical Physics Curriculum?

Author(s): Raymond K. Wu1, Colin G. Orton2, Tomas Kron3, Ahmed Meghzifene4

1. What are the common requirements to be considered a qualified clinical medical physicist
2. How do IOMP and IMPCB collaborate on maintaining and upholding the standards
3. Who are the stakeholders
4. When do we expect to reach the different milestones

Abstract

The IOMP in May 2012 approved two policy statements: The Medical Physicist: Role and Responsibilities, and Basic Requirements for Education and Training of Medical Physicists. Earlier, the International Medical Physics Certification Board (IMPCB) was established on May 23rd, 2010 after many years of discussions and planning. The Constituting Panel of the IMPCB asked the same question as the caption title and wrote into the Bylaws and the Model Certification Program the goals to establish requirements for general and medical physics education, and clinical training. The publication of the two IOMP policy statements helped IMPCB to move forward and enabled its Accreditation Committee to develop the requirements for certification and accreditation. In 2013 the International Atomic Energy Agency (IAEA) published the Human Health Series No 25 with the endorsement of IOMP. The comprehensive collection of international data and the publication point to the fact that it is possible to harmonize the roles and responsibilities of clinically engaged medical physicists and the education and training requirements in many parts of the world. Further plans are being developed for collaborations between IMPCB and the IAEA to consider conducting special certification examinations for a group of medical physicists from regions not likely to create their own certification bodies in the near future. Recent initiatives of IOMP indicated the interest of collaborations between IOMP and IMPCB to work on medical physics certification matters. It has been proposed that the IOMP be assigned a special designation of Supporting Organization of IMPCB, with three members of the Board of Directors appointed by IOMP. In addition, the IMPCB is considering amending the Bylaws to reflect the leading role of IOMP. IMPCB will adopt the IOMP standards, and clarify that other certification models are acceptable. IMPCB recognizes that there are national/regional variations to certification in medical physics based on differences in national/regional legislation and educational traditions, so it gives to national and regional certification bodies considerable freedom to decide on the manner in which a given organization seeking IMPCB accreditation conducts the certification process. However, minimum education and clinical training criteria as well as continuing education and professional development are required for all IMPCB certified medical physicists.
MPE03 - RADIATION THERAPY
INVITED SPEAKER

MPE03.2 - In Vivo Dosimetry
Author(s): Ben Mijnheer
Department Of Radiation Oncology, The Netherlands Cancer Institute, Amsterdam/NETHERLANDS

The rationale for in vivo dosimetry (IVD) is to provide an accurate and independent verification of the overall treatment procedure. It is used to detect clinically relevant differences between planned and delivered dose, to record dose received by individual patients, and to fulfill legal requirements. It will enable the identification of potential errors in dose calculation, data transfer, dose delivery, patient setup, and changes in patient anatomy. The relation between IVD and other parts of the quality assurance (QA) process, such as the commissioning and QA of the treatment planning system and machine QA, will be elucidated.

After discussing briefly the main characteristics of the most commonly used (point) detector systems, the rapid development of EPIDs for 2-D, 3-D and even 4-D, patient dosimetry during advanced treatment techniques such as IMRT and VMAT, will be elucidated. The various ways of dose determination and dose reconstruction inside a patient will be reviewed. Methods to quantify differences between measured and predicted dose distributions will then be clarified, as well as tolerance and action levels when deviations are outside clinical criteria.

A number of examples will be given to illustrate the possibilities of different types of commercially available and in-house solutions of hard- and software used for IVD. Clinical experience of IVD during external beam radiotherapy showed that most errors were due to the properties of a specific plan, human errors in the clinic, and anatomical changes. These types of error can often not be traced by means of pre-treatment dose verification using phantom measurements or independent dose calculations. Anatomy changes and modification of patient setup can generally be observed by means of in-room imaging. However, 3D IVD can compliment IGRT because it quantifies the dosimetric effects of these variations. Follow up actions, including inspection of in-room imaging data, followed by phantom measurements and improvement of procedures, if required, will be discussed.

Specific problems related to the use of IVD during brachytherapy, such as the use of a detector with a small volume and a well-defined position with respect to patient anatomy and source configuration, will be elucidated. The role of IVD in proton and ion radiotherapy by measuring the decay of radiation-induced radionuclides will also be discussed.

Large scale introduction of IVD requires implementation of a fully automated process that is integrated in the clinical workflow. Several approaches yielding alerts without or with limited human intervention will be compared.

Finally recent developments and future approaches such as real-time IVD, enabling the linac to halt in case of serious delivery errors, time-resolved dose verification, and the use of IVD during adaptive radiotherapy techniques will be discussed.

Learning objectives

1. To elucidate the rationale and type of errors that can be detected with in vivo dosimetry
2. To describe the instrumentation and techniques applied for in vivo dosimetry
3. To review the current clinical experience and future developments of in vivo dosimetry

MPE04 - QUALITY AND SAFETY

MPE04.1 - Quality Framework: The Canadian Partnership for Quality Radiotherapy
Author(s): Michael Milosevic
Radiation Medicine Program, Princess Margaret Cancer Centre, Toronto/CANADA

Radiotherapy is an important curative and palliative treatment for cancer that is indicated in 40-50% of patients. Quality assurance plays a critical role in radiation treatment planning and delivery. Driven by an urgent need to harmonize radiation treatment quality and safety in Canada, the Canadian Partnership for Quality in Radiotherapy (CPQR) was established through collaboration with national professional associations involved in radiation treatment delivery. CPQR has focussed its efforts on the creation of guidelines to measure and support programmatic quality assurance, maintain high quality radiation treatment technologies, and support incident learning and management. CPQR has uniquely incorporated a patient perspective into all of its activities, and developed a national guideline to motivate patient engagement in radiation treatment quality and safety at the individual program level.

Moving forward, priority will be placed on incorporating key CPQR deliverables into national accreditation programs, defining pan-Canadian system performance metrics for radiation treatment quality and safety, and strengthening international collaboration to support global harmonization of best practice.

At the conclusion of this program, attendees will:

Understand the stakeholder engagement model used by CPQR to build a national program of radiation treatment quality and safety
Understand how key CPQR initiatives in programmatic quality assurance, equipment quality control and national incident learning have harmonized practice across Canada and improved system resilience
Be aware of opportunities to collaborate with CPQR to improve radiotherapy quality and safety, either at the level of individual treatment programs or on a regional or national scale

MPE04.2 - Radiation Oncology Practice Accreditation in the United States
Author(s): Steven De Boer
Radiation Medicine, Roswell Park Cancer Insitute, Buffalo/NY/UNITED STATES OF AMERICA

Learning Objectives:

After attending this presentation the attendee should
1. Have an understanding of the accreditation process for Radiation Oncology facilities.
2. Know the importance of attaining practice accreditation.
3. Know the different regulatory requirements for practice accreditation.

Accreditation of a Radiation Oncology practice in the United States consists of the evaluation of an entire practice by an independent accrediting body, ensuring that it meets or exceeds guidelines.

The process varies between the different accrediting bodies, but commonly consists of ensuring that
MPE05 - COMPUTERIZED SYSTEMS

MPE05.1 - Database Rudiments and Clinical Use

Author(s): John Kildea
Medical Physics, McGill University Health Centre, Montreal/CANADA

Electronic databases are found everywhere in modern society, nowhere more so than in a radiotherapy department. However, few people understand how databases store data and even fewer are equipped with the tools to extract them. With just a little guidance it is possible to delve into any modern database and extract useful information. This workshop will cover the basics of database design and describe the tools available to extract useful data.

At the conclusion of the CE program, attendees will be able to:

1) Describe how a modern database is structured and how data is stored in relational tables
2) Download and install simple software to connect to a database
3) Write simple SQL queries.

MPE05.2 - Modern Radiotherapy Treatment Planning: Capabilities, Commissioning, and Clinical Use

Author(s): Benedick A. Fraass
Department Of Radiation Oncology, Cedars-Sinai Medical Center, Los Angeles/CA/UNITED STATES OF AMERICA

Learning Objectives:

1. Describe capabilities of modern radiation therapy treatment planning systems.
2. Summarize the clinical commissioning process and how that information can be used.
3. Illustrate ways to incorporate modern treatment planning methods into clinical use.

Modern radiation therapy treatment planning systems incorporate many advanced tools for planning, including automated segmentation (contouring), fusion of imaging datasets from multiple modalities, use of multileaf collimators, intensity modulated radiation therapy (IMRT) and volume modulated arc therapy (VMAT), image guided radiation therapy (IGRT) and advanced dose calculation algorithms. Appropriate clinical use of these advanced capabilities requires detailed and careful clinical commissioning of a multitude of functions and capabilities, followed by use of that commissioning information to educate planners, physicians, physicists about the proper use of those tools and algorithms. This presentation will summarize available modern radiotherapy treatment planning functionality, describe clinical commissioning of these complex systems, and make comments about ways to incorporate these capabilities into safe and effective clinical use.
Four-dimensional computed tomography (4D-CT) imaging has become a staple for providing 3D dynamic anatomical information used in modern radiotherapy of tumours influenced by respiratory motion. A 4D-CT dataset is composed of a time series of 3D images at multiple phases of the patient’s breathing cycle. This is accomplished by acquiring multiple projections of the same anatomical space under free breathing conditions and retrospectively binning either the projection data or sequentially acquired 2D axial slices according to a breathing trace that was acquired simultaneously. For projection binning, the CT scanner operates in low-pitch helical mode, where the pitch is related to the patient’s breathing period. For image binning, the CT scanner operates in ciné mode, where time series of images are acquired over an entire breathing cycle at one fixed couch position then reacquired at sequential couch positions until the intended scan range is imaged. While 4D-CT scanning improves image quality compared to free-breathing 3D imaging, artifacts are still present, mostly due to irregular breathing patterns exhibited by many patients. As a result, sorting algorithms combine volumes from temporally misaligned respiratory phases into a single volume. Many methods have been proposed to improve 4D-CT sorting methods for irregular breathing patients, including phase tagging adjustment, respiratory trace manipulation, amplitude-based sorting methods, and non-linear image registration. Despite these improvements, motion artifacts can also be induced due to poor correlation between the motion of the internal anatomy and that of the respiratory surrogate. Retrospective binning of 4D-CT data in the absence of an external surrogate has been proposed and has shown to reduce motion artifacts. The resulting 4D-CT dataset can be used to define an envelope of the gross-tumour volume (GTV) for conventional free-breathing treatment delivery or one or more phases can be chosen for respiratory-gated radiotherapy. In both scenarios, multiple methods have been proposed that utilize the 4D-CT dataset to construct the internal target volume (ITV), including manual delineation, auto-segmentation, or maximum intensity projection (MIP) generation via registration to the planning CT, which in itself can be a single 4D-CT phase, an average of the 4D-CT dataset, or ideally, the entire 4D-CT dataset. In the latter case, dose calculations are performed on each respiratory phase and through deformable registration the dose is summed over all phases. Although the advantages of 4D-CT imaging in modern radiotherapy of mobile tumours is clear, implementation into routine clinical practice is not necessarily straightforward. We are, therefore, proposing a CE program that is intended to address 4D-CT imaging technology, reconstruction methods, and practical solutions to common problems such as clinical implementation of 4D-CT, interpretation of 4D-CT for irregular breathing patients, construction of a planning target volume (PTV) for 4D-radiotherapy, and 4D-treatment planning considerations. Extension of 4D imaging to positron emission tomography (PET) and magnetic resonance imaging (MRI) will also be presented.
MPE07 - RADIATION SAFETY

MPE07.1 - What can IAEA do for the Clinical Medical Physicist?  
Author(s): Joanna Iżewska, Ahmed Meghzifene  
Nuclear Sciences And Applications, International Atomic Energy Agency, Vienna/AUSTRIA

Learning objectives: (1) to learn about IAEA activities in dosimetry and medical radiation physics; (2) to get acquainted with IAEA educational material and training opportunities; (3) to learn about IAEA technical assistance for medical physicists.

Shortage of medical physicists, insufficient education and training opportunities, and lack of professional recognition exist in several countries. To address these issues the IAEA conducts systematic and comprehensive activities in support of medical radiation physics worldwide. They are related to education and training, scientific advice and guidance, research and development and also include technical services.

Recently, an IAEA report has been published that defines the roles and responsibilities of a clinically qualified medical physicist in radiotherapy, diagnostic radiology and nuclear medicine. The document, endorsed by IOMP and AAPM, also recommends minimum requirements for the academic education and clinical training, and for continuous professional development. It also addresses other topics of interest for the profession.

Three IAEA handbooks for teachers and students provide the basis for education of medical physicists initiating their university studies in radiotherapy, diagnostic radiology and nuclear medicine. These volumes are supplemented by a collection of slides prepared for all book chapters. The IAEA also developed training packages for clinical residents in medical physics. This teaching material has been adopted by many universities and hospital training centres worldwide. Multiple technical reports, guidance documents and advisory books are a useful resource for medical physicists in specific areas of their activities. ‘Human Health Campus’ website serves as an educational resource for professionals and students involved in radiation medicine.

For long time, the IAEA has maintained an interest in standardization and development of Codes of Practice (CoP) for dosimetry with several publications in the field. One important example is the TRS-398 CoP that is in use in most world regions. A new CoP for small radiotherapy fields is under preparation. There is also a long tradition of organizing conferences and symposia in dosimetry and medical radiation physics to foster the exchange of information among professionals and to highlight developments in the field.

Regional and national training courses, workshops and fellowships are available for medical physicists to upgrade their skills and practices. These activities lead to improvement of the professional status, enhance specialist capabilities and strengthen medical physicists’ contributions to radiation medicine development. Opportunities exist for participation in co-ordinated research efforts, with some projects leading to a doctoral degree.

The IAEA support to medical physics also includes technical assistance for implementing and reviewing QA programmes at hospitals. Traceable dosimetry calibration services are provided through the IAEA/VWHO Network of SSDLs to promote accurate measurements of radiation doses. Dosimetry audits in radiotherapy and comprehensive clinical audits are offered by the IAEA to radiation medicine clinics. In particular, the IAEA/VWHO postal dose audit service for radiotherapy dosimetry has been in operation for over 46 years and checked radiotherapy beam calibrations in 2000 hospitals in 130 countries.

To conclude, multiple IAEA projects are in operation at various levels, which help in the development and growth of the medical physics profession worldwide.

MPE07.2 - Safety Learning and Safety Management to Prevent Radiotherapy Incidents  
Author(s): Ola Holmberg  
Radiation Protection Of Patients Unit, IAEA, Vienna/AUSTRIA

Radiation protection of patients must deal with the issues of not having dose limits, purposely exposing sensitive subgroups, and purposely using doses that could cause deterministic effects. While medical uses of ionizing radiation have been of tremendous value to the global population for nearly 120 years, it could be noted that radiation accidents involving medical uses have accounted for more deaths and early acute health effects than any other type of radiation accident, including accidents at nuclear facilities.

Safety reporting in radiotherapy can be mandatory or voluntary. There may be mandatory reporting to health authorities and/or radiation regulatory authorities in a single country, depending on the regulations in place. There are two types of events to consider in relation to mandatory safety reporting to the authorities. First, there are the recordable events that are errors that do not meet regulatory reporting requirements, but could indicate a gap in patient care. These are usually reviewed by the regulatory authority during an inspection or audit. The second type are the reportable events, or those events that have exceeded some threshold defined by a regulatory agency. The reported events should be focused on incidents with serious actual or potential outcomes, such as injury or death.

Mandatory reporting should focus on these serious events in order to avoid obscuring the incidents that need to be investigated.

On the other hand, voluntary reporting systems are often confidential and focus on events and outcomes, instead of regulatory sanctions. They can capture “less serious” and near miss events with the purpose being to share knowledge on safety-related events and conditions and on lessons learned to improve the safety environment and patient outcomes. These reporting systems encourage institutions to focus on improvement of the safety environment; protect institutions from the legal system, handle information with confidentiality and allow for anonymous reporting of errors or circumstances that could lead to errors. An incident in another hospital can lead to identification of the hazard before a similar incident is realized locally. By collecting data from a large pool of events, better defined “lessons to learn” can be created that may improve patient safety.

The IAEA has developed a voluntary safety reporting system for radiotherapy. This is called Safety in Radiation Oncology (SAFRON). The system has incorporated data from other international, national and local reporting systems, and data directly from SAFRON participants, in order to make radiotherapy safety information more accessible. In addition, this database also provides links to publications of interest in the evaluation of incidents, lessons learned, and corrective actions. The system is designed to educate facilities about incidents and corrective actions.

In addition to looking at the characteristics of this system, such as severity scales and process steps, the seminar will also look at some other database elements forming the structure of safety reporting and learning systems in practice, such as safety barriers, causes and contributing factors. Additionally, practical operation of the system and dissemination of information will be discussed.

At the conclusion of the CE program, attendees will be able to

1. Understand differences in objectives and characteristics of mandatory and voluntary safety reporting in medical uses of ionizing radiation
2. Define and describe the different elements needed to form the structure of safety reporting and learning systems in practice, such as severity scales, process steps, causes and contributing factors
3. Apply safety barriers (equipment or processes) to radiotherapy in practice, in order to strengthen safety and prevent unintended irradiation of patients

MPE07.3 - Equipment Standards and Performance Measurements for Radiotherapy Systems
Author(s): Jean M. Moran
Radiation Oncology, University of Michigan, Ann Arbor/MI/UNITED STATES OF AMERICA

Equipment standards continue to evolve with the increased complexity of treatment delivery systems. Guidance from the American Association of Physicists in Medicine (AAPM), such as that defined in Task Group 142, will be presented with respect to quality assurance (QA) standards and test frequency for linear accelerators. Mechanical, dosimetric and system safety checks will be described. In addition, Medical Physics Practice Guidelines are also becoming available from AAPM. These publicly available reports differ from Task Group reports and some impact radiotherapy system QA. The elements of the available guidelines will be presented. Finally, the evolving tools and techniques for performing QA will be discussed.

At the conclusion of the CE program, attendees will be able to
Describe the major elements of a radiotherapy system QA program
Learn about the different types of guidance available from the AAPM
Learn about evolving techniques and tools for performing QA measurements

MPE08 - QUALITY AND SAFETY
MPE08.1 - Quality Systems in Radiotherapy
Author(s): Mary Coffey
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Quality and safety are inextricably linked in radiotherapy. This is clearly expressed in the European Society for Radiotherapy and Oncology (ESTRO) Vision statement 1.1: ‘Optimal individualised patient care will be achieved by integrating new clinical and preclinical evidence from biology, molecular/functional imaging and the use of new systemic agents together with the delivery of high precision radiation therapy in a safety aware environment’.

In many instances the failures in radiotherapy, which have had catastrophic outcomes, are the result of system failures involving one or more steps in the radiotherapy process. Quality in radiotherapy is multifaceted and encompasses the full spectrum from referral to follow-up addressing both technical and clinical aspects: ‘total quality management’.

Technical quality commences with the equipment purchase decision and subsequent commissioning procedures. Clinical quality commences with accurate diagnosis including staging and grading and review at a multidisciplinary meeting. These first stages can be influenced by a range of external factors and are often outside the direct control of the radiotherapy team. Comprehensive clinical audits, such as the IAEA QUATRO programme can identify problems within the process and, as such, can directly influence quality.

Following referral to radiotherapy the radiotherapy team has a responsibility to ensure that the treatment prescribed is the treatment that the patient receives. From a technical perspective assurance that the dose set is the dose delivered is controlled by practices such as daily output measurements, in vivo dosimetry and dose verification for procedures such as IMRT coupled with the routine quality assurance procedures.

Peer review is an important factor in ensuring clinical quality and can include peer-to-peer discussion, chart review prior to first treatment and peer review of volume delineation. A recent paper by Tol et al describes how different treatment planning protocols can lead to large differences in organ at risk (OAR) sparing and other publications previously have identified the importance of adherence to protocol in minimizing dose to the OARs.

Ensuring accurate treatment delivery requires care and attention to positioning and immobilisation. This includes correct selection of the immobilisation method, regular monitoring of equipment and verification of the treatment delivered.

Quality systems in radiotherapy must also include human factors and the impact of the rapid changes currently taking place in our discipline. “Change is creating new paths for failure and new demands on worker(s) … revising their understanding of these paths is an important aspect of work on safety … missing the side effects of change is the most common form of failure for organisations and individuals”

Learning Outcomes
To be able to discuss the spectrum of quality aspects in radiotherapy
To be able to describe the process of an external comprehensive clinical audit and its role in quality
To be able to review quality processes in their own department
MPE08.2 - Cost and Resource Management of Radiotherapy
Author(s): Peter Duncombe
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The cost of health care in the 34 countries of the Organisation for Economic Cooperation and Development had been rising twice as fast as GDP up until 2009. The financial events of 2008 have tempered this growth with a third of OECD countries now reporting a decrease in per capita expenditure on health care over the period 2009-2011. Particularly as we continue to be beset with financial uncertainty, many over indebted countries and many more facing continuing negative growth, we can expect downward pressures on health care budgets to continue. Analyses suggest that the direct costs of cancer care to the health care system are around 5%. Societal costs of cancer including lost productivity and informal care actually exceed direct health care costs – a fact that we often lose sight of. However, considering the magnitude of the cancer problem, which can only increase with an aging population across the globe, cancer treatment still represents a relatively small part of the overall health care budget. And within the cancer treatment budget, radiotherapy represents less than 10%. Although the contribution of radiotherapy to overall direct health care budgets is small, <1%, we would be naïve in thinking that its relative financial insignificance will shield radiotherapy from the economic realities of today’s world. In order to justify budgets and to maintain accessible, high quality radiotherapy for the benefit of the 50% of cancer patients for whom it is indicated we need to have a much better idea of the costs and benefits of this essential modality.

In this presentation we’ll look at the economic data that support the contentions made above, search the literature for radiotherapy costing studies and examine a few relevant studies in more detail. The presentation will conclude with a brief overview of ESTRO’s Health Economics in Radiation Oncology project.

At the conclusion of the CE program, attendees will be able to:
1. Identify sources of data on health care funding and its distribution.
2. Discuss the literature on radiotherapy costing studies.
3. Appreciate ESTRO’s Health Economics in Radiation Oncology initiative.

MPE09 - RADIATION THERAPY

MPE09.1 - The Modern Physicist Tool Box: How to Choose Between Current Dosimeters
Author(s):

Learning Objectives

To review the basic principles of radiation detector dosimetry
To review the dosimetry protocols for conventional and small radiation fields
To provide an overview and a suitability discussion of dosimeters for a particular clinical applications including conventional and small fields

Dosimetric accuracy remains of paramount importance in a context of image-guided radiation therapy using clinical protocols that increasingly make use of hypofractionation with high doses per fraction. Over the past decade radiation dosimetry has seen developments including novel radiation standards for absorbed dose to water, unprecedented accuracy in the determination of correction factors for detectors and new formalisms for dosimetry of small static and dynamic radiation fields. At the same time, manufacturers have brought new water-equivalent and perturbation-friendly detectors on the market. This presentation reviews some basic aspects of detector dosimetry, new detectors and their suitability for measuring absorbed dose in challenging dosimetric conditions.

MPE09.2 - Radiobiology Applications for Clinical Physicists: Isoeffective dose calculations; Hypofractionation; TCP/NTCP; Peripheral doses and secondary cancers
Author(s): Michael Joiner
Department Of Oncology, Wayne State University, Detroit/MI/UNITED STATES OF AMERICA

The Linear-Quadratic (LQ) formulation deals specifically with the relationship between total dose and dose per fraction, and with interfraction interval using the Incomplete-Repair derivative model. The LQ description has been thoroughly tested in the clinical domain, but almost always in the “conventional” range of dose per fraction below 6 Gy. LQ is the simplest mathematical description of a non-linear relationship and though empirical in nature, it has nevertheless been subject to many attempts to connect with our understanding of how radiation injury is produced and repaired at the cell and molecular level. Yet any meaningful and clinically useful link in this respect has remained elusive. The relationship between total dose and overall treatment time is an even more complex relationship dependent on the different underlying radiobiology of different tissues even within the apparently same category of early-reacting or late-reacting tissues, distinguished by respectively a “high” or “low” ratio of α/β in the LQ equation. Overall time is therefore better handled independently of LQ.

A straightforward but untested hypothesis for the different α/β values for early- and late-reacting tissues, is that a naturally low α/β for a target cell population is smoothed out to a higher value as the sum of the responses of different proliferative subpopulations, and different phases of the cell cycle that these are in. This explanation could be applied to the responses of malignancies in the lung and head and neck, also adding in the additional response variation of cells at various levels of hypoxia in these sites. Of note is the connection between outcome of radiotherapy and HPV status in oropharyngeal cancers, which implies a possible difference in treatment strategy between these tumor subtypes and could also explain the high α/β of head and neck cancer overall as the sum of the responses of the different cancer subtypes (HPV + and −) which could...
both have low $\alpha/\beta$ but different radiosensitivity. In some malignancies, notably prostate and breast, clinical data do indeed indicate a low $\alpha/\beta$ which might also reflect more uniformity in response perhaps more characteristic of lower proliferative or early-stage disease. This has resulted in new efforts to test hypofractionation which have also been enabled by better dose localization achievable with image-guided Volumetric Modulated Arc Therapy.

There is evidence that the LQ model becomes less reliable at doses per fraction < 1 Gy, due to possible low-dose hyper-radiosensitivity, and also at > 6 Gy per fraction for reasons not yet understood though increasing vascular damage and immunological/inflammatory effects occur at higher doses per fraction. It is axiomatic that LQ must indeed overestimate effect at very high doses per fraction because the effective D0 would become unrealistically low. This makes the outcome of hypofractionated regimes less predictable: using LQ at high doses per fraction would be playing safe in predicting toxicity of hypofractionation, while overestimating the effect on the target malignancy, noting that possible hypoxia in a tumor could also limit the effectiveness of large dose fractions.

Learning Objectives

1. Understand that the simplest two-parameter LQ model is a utility for describing the relationship between total dose and dose per fraction for isoeffect
2. Know the dose range of 1-6 Gy per fraction over which using the LQ model can be most relied upon
3. Be aware of the underlying radiobiology which may explain responses at low or high dose per fraction to be inadequately predicted by LQ extrapolation of the response to 1-6 Gy per fraction

MPE10.2 - Treatment Planning Optimization: IMRT and VMAT
Author(s): Jan Unkelbach
Radiation Oncology, Massachusetts General Hospital, Boston/MA/UNITED STATES OF AMERICA

Learning objectives:

Understand the concepts of fluence map optimization (FMO), leaf sequencing, and direct aperture optimization (DAO), which form the components used to assemble modern IMRT and VMAT planning algorithms.

Understand the formulation of VMAT planning as an optimization problem that aims to determine the trajectories of multi-leaf collimator leaves while the gantry rotates around the patient.

Understand the state-of-the-art in VMAT planning from an algorithmic perspective in the research literature and in commercial implementations.

Abstract:

Treatment planning for external beam radiotherapy is formulated as a large-scale mathematical optimization problem, which determines the machine parameters of the treatment device to achieve a desired dose distribution in the patient. Treatment plan optimization for intensity-modulated radiotherapy (IMRT) was historically developed as a two-step approach. In the first step, the fluence maps of incident beams are optimized; in the second step, a leaf sequencing
algorithm converts the fluence maps into a sequence of apertures that can be delivered using a multi-leaf collimator (MLC). These two steps, fluence map optimization (FMO) and sequencing, are still important components in modern treatment planning systems (TPS). However, advanced TPS adopt direct aperture optimization (DAO) methods, which aim at directly optimizing the shape and intensity of MLC openings. DAO methods partially overcome some of the drawbacks of the two-step approach, such as degradation of the FMO dose distribution during the sequencing step.

Over the past years, volumetric modulated arc therapy (VMAT) has found widespread clinical application. In VMAT delivery, the gantry continuously rotates around the patient while the treatment beam is on and delivers radiation, promising shorter delivery times compared to step-and-shoot IMRT. Many treatment planning studies have since compared VMAT and IMRT in terms of plan quality and delivery time. In contrast, publications on the mathematical optimization algorithms used in VMAT planning are scarce. VMAT planning ultimately aims at optimizing the trajectories of MLC leaves while the gantry rotates around the patient. Unlike FMO, this represents an inherently non-convex optimization problem. Most VMAT algorithms, including the commercial implementations, use the concepts of FMO, leaf sequencing, and DAO that were originally developed for IMRT, and adapt these methods to VMAT. VMAT implementations differ in the component they rely on the most and the exact implementation of each step.

The presentation will briefly review basic concepts in treatment plan optimization, but will subsequently focus on the state-of-the-art in IMRT and VMAT planning from an algorithmic perspective. Implementations in commercial systems are explained and approaches suggested in the research literature are presented.

### MPE11 - RADIATION THERAPY

#### MPE11.1 - Linear Accelerator Technology

**Author(s):** Malcolm R. Mcewen  
Measurement Science And Standards, National Research Council, Ottawa/ON/CANADA

**Learning objectives:**

- Understand how an electron linear accelerator works to produce electron and photon beams.
- Understand the commonalities between different manufacturers’ machines and also the important differences.
- Understand what is physically being controlled by the software running on the linac workstation.

Electron linear accelerators are the workhorses of today’s radiation therapy clinics. This presentation will aim to take the covers off a modern linac and show the different components that are required to produce, accelerate and deliver the primary electron beam to the treatment head. Clinical users are often quite familiar with the treatment delivery ‘end’ of a linac (target, flattening filters, MLC, etc) so the focus of this presentation will be on the other parts of a linac, where perhaps the medical physicist has the least day-to-day experience – the electron gun, modulator, rf source, waveguide and bending magnets. The aim is to open up what has perhaps become a black (or more often, white) box. The presentation will trace the history of linac development since the 1950s to the present day and show that the modern machines of 2015 have more in common with those early accelerators than one might think.

The following systems will be dealt with in some detail:

- rf sources/amplifiers (magnetron and klystron)
- high-power modulator design
- vacuum components
- electron gun (diode and triode)
- beam transport and bending magnets

The intention is to cover the designs from the major manufacturers of rotational gantry-based linear accelerators.

Although this session is aimed primarily at clinical medical physics involved in using linear accelerator technology it has been designed to be accessible to those without a highly technical understanding of linacs.

#### MPE11.2 - Reference Dosimetry and its Uncertainties

**Author(s):** David W.O. Rogers, Malcolm R. Mcewen  
1Physics, Carleton University, Ottawa/CANADA, 2Measurement Science And Standards, National Research Council, Ottawa/ON/CANADA

**Learning objectives:**

- to understand the advances in photon beam reference dosimetry since 2000 (i.e., since publication of TRS-398 and TG-51).

- to be aware of the implications for reference dosimetry when using FFF (flattening filter free) linac beams.
- to understand the uncertainties in calculated values of kQ (= kQ,Qo).
to understand which ion chambers are suitable for reference dosimetry.

to be able to assess the various corrections needed (ion recombination, polarity, beam non-uniformity, etc).

to understand the uncertainties associated with reference dosimetry.

“Best Practice” reference dosimetry requires two components to obtain the calibration of an external beam radiation device:

1. Accurate input parameters (calibration coefficients, conversion factors), and


Calibration coefficients are determined by the primary, or secondary, standards laboratory and would be a presentation in themselves, so this session will look at conversion factors (e.g., $k_Q$ factors, perturbation factors) and ion chamber measurements. Although the presentation will focus on the two most widely-used external beam protocols (IAEA TRS-398 and AAPM TG-51) the issues discussed will be applicable to other national protocols and codes of practice currently in use.

Part 1 – Conversion factors and beam quality specifiers.

Since 2000 there have been studies (mostly Monte Carlo) which demonstrated that the data used then for the various correction factors making up $k_Q (P_{wall}, P_{rep}, P_{cell})$ were individually wrong by up to 1%. Fortunately the calculated $k_Q$ factors ($k_{Q,0}$ in TRS-398) only depend on ratios of these factors and the errors in $k_Q$ were therefore somewhat less. One study showed that the %dd(10), and $TPR_{20,10}$ beam quality specifiers were equivalent for clinical beams with flattening filters. However, since then it has become common to use linacs without flattening filters and this leads to complications which will be discussed.

To overcome issues with the individual correction factors, it is possible to calculate $k_Q$ values directly using Monte Carlo techniques with an uncertainty of 0.4% to 0.5%. When compared to measurements of $k_Q$ for 26 different ion chamber models (with uncertainties of 0.3% for reference class chambers), the agreement was excellent, with $\chi^2/df$ values less than 1. The calculated values fall on smooth curves as a function of %dd(10), except for chambers with high-Z electrodes, which are not suitable for reference dosimetry for other reasons as well. The talk will present the experimental and calculated values to demonstrate each of the above statements.

Part 2 – uncertainty and the clinical medical physicist

As part of any measurement it is essential to estimate the uncertainty in the result obtained. Development of an uncertainty budget is not just a matter of obtaining a value; the steps followed to construct an uncertainty budget are, in fact, a process review that feeds directly into the quality documentation and procedures used by each institution.

This part of the session will examine the primary components of uncertainty in an absorbed dose to water measurement and describe how they depend on the user’s experimental method, the choice of chamber, etc. We deconstruct the basic measurement equations found in dosimetry protocols to understand what is required to obtain an accurate and precise determination of $D_w$. Issues that become apparent in doing this include the correct choice of ion chamber type, the errors that can arise from inadequate detector characterization, and the importance of understanding the performance of all systems that contribute to the final measurement.

Carrying out this analysis will demonstrate that the clinical medical physicist is not simply someone following a recipe, but is actively involved in impacting the overall uncertainty in reference dose measurements.
### MPE12 - COMPUTERIZED SYSTEMS

**MPE12.1 - Image Registration**  
**Author(s):** Michael Velec  
Techna Institute, University Health Network, Toronto/ON/CANADA

Multiple imaging modalities are now commonly used to diagnose and classify disease. For radiation oncology in particular, tumor representations from several images need to be combined to define the treatment target and serial imaging is then used to guide therapy. Registration is the process by which the information in these images is combined into one model of the patient and exploited. Algorithms differ widely in how they function and therefore each have specific clinical scenarios where they are better suited. Recently deformable registration algorithms are being adopted for more advanced applications, adding further complexity to treatment processes. Understanding methods to assess if image registration is performing accurately, and techniques to apply when it is not, are essential to ensure that treatment accuracy is maintained.

At the conclusion of this session, attendees will be able to:

1) Describe fundamental components of image registration using common rigid and deformable algorithm examples
2) Understand quantitative and qualitative methods to perform validation and quality assurance for image registration
3) Discuss strategies to make tradeoffs between image registration limitations and clinical goals, using examples scenarios

**MPE12.2 - Automated Segmentation of Images for Treatment Planning Purposes**  
**Author(s):** Greg Sharp  
Radiation Oncology, Massachusetts General Hospital, Boston/MA/UNITED STATES OF AMERICA

Automatic segmentation holds great promise for improving radiotherapy practice. Although it is primarily regarded as a method for increasing efficiency, automatic segmentation can also play a role in improving standardization and consistency. The application of segmentation to clinical research is also of interest, because it can easily scale up to large numbers of patients for retrospective studies. This CE session is intended to provide a gentle, but complete, introduction to the algorithms and expected performance of radiotherapy auto-contouring software.

The goals of the CE session are to provide understanding of

- Algorithms commonly used in automatic image segmentation software
- Methods for evaluating segmentation accuracy
- Expected segmentation accuracy for commonly segmented organs-at-risk

### MPE13 - MEDICAL PHYSICS EDUCATION AND PROFESSIONAL ISSUES

**MPE13.1 - Advocacy for Physicists and How to Deal with Government, Unions, Regulators, and Employers**  
**Author(s):** Jerry J. Battista¹, Wayne Beckham²  
¹Medical Biophysics, Western University, London/CANADA, ²Medical Physics, BC Cancer Agency - Vancouver Island Centre, Victoria/BC/CANADA

**Learning Objectives:**

To understand that a medical physics career evolves to the point of requiring administrative and negotiating skills

To recognize the need to interact with governments, regulators, unions, and employers

To understand the “hot buttons” in dealing with non-scientific interactions

Medical physicists are fortunate to enjoy a career with such wide diversity in activities but the priority of each activity changes over the course of a career. Early career is focused on acquiring necessary clinical skills in the safe administration of diagnostic or therapeutic medical procedures. If there is a concurrent university appointment, this also requires some level of activity in teaching and research, initially supported by internal grants and potentially growing to nationally peer-reviewed levels. In time, the physicist is assigned progressively more supervisory roles and significant administrative duties. Interactions with hospital administrators, legislative agencies at the provincial and federal levels, and employee unions expand. The role then requires an abrupt mental shift for scientists as discussions extend beyond having good data and logic. In dealing with hospital executives, a delicate balance of budget restraint, excellent patient services, and risk management must be struck. In dealing with government regulators, attention to procedural details and a population (macroscopic) perspective is needed for justifying acquisition and assuring safety compliance of all technology. In dealing with unions, fair play of the employee and relationship with the employer is the focus, under all foreseeable circumstances. Endless hours are expended in interpreting, applying or editing collective agreements for word precision describing “what if” scenarios such as displacement of employees by technological advances. In summary, medical physicists working in hospital environments must be prepared to advocate well beyond their core scientific know-how. A stronger background in budgeting, presentation of proposals and arguments at the lay level, understanding legislative language, and “big picture” viewpoints is needed. Without such preparation, future leadership of medical physics programs may be assigned to non-physicists.
Uncertainties can be classified as systematic (e.g. source calibration) or random (e.g. interfraction variations). Recently, a lot of effort has been made to analyze dosimetric variations occurring due to anatomical changes, within and between different BT fractions for cervical cancer. For example, a multicenter study (Nesvacil et al. 2013, Radiother Oncol 107:20-25) revealed random intra- and inter-fraction uncertainties of the order of 10% for D90 of HR CTV and 20-30% for D2cm³ for organs at risk, for the physical dose of each BT fraction. In this case inter-/intra-fraction variations can be considered as the main contributors to the total uncertainty of the delivered BT doses. While dosimetric variations for the target appear to be dominated by contouring uncertainties, variations for OARs are also influenced by their changes in location and filling, as well as movements of the applicator and target in relation to the OARs.

In a hyperfractionated BT treatment protocol observed uncertainties of physical fraction dose will also lead to an accumulated uncertainty of the whole BT treatment dose (in EQD2) – which (including contributions from EBRT to the overall treatment) is used to analyze clinical dose-response relationships.

Comparison of examples for different types of uncertainties for various BT applications, tumour sites, OARs, and different treatment schedules, might help to define future goals and strategies to further increase precision in modern IGABT, and to better understand dose constraints for BT planning.

The main learning objectives of this presentation are:

To get an overview of the uncertainty budget in modern 3D IAGBT

To understand the correlation between dosimetric uncertainties and reporting of total treatment doses for different clinical sites and treatment schedules

To improve understanding of the consequences of uncertainties in the delivered dose for the usability of dose-response models in clinical decision making (definition of planning aims and decisions for/against use of IGABT vs IGBT without re-imaging before each irradiation, for individual patients)

Increasing availability of 3D image guided adaptive brachytherapy (IGABT) treatment techniques, allow us to tailor dose distributions for each individual patient to the specific anatomy and reduce risks of side effects, while increasing the dose to the tumour. However, individual dose plan optimization is always affected by dosimetric uncertainties that may lead to a difference between prescribed and delivered dose.

In this presentation we will review the most recent reports on uncertainties in brachytherapy and discuss the impact of different types of uncertainties on our understanding of dose-response analysis.

The sources of uncertainties can be of technological nature (source calibration, dose calculation and dose delivery), or due to the clinical workflow and anatomy of the patient (applicator movement, delineation uncertainties, anatomical changes (inter-/ or intra-fraction variations)). Recent reports highlight the magnitude of different types of uncertainties for different BT treatment sites (Tanderup et al. 2013, Radiother Oncol 107:1-5, Kirisits et al. 2014, Radiother Oncol 110:199-212, and references therein).
MPE15.1 - Managing Respiratory Motion in Radiation Oncology  

Author(s): Paul Keall  
Radiation Physics Laboratory, University of Sydney, University of Sydney/AUSTRALIA

Learning objectives

1. Understand the clinical drivers for respiratory motion management in radiation oncology.
2. Understand how respiratory motion management occurs at multiple stages of the patient treatment cycle.
3. Understand the current status of respiratory motion management technology in radiation oncology.

Presentation Description

One of the most exciting and dynamic areas of academic and clinical radiation oncology is the management of respiratory motion in radiation oncology. New technologies are being invented, innovations are occurring on existing technology and the growth of clinical data and findings is staggering.

Respiratory motion management in radiation oncology can be broadly classed into the four interconnecting areas where technology and the patient interact: (1) Imaging for treatment planning; (2) Treatment planning; (3) Pre-treatment imaging and (4) Treatment delivery.

In this talk the clinical drivers for respiratory motion management and associated technological development drivers will be described. Current clinical standards for the four broad respiratory motion management areas will be explained. Near and long term directions for respiratory motion management, including the interaction of respiratory motion management technologies with other emerging cancer imaging and treatment modalities will given.

MPE15.2 - RadOnc Treatment Management Systems and the Paperless Treatment Process  

Author(s): Benedick A. Fraass  
Department Of Radiation Oncology, Cedars-Sinai Medical Center, Los Angeles/CA/UNITED STATES OF AMERICA

Learning Objectives:

1. To describe differences between the traditional treatment process and the treatment process in a paperless environment.
2. To discuss the differences between paperless and truly electronic medical record and treatment management systems.
3. To discuss the issues involved in integrating quality assurance and safety concerns into our paperless and/or electronic treatment process.

Over the last decade, the radiation therapy planning and delivery process has morphed from a manual paper-chart-based process to one which is implemented with computerized treatment management systems (TMS) and electronic medical record (EMR) systems. The paperless process has numerous advantages over the older paper-based system as well as some disadvantages, especially when old techniques are carried over into the paperless environment. This presentation will discuss differences between traditional and paperless approaches and describe some of the quality assurance and safety concerns which must be properly handled in the new environment. The progress that the field of radiation oncology has made from “paperless” to fully implemented computerized TMS and EMR systems will be reviewed and evaluated.
**MPE16 - RADIATION THERAPY**

**MPE16.1 - Specialized Units: Tomotherapy and CyberKnife Systems**

**Author(s):** Martina Descovich¹, Robert J. Staton²

¹Radiation Oncology, University of California San Francisco, San Francisco/UNITED STATES OF AMERICA, ²Radiation Oncology, UF Health Cancer Center - Orlando Health, Orlando/UNITED STATES OF AMERICA

The continual advances in radiation therapy technology lead to the development of specialized treatment units. The design and function of TomoTherapy & Cyberknife systems is significantly different than traditional medical linear accelerators. This session will provide an overview of the TomoTherapy and Cyberknife systems covering design and operation, available image guidance techniques, and quality assurance recommendations. Treatment workflow, clinical applications, and treatment planning techniques will also be discussed and compared.

**Educational Objectives:**

1. Understand the core concepts of Tomotherapy & Cyberknife treatment delivery.
2. Understand the image guidance options for Tomotherapy & Cyberknife machines.
3. Understand the QA procedures for Tomotherapy & Cyberknife.

**MPE16.2 - Heavy Particle / Light Ion Therapy**

**Author(s):** Oliver Jäkel

Medical Physics In Radiation Oncology, German Cancer Research Center, Heidelberg/GERMANY

Proton beam radiotherapy celebrates it’s 60th birthday in 2015, but already 2 years after the first proton treatment in Berkeley, also helium was introduced for radiotherapy. Heavier ions like carbon, nitrogen, neon, silicon and argon have also been used for radiotherapy at Berkeley between 1977 and 1992.

After the Berkeley trials ended, the first clinical treatment facility started its operation in Chiba, Japan in 1994 with carbon ions. In Germany an experimental facility opened in 1997 and was the first facility to establish intensity modulated beam scanning for carbon ions. In the meantime five clinical centers are existing in Japan, four in Europe and two in China. One of the most advanced facilities opened in 2009 at Heidelberg University; it is the only facility with an isocentric scanning gantry for ions and also offers beams of helium and oxygen ions for pre-clinical research.

In the presentation the physics and radiobiological rationale for ion beam radiotherapy is outlined. Some current research topics in the field of medical physics will be highlighted and the status of ion beam therapy in the world as well as the current clinical evidence will be summarized.

At the conclusion of the CE program, attendees will be able to:

1. Describe the physics and radiobiological rationale for using ion beams in radiotherapy
2. Describe how the physics of ions is connected to the biological effectiveness
3. Describe the most important research directions for ions and the existing clinical evidence for carbon ions

**MPE17 - RADIATION THERAPY**

**MPE17.1 - Chemotherapy and its Influence on Radiotherapy: Basics for Clinical Physicists**

**Author(s):** Eva Bezak¹, Michael P. Brown²

¹School Of Physical Sciences, University of Adelaide, Adelaide/SA/AUSTRALIA, ²Cancer Clinical Trials Unit, Royal Adelaide Hospital, Adelaide/AUSTRALIA

In this lecture the following learning objectives are aimed at:

1. To revise the role and basic principles of chemotherapy in cancer treatment.
2. To develop understanding of biological rationale for combined radiation and chemotherapy.
3. To review most common chemotherapy agents in current clinical use.

Cancer therapy of the last two decades has been marked by rapid development of combined therapies, especially of conventional chemotherapy (CHT) drugs with radiotherapy (RT).

While a complete understanding of biological mechanisms behind combined therapies is still being investigated, clinical trials have demonstrated improved survival for a number of cancers, including head and neck, stomach, oesophagus, lung, pancreas, colon, breast, glioblastoma multiforme and others. Some of the main chemotherapy agents are cisplatin, gemcitabine, tirapazamine (TPZ), temozolomide (TMZ) and 5-Fu (Fluouracil) and analogous (1, 2).

The basic rationale for combined chemo/radiotherapy lies in so-called spatial cooperation of the two modalities; with RT affecting the local tumour and systemic chemotherapy sterilizing the diseminated clonogenic cells (3). Additionally, the main objective is to enhance tumour response without enhancing normal tissue complications (the process known as radiosensitization). Chemotherapeutic agents target different physiological characteristics of the tumour, including hypoxia that is generally associated with tumour radiore sistance. Other group of drugs (so-called radioprotectors) are used to reduce/mitigate normal tissue injury without compromising the tumour response (4).

The enhanced tumour response or radioprotection can be achieved with varying degrees of additivity, depending on the mechanisms of interaction of the drug and radiation and their interplay. Clinical data suggest that many of the enhanced tumour effects result from simple additivity; i.e. there is no direct interaction between the chemotherapy agent and radiation. Normal tissue protection, on the other hand, is often most pronounced when drugs are administered more closely to irradiation. The optimum scheduling and combinations are, however, still being investigated. Currently used scheduling has been in general developed from clinical trials and supported by modelling (1, 5).

The main/known mechanisms of interaction between drugs and radiation and the resultant additive and synergistic effects include: enhancement of DNA damage (i.e. change in the slope of the dose-response curve), formation of additional DNA adducts, interference with DNA repair processes (e.g. inhibition of repair of sublethal damage), enhancement of apoptosis, inhibition of proliferation, perturbation of cell kinetics (e.g. an increase of a number of cells in the sensitive cell cycle phase), hypoxic cell sensitization, inhibition of angiogenesis, and interference with signalling pathways.

The interaction between a chemotherapy agent and radiation is dose and time dependent, including drug dose and scheduling, time sequencing between drug and radiation delivery, radiation dose dosee as well as fractionation schedule. There seems to be lesser
dependence on the tumour/tissue type.

References:


MPE17.2 - Models of Delivery of Radiation Therapy (Private, Public, BCCA/CCO, etc).

Author(s): Michael Sherar1, Thomas Mcgowan2
1Cancer Care Ontario, Toronto/ON/CANADA, 2Oncology, The Cancer Centre Bahamas & The Cancer Centre Eastern Caribbean, Nassau/BAHAMAS

Around the world, the mix of private and public delivery of radiation therapy services varies. The challenge for any model of payment for and provision of services is the assurance of and continual improvement of quality, including equitable access to services for the entire population. An examination of where the public and private sectors have been successful, and the challenges each type of model faces in different parts of the world is useful as we look to the problem of how to expand access to high quality radiation services globally.

Cancer Care Ontario (CCO) oversees the planning of and public payment for publically provided radiation therapy services in Ontario. There is no private involvement. Interestingly, the private sector did have a role in the evolution of Cancer Care Ontario to its current state. In the latter part of the last century long waiting lists in Ontario required sending 1,000 patients a year to the United States for care. A short term private sector contract (but using public hospital facilities) was put in place to eliminate out of country rereferrals, and bring the waiting list down. This wait times crisis was a key factor in changing CCO’s role from being a provider to become a purchaser and quality improvement agency. Provision of services was reintegrated with local hospitals. Quality improvement according to provincial standards is driven as part of the Ontario Cancer Plan. Provincial and regional clinical leaders work with Regional Cancer Program Vice Presidents to drive quality improvement across all facilities. The benefits of a strong public provincial program including central capital planning and a population level approach are described as well as an analysis of some of the key challenges facing the Ontario system.

In contrast, The Bahamas provides an example of where the private sector played an essential role as it was able to provide the capital, and management expertise to build and operate a radiation facility in an environment where the government could not realistically afford to do so. Through a partnered care model, the private facility treats both public and private patients to the same standard, but provides radiation services to public patients at a reduced cost. This partnered care model is successful enough that the same private sector provider, at the request of the government of Antigua and Barbuda, is building a similar facility to provide care for the population of The Eastern Caribbean.

The global problem of access to radiotherapy will be not solved through a single approach. We will need to learn from best practice in a variety of environments to tailor a solution to each environment.

Learning Objectives:

1. Understand the benefits and challenges of the both public and private payment and delivery models for radiation therapy.
2. Understand the challenges of improving global access to radiation therapy in the context of public, private or mixed payment and service delivery solutions.
3. Understand how the mix of public and private involvement in a radiation therapy delivery model can be dependent upon the local political and economic environment.
MPE18.1 - Curriculum Design: How to Train the Next Generation of Physicists?

Author(s): John Damilakis
Medical Physics, UNIVERSITY OF CRETE, HERAKLION/GREECE

The International Organization for Medical Physics states in its Policy Statement No. 2 that 'Medical Physicists working as health professionals shall demonstrate competency in their discipline by obtaining the appropriate educational qualification and clinical competency training in one or more sub-fields of medical physics. Basic knowledge of the other sub-fields is also required. Medical Physicists practicing in hospital/clinical environments shall also participate in a continual professional development program'. Recommendations on the minimum levels of education and training for medical physicists are given in the same document. This lecture will present guidelines and recommendations developed by international organizations on the requirements for the education and training necessary for a physicist to become a clinically qualified medical physicist. These guidelines can be used for the development of the local curriculum for medical physicists.

An increasing number of higher education institutions have in recent years started to offer courses on Medical Physics. Moreover, Continuing Professional Development (CPD) for medical physicists is of great professional interest. CPD courses is an excellent way to ensure that Medical Physicists become knowledgeable about all current issues in their field and to provide the necessary knowledge, skills and competences for certified Medical Physicists to become Medical Physics Experts. However, external assessment of the quality of education or training provision is needed. Accreditation is the formal recognition that education and training on medical physics provided by an institution meets acceptable levels of quality. Accreditation should be based upon standards and guidelines. Requirements for accreditation of a training programme should take into account several aspects including facilities, staff, educational material and teaching methods.

EUTEMPE-RX is a European Commission (EC) funded project which aims to provide training opportunities to medical physicists in diagnostic and interventional radiology to become Medical Physics Experts i.e. to reach level 8 according to the European Qualification Framework (EQF). A network of excellent teaching centers in medical physics has been set up to develop a set of modules. The courses will achieve their learning objectives combining online with face-to-face teaching. More information about EUTEMPE-RX can be found at www.eutempe-rx.eu.

Learning Objectives

1. To present curricula for postgraduate education program on Medical Physics
2. To present guidelines and recommendations developed by international organizations on the requirements for the education and training necessary for a physicist to become a clinically qualified medical physicist
3. To discuss issues related to accreditation of the education and training in Medical Physics

MPE18.2 - Professional Standards and Certification of Qualified Individuals

Author(s): Matthew Schmid\(^1\), Geoffrey Ibbott\(^2\)
\(^1\)Medical Physics, BC Cancer Agency - Southern Interior, Kelowna/CANADA, \(^2\)Radiation Physics, UT MD Anderson Cancer Center, Houston/UNITED STATES OF AMERICA

Learning Objectives: 1. Understand the 4 underlying principles that form the basis for a certification program: a. Providing an examination process b. Providing a maintenance of certification (recertification) program c. Providing a public registry d. Providing a disciplinary process 2. Be familiar with the specifics of the CCPM and ABR certification processes (eligibility requirements, exam process) 3. Be familiar with the CCPM recertification process and the ABR maintenance of certification process. Abstract: The Canadian College of Physicists in Medicine (CCPM) exists to protect the public by: (a) establishing standards of competence for those involved in the application of the physical sciences in the medical field in Canada. (b) identifying individuals who meet the established standards and maintaining a registry of these individuals. Similarly, the American Board of Radiology (ABR) has as its mission: To certify that our diplomates demonstrate the requisite knowledge, skill, and understanding of their disciplines to the benefit of patients. This talk will focus on how the CCPM and the ABR meet these objectives. By way of introduction, a brief description of the structure and governance of the CCPM and of the ABR will be presented. The core business of any certification organization is centered around its examination process. The eligibility requirements for membership in each board will be detailed, along with a description of the examination process. After initial certification has been obtained, both the CCPM and the ABR require that all members meet the requirements of an on-going maintenance of certification (recertification) program in order to maintain their certification status. The structure of the MOC program will be presented. Members of the CCPM are required to comply with the Code of Ethics stated in the Regulations of the College, and this will be briefly discussed, along with a description of the disciplinary process in place to ensure member compliance with the Regulations of the College. The ABR is not a membership organization, but certification carries with it the expectation that the diplomate meet appropriate professional standards.
MPE19 - RADIATION THERAPY

MPE19.1 - Commissioning, Clinical Implementation and Quality Assurance for Stereotactic Body Radiation Therapy

Author(s):

Stereotactic Body Radiotherapy (SBRT) has been applied clinically for over two decades. The accumulation of published technical and clinical studies currently have has offered insights into both the efficacy and special concerns associated with the delivery of SBRT to different sites. The safe and effective delivery of SBRT requires careful attention to many unique technical aspects, including dosimetry of small photon fields; management of respiratory motion; immobilization, localization and image guidance; accurate dose calculation; quality assurance; and understanding of normal tissue constraints to high dose irradiation. This session will provide an overview of these important technical considerations, guidance on safe and effective implementation in the main disease sites, and a survey of reported clinical outcomes.

At the conclusion of the CE program, attendees will be able to:

1. Describe key elements of initial SBRT equipment commissioning, patient-specific QA, and routine periodic machine performance QA;
2. Describe and discuss processes for small field dosimetry, and understand limitations in available algorithms for dose calculation;
3. Describe and discuss practical issues associated with patient immobilization, motion management, use of image guidance for accurate localization;
4. Describe and discuss standard treatment regimens and normal tissue dose constraints, to incorporate clinical and technical principles into their disease site-based programs of their own.

MPF01 - IMAGERIE

MPF01.1 - Tomodensitométrie: Les Nouveaux Développements et Avenues de Recherche

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Objectifs d'apprentissage

1) Apprécier l'évolution technologique de la tomodensitométrie depuis l'avènement des appareils multicoupes.
2) Comprendre les enjeux de radioprotection associés à la tomodensitométrie et reconnaître l'apport de diverses approches pour réduire la dose.
3) Découvrir de nouvelles applications en tomodensitométrie ainsi que les avenues de recherche actuelles, notamment en imagerie bi-énergie et en reconstructions tomographiques avancées.

La tomodensitométrie (TDM) n’a pas connu de bouleversements majeurs depuis l’avènement des appareils multicoupes et des acquisitions héliocidales. Cependant, cette technologie n’a pas cessé d’évoluer pour autant. L’évolution de la TDM au cours des dernières années sera abordée durant cette présentation selon différents points de vue: technologique, social et médical. D’un point de vue technologique, la TDM peut désormais compter sur une puissance de calcul numérique bonifiée, permettant l’exécution d’algorithmes de reconstruction plus performants en des temps raisonnables. Les processeurs graphiques (GPU) à architecture hautement parallélique, notamment, permettent aujourd’hui l’exécution rapide d’algorithmes itératifs où un modèle physique de détection est utilisé durant la reconstruction. Cette approche peut mener à des images de meilleure qualité acquises à des doses inférieures pour le patient. D’un point de vue social, le recours de plus en plus fréquent à la TDM et son accessibilité toujours grandissante ont soulevé des questions importantes en radioprotection. Les fabricants d’appareils TDM, bien conscients de ces enjeux, proposent aujourd’hui des technologies destinées à minimiser la dose au patient; celles-ci seront revues et discutées. D’un point de vue médicale, la TDM permet aujourd’hui davantage d’applications grâce à certaines innovations technologiques. Le cas de l’imagerie bi-énergie sera revu et discuté. Finalement, les avenues de recherche actuelles en TDM seront abordées, tant d’un point de vue technologique que médical.

ENGLISH

Computed Tomography: new developments and research avenues

Learning objectives

Appreciate the technical evolution of Computed Tomography (CT) since the advent of multislice devices. Understand the radiation safety challenges associated with CT and recognize the role of various approaches to reduce the dose to the patient. Discover new applications in CT as well as current research avenues, notably in dual-energy imaging and advanced tomographic reconstruction. Computed Tomography did not change significantly since the advent of multislice devices and helical acquisitions. However, this technology did not stop evolving altogether. The evolution of CT during the last few years will be reviewed from different points of view: technological, social and medical. From a technological perspective, CT can nowadays rely on unprecedented computing power, allowing the execution of advanced reconstruction algorithms in a reasonable time. Massively parallel Graphics Processing Units (GPUs), for instance, allow the use of complex physical models in iterative reconstruction. These approaches can yield better images acquired at lower patient exposures. From a public health perspective, the steadily increasing number of CT studies performed each year has drawn attention from the media and radiation safety authorities. CT manufacturers, well aware of this
The field of magnetic resonance imaging continues to develop both in terms of technological innovations and of novel clinical applications. Higher magnetic field strengths along with the development of accelerated acquisition methods have led to unforeseen applications because of previously unexploited contrast mechanisms. For example, the large susceptibility contrast available at fields of 3T and above has produced exquisite images of the human brain vasculature. Radio-frequency field inhomogeneity at high field was overcome by parallel transmission and this has led to the design of parallel excitation enabling faster image acquisition. Those are becoming useful in the clinical characterization of pathologies and may help tailor better treatment options. Meanwhile, combining information from multiple imaging modalities has the potential to refine the information extracted from images by highlighting the vascular and metabolic aspects of pathologies. This is expected to translate in improvements in diagnosis, treatment planning and therapy response.

At the conclusion of this presentation, attendees will be able to

Identify novel technological developments and novel contrasts in magnetic resonance imaging

Identify recent clinical application of magnetic resonance imaging

Identify where magnetic resonance imaging, alone or in combination with other imaging modalities, may further improve tissue characterization

**Learning Objectives**

1) Understand the information technology environment in the Health-care sector, more specifically in Radiation Therapy and Radiology.

2) Learn about the communication technologies used in Radiation Therapy and Radiology.
3) Establish the links between clinical needs and technology

**Summary**

In this presentation, the essential notions in IT necessary for Medical Physicists and Engineers operating in Radiation Therapy and Radiology will be explained. This presentation, based on my more than 10 years of experience in the management of CHUM’s Radiation Oncology Information System, is composed of three sections: file formats, communication and infrastructure.

In the first section, through the introduction of the elements and concepts surrounding information digitisation, understanding of file formats will be demystified. Using these new notions, the image file format for DICOM will be explained. The Radiation Therapy extension to DICOM (DICOM-RT) will also be covered. Through the use of practical examples, the difficulties and issues that can arise when manipulating and transferring DICOM files between information systems and applications will be touched upon, this will allow participants to better understand and solve these issues.

In the second section, an explanation of the most common network technology (TCP/IP) will be discussed, in addition to the communication technologies specific to the Healthcare sectors such as those used by DICOM and the standards covered by the HL7 group. In more detail, the concepts of IP networking and transport technologies such as Ethernet will be explained.

As one of the most important aspects of communication is security, especially in today’s context, the course will address this subject by covering the notions of authentication and authorisation. In addition, encryption and secured communications will be explained. All these notions should help participants understand the basics of configuring a safe network infrastructure.

There are important factors that have to be analysed when information is exchanged between two different systems, be it two different versions of the same software application or two different software applications. Because data can be modified by these exchanges, an information system manager has to understand these issues. Thus, this presentation will include a few examples of the dangers users are exposed to when exporting and/or importing data from one system to another.

Finally, the third section will overview the hardware and infrastructure required to run a Radiology Information System (RIS/PACS) and a Radiation Oncology Information System (ROIS). This section will cover database concepts as well as the technical details of the physical hardware to run such information systems (server, SAN, RAID).

**MPF03 - RADIOTHÉRAPIE**

**MPF03.1 - Appareils Spécialisés: Tomotherapy, CyberKnife, Brainlab, Gamma Knife**

**Author(s): Veronique Vallet**

**Ira, Centre hospitalier universitaire vaudois, Lausanne/SWITZERLAND**

La radiothérapie 3D, par modulación d’intensité (IMRT) ou d’arc-thérapie volumétrique modulée (VMAT), font de plus en plus partie des techniques habituelles de traitement. En revanche, d’autres installations de traitement, comme la Tomothérapie, le CyberKnife, le Novalis (Brainlab) et le GammaKnife, sont des systèmes moins couramment utilisés dans la pratique clinique. Ces installations permettent des traitements hautement spécialisés et ont un véritable potentiel d’amélioration des traitements. Les spécificités de ces installations impliquent d’autres manières de préparer et de délivrer les traitements.

**Les objectifs de ce cours sont les suivants:**

1. Décrire ces installations et mettant l’accent sur les différences par rapport à des accélérateurs linéaires “conventionnels”.
2. Montrer et décrire des plans de traitement typiques qui peuvent être obtenus avec ce type d’installations.
3. Décrire les avantages et les inconvénients de tels systèmes.

**ENGLISH**

3D conformal radiotherapy, intensity modulated radiotherapy (IMRT) or volumetric modulated arc therapy (VMAT), are increasingly used as standard treatment techniques. However, other treatment machine, such as TomoTherapy, CyberKnife, Novalis (Brainlab) and GammaKnife are less commonly used in clinical practice. These machines allow highly specialized treatment and have real potential to improve treatments quality. The specificities of these machines imply other ways to prepare and deliver treatments.

The objectives of this course are:

1. Describe the different treatment units focusing on their differences from “standard” linear accelerators
2. Show and describe typical treatment plans that can be achieved with this type of machines.
3. Describe the advantages and disadvantages of such systems.

**MPF03.2 - Curiethérapie Guidée par l’image**

**Author(s): Luc Beaulieu**

Radio-oncologie, CHU de Quebec, Quebec/CANADA

**Objectifs d’apprentissages**

- Identifier la ou les modalités d’imageries les plus appropriées selon le type de procédure de curiethérapie visée.
- Connaître les forces et les limites des diverses modalités.
- Reconnaître les nouveaux besoins dans le cadre d’un programme de contrôle de la qualité.
- Identifier les nouvelles techniques d’imagerie pertinentes au domaine.

La curiethérapie a connu une évolution importante grâce à l’apport de l’imagerie dans le processus de préparation (positionnement d’aiguilles, de cathéters et d’applicateurs) ainsi que dans celui de la planification des traitements. Dans ce dernier cas, le passage d’une planification de traitement 2D basée sur la localisation des cathéters...
et applicateurs vers une planification 3D basée sur la délimitation de volumes cibles et des organes à protéger a profondément transformé la pratique clinique. Pour un site comme la prostate, l’utilisation de l’imagerie en temps réel pour le guidage de l’insertion d’aiguilles ou encore de cathéters a révolutionné la curiethérapie pour ce site pour en faire une procédure rapide, précise et efficace, au plus grand bénéfice des patients.

Cette présentation, faite dans le cadre d’une session de formation continue, fera un survol des modalités d’imagerie les plus courantes en curiethérapie, notamment la tomodensitométrie, l’imagerie par ultrasons, l’imagerie par résonance magnétique ainsi que le tomographe par émission de positron comme modalité de support. Les avantages et inconvénients de chacune de ces modalités seront présentés. La question des besoins supplémentaires en terme de qualité de ces modalités pour assurer une planification de traitement optimale sera abordée.

Finalement quelques avancées en imagerie, telle que l’IRM multiparamétrique, ayant de fortes probabilités d’influer la pratique de la curiethérapie à court et moyen terme seront discutées.
MPF05 - QUALITÉ ET SÉCURITÉ

Title: Human Factors Engineering

Abstract – English

The constant increase in technological possibilities leads to a complexity of the interaction with the equipment and software used in medical physics and biomedical engineering. Human factors engineering can be used to reduce and prevent this complexification. This lecture will describe methods, practices and standards to achieve this. A case study will be presented to illustrate how to integrate those elements.

At the end of this lecture, you will be able to:

1. Describe and discuss means to improve human performance and reduce human error
2. Identify activities where it is possible to intervene to prevent human error
3. Consider appropriate standards and practices when designing, procuring or selecting equipment and software.

Abstract – Français

L’augmentation constante des possibilités technologiques entraîne une complexification de l’interaction avec les équipements et les logiciels utilisés en physique médicale et en génie biomédical. L’ingénierie des facteurs humains peut être mise à contribution pour réduire, et prévenir, cette complexification. Cette présentation décrit diverses méthodes, pratiques et normes pour y arriver. On illustrera le tout au moyen d’une étude de cas.

À la fin de cette présentation, vous serez en mesure de (d’)

Décrire et discuter de moyens pour améliorer la performance et à réduire l’erreur humaines
Identifier des activités où il est possible d’intervenir pour réduire l’erreur humaine
Tenir compte de normes et de pratiques appropriées lors de la conception, l’achat ou la sélection d’équipement ou de logiciels

Quality assurance guidance and indicators

The intent of this program is to provide national guidance and indicators to motivate continuous quality improvement in a radiation treatment program. The published document outlines the overarching organizational structure and processes that are required to assure high quality and safe radiotherapy, along with key quality indicators for programmatic assessment.

In 2014, CPQR, CPAC and Accreditation Canada partnered to develop a Radiotherapy module for the Accreditation Canada’s Qmentum program which uses a range of standards to focus on quality and safety. This module will adopt many of the indicators contained within CPQR’s document and will help assure long-term sustainability of quality and safety measures in radiotherapy. Performance will be publicly reported to motivate utilization across Canada.

Technical quality control guidance

The intent of this program is to provide direction for assuring optimal performance of radiotherapy equipment in programs across Canada. Several guidelines are published and others are to come. A structured process was developed in the creation or revision of each guideline. It includes an expert review and revision, a broad community consultation to assure relevance and practicality, validations in real-world clinical environment, endorsement by the Quality Assurance Radiation Safety Advisory Committee of COMP, and a sustainability plan to assure continued relevance over time.

National reporting system

The intent of this program is to provide radiotherapy programs with a national reporting system which will provide a tool to report, track and analyze incidents from their own center and anonymously from other Canadian centers. Learning from near misses and incidents that occur during treatment planning and delivery is a key element of quality assurance. CPQR is partnering with the Canadian Institute of Health Information (CIHI) on this project.

Patient satisfaction

The intent of this program is to establish an approach for measuring and reporting the patient experience in a meaningful way. A patient perspective will be integrated with each of the three other programs described above. In addition, new indicators of patient satisfaction and patient experience will be developed and incorporated into Qmentum program accreditation. We should not forget that the Patients and Canadian public are the ultimate beneficiaries of safe and effective radiation treatment.

MPF05.1 - Le Partenariat Canadien pour la Qualité en Radiothérapie

Author(s): Normand Frenière
Radio-oncologie, CSSSST - CHAUR, Trois-Rivières/Canada

Learning objectives:

1) Understand who the Canadian Partnership for Quality Radiotherapy is, its organizational structure and the opportunities to contribute
2) Be up-to-date with four priorities determined by CPQR which constitute the four main programs
3) Understand the process developed for the creation and revision of Technical quality control guidelines. Be up-to-date with guidelines published and those to come

Radiotherapy benefits to approximately 50% of cancer patients at some point in their cancer journey, either as curative treatment or to palliate symptoms. Currently, there are 42 radiotherapy programs across Canada. In 2010, national professional organizations involved in the delivery of radiation treatment in Canada founded the Canadian Partnership for Quality Radiotherapy (CPQR) with the objective to support the universal availability of high quality and safe radiotherapy for all Canadians. Professional organizations are: Canadian Association of Radiation Oncology (CARO), Canadian Organization of Medical Physicists (COMP) and Canadian Association of Medical Radiation Technologists (CAMRT). Strategic and financial support are provided by the Canadian Partnership Against Cancer (CPAC).

Four programs have been identified as offering the greatest potential to improve quality and safety and mitigate risk.

Quality assurance guidance and indicators

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In 2014, CPQR, CPAC and Accreditation Canada partnered to develop a Radiotherapy module for the Accreditation Canada’s Qmentum program which uses a range of standards to focus on quality and safety. This module will adopt many of the indicators contained within CPQR’s document and will help assure long-term sustainability of quality and safety measures in radiotherapy. Performance will be publicly reported to motivate utilization across Canada.

Technical quality control guidance

The intent of this program is to provide direction for assuring optimal performance of radiotherapy equipment in programs across Canada. Several guidelines are published and others are to come. A structured process was developed in the creation or revision of each guideline. It includes an expert review and revision, a broad community consultation to assure relevance and practicality, validations in real-world clinical environment, endorsement by the Quality Assurance Radiation Safety Advisory Committee of COMP, and a sustainability plan to assure continued relevance over time.

National reporting system

The intent of this program is to provide radiotherapy programs with a national reporting system which will provide a tool to report, track and analyze incidents from their own center and anonymously from other Canadian centers. Learning from near misses and incidents that occur during treatment planning and delivery is a key element of quality assurance. CPQR is partnering with the Canadian Institute of Health Information (CIHI) on this project.

Patient satisfaction

The intent of this program is to establish an approach for measuring and reporting the patient experience in a meaningful way. A patient perspective will be integrated with each of the three other programs described above. In addition, new indicators of patient satisfaction and patient experience will be developed and incorporated into Qmentum program accreditation. We should not forget that the Patients and Canadian public are the ultimate beneficiaries of safe and effective radiation treatment.
MPF06 - IMAGERIE

MPF06.1 - La Boîte à Outils du Physicien Moderne: Instruments de Contrôle de Qualité
Author(s): Alain Gauvin
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Une classification des tests sur la base du type de mesure est proposée. La construction de cette classification est effectuée de façon à se rapprocher de la quantité physique mesurée plutôt que de la composante de la chaîne d’imagerie faisant l’objet de la mesure. Cette façon regrouper les différentes mesures par type permet de bien faire ressortir les caractéristiques de l’instrumentation du physicien, et l’impact qu’ont ces caractéristiques sur les différentes mesures produites. Les situations où certaines caractéristiques des appareils de mesure ont un impact sur l’interprétation, voire la pertinence de certains tests sont discutées en détail. De plus, certains changements technologiques qui sont en cours sont aussi discutés, qu’il s’agisse de changement au niveau de l’appareillage de mesure, ou au niveau de la technologie de la chaîne d’imagerie faisant l’objet de cette mesure. De plus, il existe de nombreuses méthodes de mesure utilisant des objets de tous les jours pour mener à bien certains tests, souvent sans compromis au niveau de la qualité des mesures. Il est important d’identifier ces solutions de mesure simples et peu onéreuses en fonction de l’objectif recherché.

Finalement, les outils logiciels occupent un rôle croissant dans la pratique du physicien en imagerie médicale. Dans beaucoup de cas, il s’agit de méthodes d’appoint pour certains tests, par exemple en permettant l’analyse des valeurs obtenues. Dans d’autres cas, il s’agit plutôt de méthodes logicielles dont la portée est plus globale, comme pour la collecte, l’organisation ou la présentation des résultats du contrôle de la qualité. Finalement il devient de plus en importance pour le physicien de disposer de visibilité sur certains aspects de la connectivité de l’appareil. En effet, certaines mesures obtenues par le physicien sont souvent présentées à l’opérateur et expédiées par l’appareil vers d’autres systèmes, par exemple le produit dose-aire. Puisqu’il était déjà important pour le physicien d’assurer le bon fonctionnement de tels dispositifs, la communication des mêmes résultats doit naturellement elle aussi être scrutée par le physicien, ce qui introduit une nouvelle classe d’outils logiciels.

En somme, l’appareillage utilisé par le physicien médical est typiquement très onéreux en acquisition, mais aussi en entretien. La compréhension du fonctionnement de cet appareillage doit être attentivement recoupée avec la finalité des différents tests effectués par le physicien afin que l’investissement engende une valeur concomitante en termes de qualité et d’efficacité.

Au terme de cette session, les participants seront en mesure de

1- Comprendre la classification proposée pour les mesures effectuées par le physicien.
2- Comprendre le fonctionnement des différentes technologies utilisées pour chaque type de mesure de la classification, et certains enjeux découlant de ces technologies.

3- Connaître les outils logiciels employés par le physicien et la place croissante qu’ils occupent dans la pratique du physicien.

ENGLISH

The toolbox of contemporary medical physicists: quality control instruments.

The practice of medical physics in diagnostic radiology has evolved substantially in recent years. Obviously, this is largely due to changes in medical imaging technologies, in particular the transition to digital imaging. However, the development of some other new technologies has also led to the introduction of new categories of measurement and testing, for example display monitors. Moreover, the measuring instruments have themselves undergone substantial changes. Therefore, it is useful to present the test equipment used in the contemporary practice of medical physicists.

A classification based on the type of measurement is proposed. The construction of this classification is in contrast to an imaging system based approach, since the measurement of a given physical quantity can be required for many types of system. This in turn allows for a greater emphasis on the characteristics of measurement instruments, and on the impact that they have on the various types of use. In particular, some situations for which some of these characteristics have an impact of the interpretation, or even or the relevancy of some of the tests are described. In addition, some technological changes that are under way are also discussed, be it change in the measuring apparatus, or at the imaging chain technology. Furthermore, there are many methods of measurements using simple and inexpensive test objects to carry out certain tests, often with no compromise in the quality of the measurements. It is pertinent to identify these simple measurement solutions and their adequacy as a function of the survey objective.

Finally, software based tools occupy an increasingly important role in the practice of medical physicists. In some cases, these methods are used as an adjunct to some tests, for example for analyzing the values obtained. In other cases, they can be used for survey data collection and management. It is becoming more and more important for physicists to have some visibility on certain aspects of the connectivity of imaging systems. For example, some measurements obtained by the physicist are often also available to the operator and sent by the device to other systems, such as the dose-area product. Since it is important for the physicist to verify that imaging systems operate properly, the communication of the data pertaining to its operation must naturally also be verified by the physicist, which introduces a new class of software based tools in the physicist’s toolbox.

In summary, the equipment used by the medical physicist is typically expensive to acquire and maintain. Understanding how this equipment operates allows for the physicists to maximize the quality and the efficiency of the survey.

After this session, participants will be able to

1- Understand the proposed classification for the measurements carried out by the physicist.
2. Understand how different measurement technologies are used and some of the issues arising from the use of these technologies.
3. Know the software tools used by the physicist and the growing position which they occupy in the practice of the medical physicist.
MPF06.2 - La Radiologie Interventionnelle, Incluant un Survol des Nouvelles Technologies et Approches
Author(s): Cécile Salvat, Jérémie Ragot, Annick Gotti, Antonella Jean-Pierre
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La radiologie interventionnelle est définie par un consensus d’experts français comme l’ensemble des actes médicaux invasifs diagnostiques et/ou thérapeutiques ainsi que les actes chirurgicaux utilisation des rayonnements ionisants à visée de guidage per-procédure, y compris le contrôle.

La radiologie interventionnelle se développe considérablement depuis quelques années. Les applications cliniques de plus en plus audacieuses se multiplient tant sur le plan des équipements vasculaires dédiés qu’au bloc opératoire sur des arceaux de bloc. Le nombre d’actes de radiologie interventionnelle à visée thérapeutique, le plus souvent possible en ambulatoire pour améliorer la prise en charge du patient, croît chaque année en France au détriment d’autres actes chirurgicaux souvent plus invasifs et plus lourds pour le patient.

Les domaines de la cancérologie, de la cardiologie, de la neuroradiologie, de la radiologie interstitielle, tous sont concernés par les nombreuses innovations technologiques que proposent les constructeurs visant à améliorer la qualité de l’image. Les avancées technologiques concernant à la fois les matériels (capteurs, tubes, filtration...), les protocoles d’acquisition et les logiciels. Par conséquent, les procédures cliniques se réalisent avec des technologies de plus en plus complexes (acquisitions bi-plan, angiographie rotationnelle, roadmap 3D, acquisitions hybrides...) nécessitant des temps d’acquisition parfois très longs sous rayons X avec une formation des opérateurs de plus en plus pointue et évolutive. Les études en France constatent une augmentation globale de la dose patient en imagerie ces 10 dernières années et notamment dans le cadre des nouvelles approches thérapeutiques interventionnelles. Les accidents ou incidents en radiologie interventionnelle déclarés à l’Autorité de Sureté Nucléaire française ne représentent que 3 % des événements significatifs en radioprotection déclarés mais sont les plus graves enregistrés avec des effets déterministes importants chez le patient.

Nous présenterons les innovations technologiques proposées par les constructeurs ainsi que les paramètres qui sont à l’origine, en permanence, du compromis entre la dose et la qualité image nécessaire à l’élaboration du diagnostic et/ou des gestes thérapeutiques. Nous aborderons l’optimisation des protocoles et les outils de réduction de dose ainsi que l’arrivée récente sur le marché des DACS, logiciels de suivi et de cumul de dose patient dont le rôle est devenu incontournable.

Nous détaillerons le rôle essentiel que doit jouer le physicien médical, à l’interface entre les équipes médicales et les constructeurs, aidé par des outils désormais disponibles et de plus en plus performants, dans l’intérêt de la radioprotection du patient mais également des opérateurs.
A clear evolution is seen in the technology, mainly in the accelerators (cyclotrons, synchrocyclotrons, synchrotrons, planes linacs and new approaches) as well as in gantries to propose compact and cheaper solutions, including single room approaches (as with electrons-photons). Ancillary tools include specific solutions in treatment planning software, patient positioners, dosimetry and range verifier devices. The present tendency is to use pencil beam scanning to treat with intensity modulated proton beams, in combination with conventional methods of image guided radiation therapy, management of organ movements and adaptive therapy.

Clinical protocols include well accepted but rather rare locations (uveal melanoma, base of skull chordomas and chondrosarcomas, pediatric, radiosurgery for intracranial targets) and more common clinical sites including lung, breast and prostate, with a tendency to include all targets treated in radiation therapy with photons. There are also comparative studies with the use of heavier ions (e.g. Carbonne), which add radiobiological advantages to their physical specifications.

Research and development in the field include physical and engineering aspects (detectors, micro-beams, delivery systems, models and optimizations, robotics for positioning,...), radiation biology (equivalent doses, effects of dose rate, LET, neutrons, radiosensitizers...), and clinical research (combined treatments, hypofractionation, ...). The main limit to spread protontherapy today is the investment cost.

At the end of the CE program, attendees will be able to:
1- Describe the main physical interactions and dosimetric characteristics of clinical proton beams and define the existing technology and its evolution.
2- Understand the rational for existing and upcoming clinical protocols
3- Have a scope of the research and development programs in the field.

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MPF09 - IMAGERIE

MPF07.2 - Dosimétrie et Radioprotection en Radiologie

Author(s): Sylvain Deschénes
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Objectifs pédagogiques:

1. Connaître les radiations ionisantes et mieux comprendre leurs effets.
2. Mieux connaître les risques reliés à la radiation ionisante.
3. Connaître les bonnes pratiques en matière de radioprotection en imagerie diagnostique et interventionnelle.

Abrégé:

Au cours des quinze dernières années, plusieurs publications ont traité des risques reliés aux radiations ionisantes lors d'examsens de radiologie diagnostique et interventionnelle. Dans la même veine, des campagnes comme *Image gently* et *Image wisely* ont vu le jour afin de sensibiliser à cette réalité les institutions utilisant l'imagerie médicale. Or, de façon générale, les méthodes proposées afin d'évaluer quantitativement le risque associé à ce rayonnement s'accompagnent d'une certaine ambiguïté pour les niveaux de doses rencontrés en imagerie médicale. De plus, à l'heure d'une approche personnalisée de la médecine, cette estimation dosimétrique rencontre plus embûches : indicateurs de dose non standardisés, passage vers une dose à l'organe complexe, etc.

Parallèlement, on voit apparaître plusieurs articles de loi, notamment aux États-Unis, qui obligeront prochainement les établissements de santé à tenir un registre des doses reçues par leurs patients. Dans cette foulée, plusieurs logiciels sont apparus dans les dernières années afin d’offrir la possibilité d’effectuer un tel suivi.

Dans cette présentation, nous tâcherons de mieux comprendre les effets de la radiation ionisante sur le corps humain. Par la suite, les différents indicateurs de dose rencontrés en imagerie médicale diagnostique et interventionnelle seront présentés. L’emphase sera mise sur les deux types d’examens les plus irradiants en radiologie : la tomodensitométrie (CT-scan) et la radioscopie interventionnelle. Dans le cas du tomodensitomètre, les indicateurs proposés sont le Computed Tomography Dose Index (CTDI), le Size-Specific Dose Estimate (SSDE) et le Dose Length Product (DLP). La radioscopie, de son côté, présente la dose sous forme de produits dose-surface (Dose Area Product ou DAP) et de doses cumulées à la peau.

Nous verrons comment ces différents indicateurs peuvent être utilisés pour évaluer une valeur personnalisée sous forme de dose aux organes et de dose effective. Nous verrons aussi comment ces métriques permettent de calculer les niveaux de référence diagnostiques (NRD) aident à identifier les examens où la dose est potentiellement problématique, à optimiser les protocoles et à se comparer aux autres dans notre gestion de la dose. Des pistes de solution afin d’optimiser les procédures seront également présentées.

ENGLISH

Learning Objectives:

1. To understand the nature and effects of ionizing radiation.
2. To better understand the risks associated with ionizing radiation.
3. To learn good radioprotection practices in diagnostic and interventional imaging.
Abstract:

In the past fifteen years, there has been a growing interest for assessing the risks incurred by radiation exposure during diagnostic and interventional radiology procedures. As a result, campaigns such as Image Gently and Image Wisely have raised awareness regarding such issues. However, the information provided by radiological systems is oftentimes ambiguous, hindering the efforts to assess such risks. For example, in this age of personalized medicine, dose estimates have to address issues such as non-standardized dose indicators, the need for more accurate organ doses, etc.

Meanwhile, legislations have been or soon will be passed in North America regarding dose monitoring and reporting. For example, Bill 1237 is now enforced in California and it is a matter of time before such laws proliferate in many other states and countries. Accordingly, several software solutions are now offered to perform this monitoring.

In this talk, we will cover the nature of ionizing radiation and its effects on the human body. Then, we will introduce various dose indices describing patient’s exposure for diagnostic and interventional imaging modalities. Emphasis will be placed on CT-scan and interventional radioscopy since they deliver substantial radiation to the patient. For CT-scan, the relationship between Computed Tomography Dose Index (CTDI), Size-Specific Dose Estimate (SSDE) and Dose Length Product (DLP) will be explored. For radioscopy, we will show how Dose-Area-Product (DAP) and cumulative entrance skin dose describe patient’s irradiation.

We will finally see how these indices may be used to compute personalized dose reports where organ dose and effective dose are used to evaluate the risk for a specific patient. We will also see how computing Diagnostic Reference Levels (DRL) may help optimizing institutions protocols and identify exams where excessive dose has been delivered to a patient. Some tips will be provided to help minimize dose during procedures.
from significant changes (special causes) that disturb the process. Thanks to the statistical control limits, the effects of special causes can be detected, and then actions can be undertaken to reduce or eliminate their effects. A process that is only subject to random causes of variation is statistically under control and thus statistically predictable.

In the presentation, we will develop a practical example of the use of SPC in the field of Radiotherapy. We will show how SPC can be used to monitor the IMRT (Intensity Modulation Radiation Therapy) pre-treatment quality controls and to make the dose delivery process under control. The aim is to increase the security of each patient’s treatment while controlling the whole dose delivery process, without increasing time devoted to the analysis.

To conclude, SPC is a method that helps reducing the variability of a process, and thus decreasing the number of data out of specifications. We are convinced that SPC should secure and improve quality of many processes in radiotherapy and in health in general. It could serve as a common language to evaluate processes’ performance. Moreover, the ultimate goal of SPC is, considering a process is under control, to streamline the amount of quality control in a safe statistical environment by taking objective decisions to balance resources and quality.

À la fin de ce programme d'éducation continue, les participants seront en mesure de :

1- Décrire et discuter les principes de l'imagerie TEP, les technologies et les applications utilisées en médecine nucléaire diagnostique et en recherche biomédicale.

2- Comprendre les limitations physiques sous-jacentes et les possibilités d'amélioration de la modalité d'imagerie TEP.

3- Expliquer les divers avantages et limitations des différentes approches d'imagerie multimodales.
**Abstract:**
Radiotherapy consists in delivering ionizing radiation to the tumor while avoiding the surrounding normal tissue. Treatment efficacy is often limited by the resistance of tumors and the toxicity of healthy organs. Then prescription must represent a trade-off between risks and benefits. The dose-response curves for tumor control and normal tissue complications determine the therapeutic window that is the possibility of delivering a sufficient dose with an acceptable level of side-effects. The development of imaging modalities and treatment techniques aims at improving this therapeutic window. 3D and 4D imaging modalities allow to describe tumors and normal tissues and their motions. Intensity-modulated radiation therapy with static beams (IMRT) or arcs (VMAT), stereotactic body radiation therapy (SBRT) allow to deliver accurately highly conformal doses to the tumor and to spare a large volume of normal tissue. These developments that are changing the clinical practice are made possible thanks to the emergence of image-guided radiotherapy (IGRT).

IGRT is based on the acquisition of frequent in-room images during a course of radiotherapy. These images are used to verify the position of the target volume and/or the organs at risk with a higher frequency and a greater accuracy than portal images, more irradiating and of lower quality. IGRT integrates various imaging modalities that allow either direct visualization of the tumor by two-dimensional or three-dimensional images or indirect visualization of the tumor using surrogates such as implanted markers or bony structures. The anatomical data acquired during those imaging sessions lead to two types of decisions: the correction of the positioning and the modification of the treatment plan. After a rigid registration between planning images and in-room images, positioning of the tumor target can be corrected by moving the couch. This is done daily in radiotherapy departments. The treatment plan modification taking into account the anatomical deformations is more complex. It may impose one or more replanning during the course and requires the development and validation of tools not yet fully mature to date for clinical routine use. This is the concept of adaptive radiotherapy.

IGRT requires a close collaboration between physicians, technicians and physicists. Specific training should be put in place to help decision making when registering images. Depending on the therapeutic goal, the treatment site and the equipment, IGRT strategies may differ in terms of imaging modality and frequency. Each department should define its own protocols specifying the roles of each professional. The commissioning of the imaging systems should be performed by the physicists, whatever the modality (ionizing or non-ionizing, 2D or 3D, ...). In addition a quality control program should be implemented based on the international publications such as AAPM reports. The use of ionizing radiation devices raises the problem of the additional dose delivered to patients. The dose due to in-room imaging sessions should be estimated by measurements or calculations to be reported. The management of this extra dose should be part of on site IGRT protocols.

IGRT offers new treatment opportunities such as toxicity reduction, dose escalation, hypofractionation, voxelization and adaptation. But the clinical implementation requires the staff to perfectly define the goals (positioning and/or replanning) and the roles.

**Learning objectives:**
- To define errors occurring during the treatment and their clinical impact
- To list the different technologies currently available for the IGRT and their specific QA / to define the concept of adaptive radiotherapy
- To discuss the dose delivered by the different devices

**Objectifs d'apprentissage:**
(1) décrire les différents outils permettant de faire de la dosimétrie in vivo; (2) identifier les champs d'application et les avantages potentiels de cette pratique; (3) se familiariser avec différentes approches pour faire l'implantation clinique d'une stratégie de mesure in vivo.

En radiothérapie, la dosimétrie in vivo est généralement définie comme la mesure de la dose de radiation faite au moment même où un patient reçoit une fraction de son traitement. L'attrait de la dosimétrie in vivo est grand, puisqu'elle est la seule manière de connaître réellement la dose de radiation administrée au patient. Toutefois, malgré cet avantage notable, ce type de mesure n’est toujours pas utilisé à grande échelle. Dans de nombreuses cliniques en Amérique du Nord, la dosimétrie in vivo n’est utilisée que marginalement ou pour des cas très particuliers. Des sondages ont démontré que l’apparente lourdeur clinique de la dosimétrie in vivo est un obstacle majeur à son adoption généralisée.

Dans un premier temps, nous ferons l’inventaire des différents détecteurs pouvant être utilisés pour faire la mesure de dose in vivo. Nous présenterons les forces et les faiblesses d’un grand nombre d’instruments, allant des appareils embarqués servant à faire la mesure de la dose à la sortie du patient (imageur portal) jusqu’aux appareils implantables directement au voisinage d’une tumeur ou d’un organe à risque. Nous porterons aussi une attention particulière à l’utilisation de ces instruments dans des conditions non standard telles que les mesures hors du champ primaire de radiation, les mesures de très faibles doses de radiation ou les mesures de patrons de dose fortement modulés. À moins que des précautions ne soient prises, la mesure dans des conditions non standard peut introduire une erreur systématique dans l’évaluation de la dose.

Deuxièmement, nous ferons un survol des champs d’application où la dosimétrie in vivo offre un grand potentiel tel que le contrôle de la qualité et le suivi des patients tout au long de leur traitement par imagerie portale; l’évaluation des doses reçues par des appareils cardiaques implantables (pacemakers) et la protection des organes à risque dans la radiothérapie hautement conforme. Nous discuterons aussi des avantages d’intégrer un programme de dosimétrie in vivo avec une approche de radiothérapie adaptative.

Finalement, dans un troisième temps, nous verrons comment il est possible d’implanter une stratégie de mesure in vivo tout en minimisant son impact négatif sur le flot des opérations cliniques. Nous passerons en revue des exemples de centres ayant implanté de telles stratégies et nous présenterons les rôles et responsabilités de chaque intervenant (physicien, technologue, etc.) ainsi que les besoins de formation. Nous discuterons aussi des outils logiciels et autres systèmes de bases de données nécessaires pour stocker et analyser l’information recueillie et garantir un suivi et une rétroaction efficace.
Stereotactic Body Radiation Radiotherapy (SBRT) is rapidly expanding. This rising treatment strategy shows comparable clinical results with surgery concerning primitive tumors local control (Non-Small Cell Lung Cancer). SBRT can also significantly increase the overall survival of oligometastatic patients. This advanced technique classically delivers single or few fractionated large dose to tumors located in various sites of the body (thoracic, paraspinal, abdominal and pelvic sites). The treatment principle is based on the use of small size photon beams, providing high target conformity and narrow dose fall-off for better critical organs sparing. Consequently, this special treatment strategy requires a high level of accuracy, first, in the beam commissioning (dose measurements) and then, at each step of the treatment process, i.e simulation, treatment planning, delivery. The global uncertainty of the process must be kept as low as possible in order to keep clinical benefits without increasing the toxicity probability.

Key linac features that determine the SBRT feasibility are the beam collimation that allows a sharp beam penumbra and complex target management, and reliable image guidance. Various techniques can currently perform SBRT: conventional linac with appropriate image guidance, Tomotherapy™, Cyberknife™ and Vero™. In case of moving targets, additional systems exist to manage the patient breathing (breath hold, abdominal compression, Gating) in order to minimize the uncertainty due to target motion. Other solutions monitor the breathing patient combined with image guidance, and thus can allow a real time tumor tracking.

Imaging is crucial in SBRT because it helps to define the more precisely the target volume and position in the patient and it also guarantees the correct tumor targeting before and/or during the treatment delivery. Acquisitions parameters of the reference CT scan have to be optimized so that the best quality image is obtained (spatial resolution, contrast). 4D CT scan is necessary for all moving tumors as it gives the spatio-temporal position and deformation of the target. Multi-modality imaging, such as MRI, PET-CT and contrast-enhanced-CT, is mandatory too, to improve the tumor and critical organs delineation.

Concerning beam commissioning, critical aspect is the detector used for measurements. Caution must be paid to its resolution, volume and response considering the very small size beam. Performance of dose calculation algorithm is important especially in low density media because it can have a large impact on the isodose prescription. The periodic tests of Quality Assurance depend on the treatment delivery used for SBRT. For each new localisation to be validated, and regularly, End-to-End (E2E) tests are recommended. Many commercial E2E phantoms exist and help physicists to validate the overall workflow of the treatment.

The SBRT implementation in a clinic needs a robust educational program followed by all professionals involved in the patient treatment. These latter must refer to the recent published guidelines (AAPM Task Group 101 report, etc…). In parallel, an “a priori” risks analysis should be done to refine the workflow and patient safety. Then, incidents have to be reported as part of an Experience Feedback Committee program.

**Learning objectives:**

- To list the different technologies currently available for SBRT
- To discuss about the crucial points in the implementation of SBRT(dose measurements, algorithm, ...) and the periodic QA to perform

**Abstract:**

Stereotactic Body Radiation Radiotherapy (SBRT) is rapidly expanding. This rising treatment strategy shows comparable clinical results with surgery concerning primitive tumors local control (Non-Small Cell Lung Cancer). SBRT can also significantly increase the overall survival of oligometastatic patients. This advanced technique classically delivers single or few fractionated large dose to tumors located in various sites of the body (thoracic, paraspinal, abdominal and pelvic sites). The treatment principle is based on the use of small size photon beams, providing high target conformity and narrow dose fall-off for better critical organs sparing. Consequently, this special treatment strategy requires a high level of accuracy, first, in the beam commissioning (dose measurements) and then, at each step of the treatment process, i.e simulation, treatment planning, delivery. The global uncertainty of the process must be kept as low as possible in order to keep clinical benefits without increasing the toxicity probability.

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Key linac features that determine the SBRT feasibility are the beam collimation that allows a sharp beam penumbra and complex target management, and reliable image guidance. Various techniques can currently perform SBRT: conventional linac with appropriate image guidance, Tomotherapy™, Cyberknife™ and Vero™. In case of moving targets, additional systems exist to manage the patient breathing (breath hold, abdominal compression, Gating) in order to minimize the uncertainty due to target motion. Other solutions monitor the breathing patient combined with image guidance, and thus can allow a real time tumor tracking.

Imaging is crucial in SBRT because it helps to define the more precisely the target volume and position in the patient and it also guarantees the correct tumor targeting before and/or during the treatment delivery. Acquisitions parameters of the reference CT scan have to be optimized so that the best quality image is obtained (spatial resolution, contrast). 4D CT scan is necessary for all moving tumors as it gives the spatio-temporal position and deformation of the target. Multi-modality imaging, such as MRI, PET-CT and contrast-enhanced-CT, is mandatory too, to improve the tumor and critical organs delineation.

Concerning beam commissioning, critical aspect is the detector used for measurements. Caution must be paid to its resolution, volume and response considering the very small size beam. Performance of dose calculation algorithm is important especially in low density media because it can have a large impact on the isodose prescription. The periodic tests of Quality Assurance depend on the treatment delivery used for SBRT. For each new localisation to be validated, and regularly, End-to-End (E2E) tests are recommended. Many commercial E2E phantoms exist and help physicists to validate the overall workflow of the treatment.

The SBRT implementation in a clinic needs a robust educational program followed by all professionals involved in the patient treatment. These latter must refer to the recent published guidelines (AAPM Task Group 101 report, etc…). In parallel, an “a priori” risks analysis should be done to refine the workflow and patient safety. Then, incidents have to be reported as part of an Experience Feedback Committee program.
cette problématique des variations quotidiennes de la position du patient ainsi que de ses changements anatomiques. Les diverses stratégies d’adaptation visent à gérer le traitement d’un individu en identifiant et en quantifiant les variations propres au patient au cours de sa série de traitement et en utilisant ces informations pour optimiser le processus de planification et de délivrance du traitement. Toutes ces stratégies reposent sur l’utilisation d’une forme ou d’une autre d’imagerie embarquée, nous permettant d’obtenir des images planaires et/ou volumétriques du patient au moment même du traitement. C’est le développement récent de diverses technologies d’imagerie embarquée qui a rendu possible l’émergence de la thérapie adaptative.

Dans sa forme la plus simple, la thérapie adaptative se réduit à la radiothérapie guidée par l’image (IGRT : image guided radiation therapy) qui consiste au repositionnement quotidien du patient sans modification du plan initial. Des images planaires ou encore des images volumétriques sont comparées à des images de références acquises et/ou produites lors de la planification du traitement. Sur la base de cette comparaison, le patient est déplacé en translation et potentiellement aussi en rotation pour conformer sa position le plus possible à la position de planification.

En thérapie adaptative, on utilise l’information obtenue par l’imagerie embarquée pour modifier la planification initiale. Le processus d’adaptation peut-être relativement simple : modifier les marges de sécurité initiales après quelques observations et créer un second plan de traitement ; ou encore très complexe : créer un nouveau plan en temps réel avant chaque fraction.

Un survol des diverses stratégies d’adaptation sera présenté. Les processus techniques impliqués ainsi que les outils technologiques nécessaires seront discutés. L’expérience du CHU de Québec dans le traitement adaptatif au niveau pelvien (traitement de l’adénocarcinome de la prostate et du cancer de la vessie) et au niveau de la sphère ORL sera en autre utilisée pour illustrer le propos.

**ABSTRACT**

En thérapie adaptative, on utilise l’information obtenue par l’imagerie embarquée pour modifier la planification initiale. Le processus d’adaptation peut-être relativement simple : modifier les marges de sécurité initiales après quelques observations et créer un second plan de traitement ; ou encore très complexe : créer un nouveau plan en temps réel avant chaque fraction.

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**MPS01 - RADIATION THERAPY**

**MPS01.1 - Radiobiology Applications for Clinicians - Isoeffective Dose Calculations, Hypofractionation, TCP/NTCP**

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**Learning objectives:**

To understand the relationship between dose and dose per fraction in the dose response curves of late- and acute- response tissues as well as for tumours.

To learn how to do isoeffective calculations in clinical practice

To learn the basic of commonly used TCP and NTCP biological models and how they can help in clinical decisions

**ABSTRACT**

Isoeffective dose calculations

It is well known that the biological effect of a given absorbed dose of ionizing radiation depends on how this is distributed over time. Moreover, the steepness of the isoeffective curves obtained for different combinations of total dose and fraction size strongly vary among different tissues [1]. The Linear Quadratic (LQ) model has been extensively used to quantify the relationship between total isoeffective dose and dose per fraction in fractionated radiotherapy [2]. And so, parameters such as BED, EQD2, TE, NTD have been used in order to allow comparisons between different treatment schemes or, for example, to predict the effect on tumours/normal tissues of changes in fractionation. These concepts have regained interest in the last years with the new radiotherapy techniques which allow a better sparing of normal tissues and so larger fraction sizes can be explored. From the point of view of isoeffective dose calculations, the current status of modified fractionation schemes (with the respect to the conventional 1.8-2Gy fraction size) will be revised (hypo-, hiper- and acceleration fractionation).

And yet, the problem is more complex. The inhomogeneous dose distributions usually delivered during radiotherapy imply different fraction sizes for the different sub-volumes and consequently an inhomogeneous biological response throughout the irradiated volume (double-trouble effect) [3]. The above problem can be addressed by using BED distributions or, the more compact, Biologically Effective DVHs (BEDVHs). This approach is compulsory, for example, if external RT and brachytherapy techniques are going to be combined.

**TCP/NTCP models**

The end points which are truly relevant in radiotherapy are the probabilities of tumour control (TCP) and of toxicity of the normal tissues (NTCP). There are several reasons which justify why TCP and NTCP models are desirable [4]. The Marsden TCP model [3] and the Lyman model [5] will be presented as example of models which, correctly parameterized, reproduce the sigmoid shape of the dose-response curves. Clinical applications of those models will be also presented together with description of some freely available software (BIOPLAN and BioSuit) [6,7].

**References:**


Learning objectives:

Discuss about the actual requirements for dose calculation for complex radiotherapy techniques.

Discuss the different dose calculation algorithms and Monte Carlo simulation, and how the latter is implemented in commercial treatment planning systems.

Presenting full Monte Carlo simulation as alternative for treatment planning.

Abstract:

Several studies show that a prescription dose deviation of 5% may compromise tumor response and morbidity. Although the accuracy of dose delivered to the patient depends on multiple factors involved in the radiation therapy process, it is considered that the criterion of acceptability for dose calculation algorithms ranges between 2% and 5% in dose. The dose calculation is performed with different degree of success by means of analytical algorithms such as convolution methods, collapsed cone, pencil-beam with corrections, convolution/superposition or anisotropic analytical algorithm. Apart from the electron beams, the dose distribution with photon beams can be calculated accurately enough in most of cases by means the planning system based on analytical algorithms. Nevertheless, when the radiotherapy techniques use a highly conformed radiation treatment, the media heterogeneities in the path of the photon beam has to be incorporated on the planning algorithm. For the pencil beam model, the necessary heterogeneity corrections are based on dose values calculated in a water equivalent material multiplied by a heterogeneity correction factor generated from an electron density matrix derived from a CT value matrix. It has been probed that the pencil-beam convolution algorithm does not work well in regions of electron disequilibrium, particularly when the field size is small. Other algorithms take into account satisfactorily the 3D scatter such as convolution/superposition, so the drawbacks linked to the heterogeneities in the patient are solved for most cases, although they present limited accuracy under certain circumstances due to several approximations used. Anisotropic analytical algorithm is a pencil-beam convolution/superposition algorithm which uses a multiple–source model to represent the beam and a patient scatter model represented by density scalable poly–energetic kernels. Regardless of the differences that have each other semi-analytical or analytical algorithms, all have in common the fact of having been tested with Monte Carlo (MC) simulations.

The dose calculation with MC is considered the most accurate technique today. MC has been used to validate these algorithms for complex techniques, such as intensity modulated radiotherapy (IMRT) where there is a significant amount of nonstandard conditions and where the beam modifiers play an important role in the characterization of the beams composing the modulated fields. Commercial companies have made efforts in the implementation of MC as alternative to analytical treatment planning systems. They try to maintain the MC advantages about the precision, while reducing...
simultaneous simulation time, but not always is easily to achieve the adequate compromise. For some radiotherapy plans or techniques, the level of approximation of the transport or the low number of sampling may end up making unjustified the implementation of MC.

The most complex techniques are being more and more frequent in the clinical practice. These techniques based on intensity modulation involve an important role of the beam modifiers. The contribution of scattered and transmission radiation from the collimators can represent a fraction of the dose in the organs at risk (OAR). In this scenario, MC could be an excellent tool in order to consider the particle transport and scattering, not only in the patient, but also along the linac head. Full MC (FMC) simulations, in addition to the dose calculation based on the physical heterogeneities in the patient, make possible to consider MLC transmission, scattering and secondary particles contributions in order to take into account the physical characteristics of the beam. Unfortunately, FMC based on an explicit radiation transport can be inefficient due to the time required to get a low statistical uncertainty.

The use of variance reduction techniques and parallel computing could overcome the problem of time consuming, whether it is performed also together with the implementation of algorithms along the optimization process which are especially appropriate to the characteristics of the MC simulation. The necessary number of histories to reach a precise dose distribution is related to the total number of voxels (dose points) defined in the CT patient and to the total number of incident beams (beamlets). A reduction of the number of beamlets and/or voxels will mean simplify the initial problem and will make possible to decrease the overall treatment planning time.

The approach of Direct Aperture Optimization (DAO) has been applied to both IMRT as well as VMAT with the main purpose of incorporating MLC properties directly into the optimization process. The reduction of involved geometries seems to be a convenient approach for the explicit transport by means of the MC simulation of the linac head.

On the other hand, it is also possible to reduce the size of the initial optimization problem by reducing the set of dose points. Usually, all the voxels composing the structures of interest are considered, since all of them are included when dose-volume constraints are implemented in the inverse planning optimization process. A selection could be done randomly or considering only those voxels directly involved in the complexity of the relative dose distribution, for example, the voxels in the intersection of PTV and a specific OAR. Linear functions and piecewise linear convex objectives and constraints can be solved with linear programming (LP). Optimization model can be written under LP formulation, in which each voxel can be identified in the objective function. If this voxel reduction is combined with few apertures the number of equations involved in a LP formulation can significantly reduce the computation time inherent to FMC in the optimization process. Furthermore, this formulation could make possible to take advantage of considering the problem at the voxel scale, what could be especially suitable for a dose painting approach to be applied according to functional and molecular information assessed by combined PET/CT imaging. It seems appropriate to make matching the more accurate dose calculation with the challenge of heterogeneous dose, as proposed with the application of dose painting, for both modalities by contour or by number.

**MPS03 - RADIATION THERAPY**

**MPS03.1 - Protontherapy**

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Protontherapy is one of the most promising conformal approaches for radiation therapy and the number of operational facilities is increasing all over the world (around 40 centers in operation and more than 40 en preparation).

The rational of its use is based on physical properties of accelerated protons in media, in particular the dose deposition by ionization in depth with the shape of a peak (the Bragg peak). Adding different energies (energy modulation) produces a spread out Bragg peak (SOBP) to cover a target volume in depth with a homogeneous dose, but this also increases the entrance dose.

The main advantages of a proton beam compared to photons are the distal fall off and the lack of exit dose (reducing the integral dose to the patient), a homogeneous dose to the target, an homogeneous dose at the entrance path and a small penumbra at the entrance. There are some limits such as the skin dose, the uncertainty in the range, the large penumbra in depth (related to multiple scattering) and the neutron dose (related to nuclear interactions).

A clear evolution is seen in the technology, mainly in the accelerators (cyclotrons, synchrocyclotrons, synchrotrons, planes linacs and new approaches) as well as in gantries to propose compact and cheaper solutions, including single room approaches (as with electrons-photons). Ancillary tools include specific solutions in treatment planning software, patient positioners, dosimetry and range verifier devices. The present tendency is to use pencil beam scanning to treat with intensity modulated proton beams, in combination with conventional methods of image guided radiation therapy, management of organ movements and adaptive therapy.

Clinical protocols include well accepted but rather rare locations (uveal melanoma, base of skull chordomas and chondrosarcomas, pediatrics, radiosurgery for intracranial targets) and more common clinical sites including lung, breast and prostate, with a tendency to include all targets treated in radiation therapy with photons. There are also comparative studies with the use of heavier ions (e.g. Carbone), which add radiobiological advantages to their physical specifications.

Research and development in the field include physical and engineering aspects (detectors, micro-beams, delivery systems, models and optimizations, robotics for positioning, ...), radiation biology (equivalent doses, effects of dose rate, LET, neutrons, radiosensitizers, ...), and clinical research (combined treatments, hypofractionation, ...). The main limit to spread protontherapy today is the investment cost.

At the end of the CE program, attendees will be able to:

1- Describe the main physical interactions and dosimetric characteristics of clinical proton beams and define the existing technology and its evolution.

2- Understand the rational for existing and upcoming clinical protocols.

3- Have a scope of the research and development programs in the field.
Learning objectives of the lecture:

1. To provide an introduction to nanoparticles as radiosensitizers and its theoretical basis
2. To give an overview on the existing multi-disciplinary research on nanoparticles in radiotherapy
3. To understand the prospects for future studies and innovations and the potential for applications of nanoparticles in radiation therapy

Radiotherapy is one of the most important methods for cancer treatment. The major limitation to be able to deposit a tumoricidal dose is the deleterious side effects in the surrounding normal tissues. Therefore, the study of radiosensitizers has emerged as a persistent hotspot in radiation oncology as a means to enhance the biological effect of the deposited dose. Nanoparticles, especially noble metal nanoparticles (NPs), may be useful in enhancing the efficacy of radiotherapy because of their unique physical and chemical properties [1]. To date, several different NPs have been successfully applied as potential tumor-selective radiosensitizers in vitro and in vivo studies. Among them, the pioneer work of Hainfeld et al. [2] reached a factor 4 increase in one-year survival rate of mammary tumor-bearing mice injected with 1.9 nm gold nanoparticles prior to irradiation.

Understanding of the underlying nanoparticle-radiation interactions still demands further research, since there is a disconnect between the theoretically predicted increases in cell killing and experimentally observed results. Although Monte Carlo simulations of high-Z nanoparticles have demonstrated significant local dose enhancement in low energy photons of 192Ir brachytherapy sources and also X-rays in kilovoltage range [3], some biological studies found comparable sensitization effects at kilovoltage and megavoltage X-ray energies [4]. Therefore, it was suggested that physical dose enhancement based on increased X-ray absorption could not be the main mechanism of sensitization.

In this lecture, an overview the existent, multi-discipline research on nanoparticles in radiotherapy, will be presented. The principles behind NP radiosensitization will be discussed. Special emphasis will be put to physics studies assessing the dose-enhancement effects and their limits. Relevant results of related in vitro and in vivo experiments will be reviewed. An outline of new combined strategies like theragonics, that takes advantage of the ability of a nanoplatform to ferry cargo—both therapeutic and imaging agents will be sketched. Other approaches like the use of magnetic NPs for hyperthermia plus RT or luminescent NPs for RT followed by photodynamic therapy will be briefly described. A reflection on the prospects for future studies and innovations and the potential for applications of nanoparticles in radiation therapy will conclude the lecture.

References
El manejo del movimiento respiratorio es de gran importancia en localizaciones de tórax y abdomen, siendo especialmente relevante en los tratamientos de SBRT de pulmón e hígado.

Existen diferentes sistemas para poder realizar estos tratamientos, desde los sistemas de compresión diafragmática con indicadores analógicos o digitales de la presión realizada al paciente, hasta los sistemas de respiración libre empleando marcadores fiduciales internos.

La adquisición de imágenes mediante TC se obtiene mediante respiración libre con métodos de Slow CT scan, Breath-hold CT o bien TC 4D. Estos últimos tienen dos métodos de adquisición de imágenes: sistemas prospectivos o sistemas retrospectivos.

Los métodos de irradiación pueden variar desde los que permiten realizar respiración libre y controlar el movimiento del tumor con CBCT 4D hasta los sistemas que emplean gating para realizar los tratamientos. Entre estos podemos diferenciar entre los que el paciente controla la respiración con un espirómetro y permiten la irradiación solamente en la fase de expiración y los que emplean sistemas de imágenes comparado con el CBCT.

Los sistemas de sistemas para poder realizar estos tratamientos, es recomendable los CBCT de kilovoltaje para pulmón e hígado siendo aconsejable disponer de CBCT 4D. Los sistemas de radiografías estereoscópicas son favorables en SBRT siempre que se empleen marcadores internos, estos pueden ser bolas de oro o bien hilos de oro, [1] ya que pueden permitir: correcciones en 6D, control intrafracción y una mayor rapidez en la adquisición de imágenes comparado con el CBCT.

Los sistemas de QC son imprescindibles en este tipo de técnicas, siendo muy variados en función del equipamiento empleado. Entre los procedimientos más relevantes podemos encontrar los siguientes: -respiración vs inspiración + respiración, localización del isocentro en un volumen blanco móvil, -correcta localización del isocentro independientemente de la fase del ciclo respiratorio elegida para tratamiento, -medida de dosis absorbida en radiaciones con control respiratorio, medida de distribución de dosis absorbida en radiaciones con control respiratorio.

1) Conocer los beneficios que aporta el control respiratorio en los tratamientos de radioterapia especialmente en los de SBRT. Entre ellos podríamos destacar la reducción de los márgenes entre GTV y PTV que trae como consecuencia la disminución de los tejidos sa-
os irradiados. También la necesidad de realizar el TC de simulación con un control del ciclo respiratorio.

2) La exactitud con que deben ser administrados los tratamientos de SBRT mediante la IGRT y el control de la irradiación durante la irradiación. Para ello se deberán conocer los diferentes sistemas de irradiación: respiración libre, compresión diagramática, ABC y gating.

3) Realizar el control de calidad del equipamiento empleado en el control respiratorio. Para ello se verán los diferentes sistemas para cada método de control respiratorio.

Respiratory motion management has shown its importance at chest and abdomen radiotherapy treatments, being particularly relevant for lung and liver stereotactic body radiotherapy (SBRT) treatments. Several systems are available to consider respiratory motion, such as systems involving abdominal compression with analogic or digital pressure indicators or free breathing gating systems using internal fiducial markers.

Image acquisition with computed tomography (CT) can be performed through several solutions: slow scanning, breath-hold or prospective and retrospective 4D CT.

Irradiation techniques include free breathing and tumor motion control with 4D CBCT and gated treatments. Among them, it can be found techniques where patient controls breathing with a spirometer and irradiation is only allowed at exhalation phase. Or systems based on infrared external markers and internal fiducial markers. These systems use stereoscopic X-Ray as imaging system and each pair of images is related to a phase of the respiratory cycle, in such a way that the fiducial marker motion is defined (which is linked to the tumor, since it is located nearby) and therefore allowing the selection of the phase of the respiratory cycle for the irradiation.

Interfracion and intrafraciton control is necessary. Kilovoltage (kV) cone-beam CT (CBCT) is highly recommended for lung and liver treatments and 4D CBCT would be an advantage. Stereoscopic X-ray imaging systems are also valid for SBRT if internal fiducial markers are used, such as gold seeds or cylinders, as they enable 6D corrections, intra-fraction control and a faster image acquisition compared to the CBCT system.

Quality assurance is extremely important at these techniques. Quality tests vary depending of the equipment. Among the most relevant we could highlight: exhalation vs exhalation + inhalation, isocenter localization at a moving target volume, correct isocenter localization, independent of the phase of the respiratory cycle chose for treatment, absorbed dose and dose distribution measurements when irradiation with breathing control.

Goals:

1 - Benefits of the respiratory control in radiotherapy treatments, mainly in SBRT. Among others, margin reduction between GTV and PTV with the consequence of a decrease in normal tissue irradiation. Also the need of a respiratory control during the simulation CT.

2 - SBRT treatments accuracy by means of IGRT and respiratory control. For that purpose all systems in respiratory control will be reviewed: Free breathing, Gating, ABC and diaphragmatic compres-

3 - Respiratory control equipment and Quality Assurance. Review of the different systems in respiratory control.

MPS05.2 - Computerized Systems Basics: Servers, Data Standards (DICOM, HL7), Virtual Machines, Portable Devices

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In the realm of medicine, Radiotherapy was a pioneer specialty in the use of computer technology, in particular for therapy planning. The first International Conference on the Use of Computers in Radiation Therapy (ICCR) took place in 1966 (Cambridge, UK). Since 1966, seventeen editions of ICCR took place, and the next, in London 2016, will celebrate the 50th anniversary of ICCR.
Today, several radiotherapy modalities are as entangled on computer infrastructure as with radiation treatment machines. This presentation will focus on a subset of the computerized framework on which modern radiotherapy depends, including hardware and software elements. Major breakthroughs in the computer industry with influence in radiotherapy will be mentioned, such as massive parallelization and portability. Two standards for handling, storing and transmitting digital medical information will be introduced: DICOM and HL7.

Learning objectives:
1. Know the purpose and main modalities of the DICOM standard, in particular those supporting Radiotherapy workflow.
2. Define the scope and purpose of HL7.
3. Explain the role of informatics support infrastructure, such as servers, workstations, portable devices, networks, virtual machines, etc., in the context of the radiotherapy department.

Abstract:
Recent technical developments and the ongoing pursuit to achieve an optimal dose distribution have led to the routinely use of modern techniques in the treatment of cancers, including intensity-modulated radiotherapy (IMRT). More recently, the interest in arc-based IMRT techniques (IMAT) is growing, in an attempt to overcome some of the limitations associated with conventional IMRT, such as increased treatment times and considerable rise in number of monitor units (MUs) delivered. These techniques involve delivering dose by means of a sequence of continuously evolving apertures with associated intensities as the gantry moves around the patient in one or more arcs. Additionally to the dynamic multileaf collimator (MLC) movement, the dose rate and gantry rotation speed may vary simultaneously during irradiation for volumetric modulated arc therapy (VMAT), as opposed to the original IMAT definition. VMAT has the theoretical potential to offer similar dose distributions in shorter treatment times compared with conventional static field IMRT, and is currently commercially available as either RapidArc™ (Varian Medical Systems, Palo Alto, CA) or VMAT™ (Elekta AB, Stockholm, Sweden).

It could be argued that the high complexity of VMAT presents a revolutionary treatment delivery, generating two different sources of uncertainty:

The classical issue linked to the dose calculation accuracy performed by commercial software. This is a dual problem concerning both, patient heterogeneities consideration and the beam modifiers contribution to the final dose.

The potential differences between the planned and delivered treatment, due to the discrete calculation of a continuous technique.

On the theoretical definition of VMAT presented by Otto, Monte Carlo was already proposed as an effective and necessary tool. Analytical algorithms cannot take into account the dose with the same accuracy as it is done with Monte Carlo. Moreover, the analytical algorithms are based on previous experimental measurements performed in different dosimetric conditions to those present in VMAT treatment. Consequently, MC has been used to validate these algorithms for techniques such as IMRT, where there is a significant amount of non-standard conditions and the beam modifiers play an important role in the characterization of the beams composing the modulated fields. The scenario for VMAT is similar to IMRT, and even more complex, due to the increment of parameters for the op-
timization process involved. The fundamental challenge of applying MC to solve these techniques is to enable the explicit consideration of all geometries implicated and perform the dose calculation in operating times for clinical practice. To this end, approaches based on parallel computing solutions are implemented in addition to the application of variance reduction techniques, allowing the use of Monte Carlo simulation in reasonable times. Apart from these points, radiotherapy techniques with many incidence beams, such as VMAT and dynamic IMRT approaches based on sliding windows, do not necessarily require a time longer for MC simulation than the time spent for simple treatments with fewer beams, while analytical algorithms take a longer time when increasing number of incidence beams. In these cases, a limited number of histories are required for each individual beam contribution, as it is the final dose due to the sum of all beams that should provide enough statistics. Nevertheless, MC never will be efficient enough, if we face the optimization problem in the same way as traditionally it has been done with the analytic algorithms.

In general, a reduction of the number of beamlets and/or voxels simplifies the initial problem and makes it possible to decrease the overall treatment planning time. Specific combination of mathematical algorithms along the optimization process will be discussed in order to establish the more appropriate set to the characteristics of the MC simulation. Actually, some of these approaches could be exported to the systems based on analytic dose calculation engines.

On the other hand, the accuracy assurance of the predicted dose distribution could be compromised by the possible differences between the discrete apertures proposed by the TPS and the finally delivered by the linac. If there are dramatic changes in the aperture shapes from one control point to the next, the linac can execute a different configuration to the parameters combination that was planned by the TPS. The mechanical limitations related to the relative speed between leaves and gantry and also the required changes in the dose-rate can generate these discrepancies. Therefore, the estimation of the patient dose based on information from the treatment delivery log files (e.g. MLC DynaLog files in Varian RapidArc), in which the MLC leaf and jaws positions, fractional MUs, and gantry angle are recorded, is essential for VMAT QA. In fact, it is necessary to know what is actually being performed by the linac during the VMAT treatment delivery.

Definitely, MC provides an adequate tool for the verification of the dose distribution within the patient geometry, allowing the verification of the dose calculated from the complex MLC apertures commonly used in the delivery of VMAT treatments. Furthermore, MC simulation of log files, recorded during treatment delivery, should be considered for a general VMAT QA able to cover both type of uncertainties commented above.

We will try to expose the essential characteristics that we believe the optimization algorithm has to fulfill to achieve a treatment planning system based on explicit MC simulation that could be used efficiently in the clinical routine.

We will also present an alternative VMAT QA system, based on an automated MC simulation of the explicit transport through the linac head and patient heterogeneities and experimental measurements with Gafchromic EBT3 film within a cylindrical phantom specifically developed to host the films rolled at different depth, available for a 3D and continuous dosimetric verification.
### MPS07 - RADIATION THERAPY

**MPS07.1 - Image-Guided Radiotherapy, Including QC and Imaging Dose; Adaptive Radiotherapy**  
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**Learning objectives:**
1. Understand the principles and challenges for image guidance radiation therapy (IGRT)
2. Understand issue related to IGRT commissioning, implementation in the routine clinical practice as well as quality assurance
3. Understand existing IGRT systems, specially room mounted kV x-ray systems

Delivery of conformal radiation dose to the target volume with conformal avoidance of critical structures requires a precise knowledge of the relationship between the patient’s anatomy and treatment isocenter. Precise Radiotherapy allows us to reduce complications and improve the quality and likelihood of successful treatment. Uncertainties in Radiotherapy are associated with patient setup variation, internal organ movement and anatomical deformation. Image Guidance Radiotherapy (IGRT) gives us the possibility to reduce radiotherapy uncertainties improving the ability to setup patients on a daily basis and gives tools to detect anatomical changes which could require re-planning, Adaptive Radiation Therapy (ART). IGRT has become today, routine part of the modern Radiotherapy.

IGRT systems currently available allow us to get projection or volumetric imaging. Projection imaging used setup based on surrogates and includes conventional port films (films or CR), MV electronic portal imaging device (EPID), room mounted kV x-ray (ExacTrac, Cyberknife), ultrasound (BAT, Clarity) and active fiducial with GPS (Calypso). Volumetric imaging used setup based on GTV and includes CT/MRI on rail in the treatment room, MV spiral CT (Tomotherapy), kV CBCT (Elekta, Varian, BrainLAB) or MV CBCT (Siemens). IGRT systems use direct alignment (visualization of the target volume) or indirect alignment (bone and fiducial active or passive structures). The alignment method can be manual, automatic or point matching. IGRT strategies may involve an adjustment of the treatment parameters at the time of treatment (On-line) or the correction based on the accumulation of information (Off-line). Depending on the characteristics of IGRT system, its use would involve not deliver an additional dose to the patient, a low dose (< 1mSv) or medium (> 2mSv).

The use of IGRT requires a specific knowledge of the system and specific training for therapists, dosimetrists, radiation oncologists and medical physicists. IGRT systems require strict QC process. Problems associated with the system can lead to a global generation of systematic errors in the positioning. The coincidence between the treatment isocenter and reconstructed image isocenter is one of the most critical points. The image quality is related to clinical intervention.

This presentation will give an overview through all existing IGRT systems emphasizing on kV projection systems with radio opaque implanted fiducials. ART concept will be analyzed showing practical examples of application in head and neck IMRT.

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### MPS08 - MEDICAL PHYSICS EDUCATION AND PROFESSIONAL ISSUES

**MPS08.1 - Curriculum Design: How to Train the Next Generation of Physicists?**  
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**Learning objectives:**
1. Understand current recommendations for education + training of medical physicists.
2. Learn the situation of education + training of medical physicists in Latin America.
3. Be informed about the main difficulties faced by program organizers in Latin America to comply with recommendations, and strategies to cope with them.

**Abstract:**
Current recommendations for the formation of medical physicists describe the process as a “3-act” play. The first act is university education at the undergraduate level, in physics, engineering or another career with a strong content of physics. The second act is graduate-level education, typically a master degree in medical physics, aimed at teaching basic principles behind the main applications of physics in medicine. The last act is a formal clinical training. After these 3 steps, the interested individual has received the education and acquired the skills that make him/her a medical physicist qualified to work independently in the clinic.

This play is not easy to stage. In the last 15 years, Latin America has witnessed the creation of a relatively large number of university master programs --with different degrees of success-- and the number of graduated medical physicists increases steadily. However, clinical residencies are still missing in most of our countries.

The talk will present statistical information about programs and residencies, description of the academic curricula, identification of the problems faced to run programs and residencies, and strategies devised to cope with local limitations and lack of resources.
MPS09 - RADIATION THERAPY

MPS09.1 - Peripheral Neutron and Photon Doses

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Learning objectives:
- Importance of peripheral dose in radiotherapy patients
- Dosimetrical problems for neutron and dose estimation
- Necessity of the introduction of a new parameter SCP (Second Cancer Probability), in addition to the TCP and NTCP, for a better clinical decision of the best treatment planning

Abstract

The comprehensive study in radiotherapy, of the dose estimation outside the target, is usually restricted to closely surrounding volumes. The dose affecting the rest of the body, currently known as peripheral dose, has rarely been considered in the clinical routine. This approach is mainly based on the argument of the risk-benefit ratio, applied to a patient with a "fatal" disease, such as cancer. However, in the last years, there has been a fast-growing concern about this unnecessary radiation dose. There are three main reasons that make this situation clear: a) the large size of the affected population; b) the great success rate, which guarantees a high life expectancy, allowing the appearance of long term side effects, including second cancer; and finally c) the new radiotherapy techniques, which increase the long time survival, but at the cost of larger volumes irradiated to low dose [1-2].

Peripheral dose in conventional radiotherapy has two main components: leakage and scattered photons and neutron contamination. Photon dosimetry is well stablished whereas the neutron contribution to the peripheral dose is complex to determine. Our group has developed [3-8] photon and neutron peripheral dose models which are being implemented on a TPS. The equivalent dose to peripheral organs should be taken into consideration during planning selection and/or optimization.

The classical consideration of tumor control and normal tissue complication probabilities functions (TCP and NTCP) should be extended, as an extra complication term, which considers the secondary cancer probability (SCP) [9].

Therefore, an efficient use of MU is mandatory throughout the balance of potential long term benefits and side effects (organ toxicity and second cancer), together with the clinical judgment on illness prognosis and, consequently, life expectancy [10-12].

References
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MPS10 - RADIATION THERAPY

MPS10.1 - The Modern Physicist Tool Box: How to Choose Between Current Dosimeters

Author(s): Faustino Gómez1, Luis G. Brualla2, Diego Miguel González-Castaño1

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Current radiotherapy dosimetry toolbox for the medical physicist involves different technological embodiments of radiation detectors. This toolbox comprises old and new instruments such as:

1. Passive systems: film, alanine, TLD and gel dosimetry
2. Active systems:
   2.1. Point detectors: air filled ionization chambers, diode, diamond, scintillator detectors
   2.2. Multidetector systems: air and liquid filled ionization and silicon diode arrays
   2.3. Electronic portal imaging devices (EPID)

On the other hand, the development of radiotherapy modalities is growing steadily including nowadays those as IMRT, VMAT, FFF linacs, Radiosurgery, Gating, etc. The medical physicist is confronted with an increasing space and time modulation of the radiation fluence and high dose gradients to deal with the clinical goal of a better conformation of the dose distribution to the target volume.

Thus, the medical physicist must decide what dosimeters to use in the different phases of the clinical dosimetry process: modeling, commissioning, verification and quality assurance. It is very important in each situation to be conscious about the idoneity and limitations of the different dosimeters available: tissue equivalence, energy and dose rate dependence, detector size and volume averaging effect, sampling rate, repeatability, etc.

Some of the passive dosimetry tools, like radiochromic film exhibit excellent tissue equivalence and high resolution, although the dose uncertainty can be significant in some cases depending on the methodology and instrumentation employed.

In the case of point detectors for absolute and relative dosimetry, the family of air ionization chambers and silicon diodes has been enlarged recently with the new CVD diamond and organic scintillating detectors that provide tissue-equivalent composition and geometries adequate for small field and high dose-gradient dosimetry.

On the other hand the use of two dimensional dose distribution measuring arrays has become very common, because they offer a higher verification efficiency, since they can be used for a large number of immediate dose measurements in a single irradiation procedure. Current state-of-the-art detectors are also including 2D and 3D array measuring systems or assemblies of 2D systems that provide a 3D verification methodology. The dose fidelity of these detectors will be analized in terms of their response function and repeatability characteristics.

The use of point detectors require the choice of the adequate chamber geometry, materials and size. Their position in the radiation field has to be studied in order to provide a sufficiently homogeneous dose distribution to ensure measurement accuracy. Phantom selection in terms of geometry and materials is also a key factor for the adequate dosimetric verification. Eventually the use of EPID for dosimetry verification and treatment quality assurance is an complementary tool for the medical physicist.

This course is oriented to the description of the physical properties and main characteristics of current dosimeters to provide the necessary insight for their application. The talk will focus in the following learning objectives:

i) Radiation transport: physical constraints on dosimetry.

ii) Characterization of the different technologies of active and passive dosimetry systems.

iii) Implications of the use of array systems. Advantages and drawbacks.

iv) Application of the dosimeter choice to the different dose verification situations.

All this concepts will be explained in a typical medical physics environment showing how to travel from theory to practice.
MPS11 - RADIATION THERAPY

MPS11.1 - Dosimetry Under Non-Reference Conditions

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Dosimetry under non-reference conditions

This course is oriented to the description of the problems arised from the use of small and composite fields in the clinical treatments and the need of reliable standard dosimetry procedures for their verification. The main learning objectives of the course are:

Explanation of the physical problems on small static field and composite dosimetry: energy response of the detector, beam hardening, charged particle equilibrium, field size definition and beam quality description.

New code of practice for standard non-reference conditions. Introduction and explanation of the new formalism: machine specific reference field (MSRF), plan class specific reference field (PSRF) and clinical fields.

The new CoP applied to the small static field dosimetry: factors to be considered and their determination and use.

The development of the standards of absorbed dose to water has lead to Codes of Practice for dosimetry in reference conditions such as IAEA TRS398 or AAPM TG-51. The use of reference conditions was intended for the calibration of a broad beam in a close to charged particle equilibrium situation for conventional radiotherapy or clinical reference dosimetry. The development of new radiotherapy techniques has lead to more frequent use of small and composite fields, such as those involved in Stereotactic Radiotherapy (SRT), Stereotactic Radiosurgery (SRS) or Intensity Modulated Radiation Therapy (IMRT). The proliferation of these narrow and composite fields has been boosted through the use of different multi-leaf collimator systems and new treatment delivery techniques. These developments have increased the complexity of clinical dosimetry and compromised the traceability to reference dosimetry based on conventional reference dosimetry protocols. There are two main reasons that affect the accuracy of dosimetric measurement in several of the new radiotherapy modalities:

CoP reference conditions can not be achieved in some of the new treatment machines.

In general terms, procedures for absorbed dose to water measurement in small and composite fields are not standardized.

Related to the first limitation in the realization of reference conditions, the new CoP approach is the definition of a reference field for each specific machine as close as possible to the standard conventional reference conditions. The correction factors for each chamber and specific reference field are tabulated in order to provide a standard dosimetric procedure. On the other hand, the determination of the beam quality has to be modified according to the achievable measurement conditions. The use of flattening filter free linacs imply the need of an extra correction factor to account for the difference in the beam quality correction respect to linacs that use a flattening filter. Additionally the ionization chamber volume-averaging effect may be taken into account with a proper convolution methodology. On the other hand, the new approach on composite field dosimetry imply the definition of PSRF (Planclass Specific Reference Field) with the purpose of reproducing the delivery features similar to those of clinical treatments. In this case a geometrically simple volume will receive a homogeneous dose distribution. Different realizations of these PSRF have been already proposed in the literature for various treatment modalities. Substantial progress has been achieved in the last years, although this topic is still an important evolving subject for the international medical physics community.
The combination of a magnetic resonance imaging (MRI) scan protocols from bed planning protocols to organ specific examination view. The development of the continuous bed motion has improved patient and detection of the attenuated transmission signals. Con similar to a PET/CT, a PET system within the MRI, and the two scan including the two scanners mounted back-to-back to each other, approaches have been proposed for the scanner configuration, modifications, especially in the PET detector technology. Different ner with a PET scanner into a PET/MRI device has involved major have been developed.

Abstract:

Inorganic scintillator crystals are the detectors used with photomultiplier tubes (PMT) in positron emission tomography (PET). Bismuth germanate (BGO) has been widely used as scintillator. With the introduction of lutetium-orthosilicate (LSO) as scintillator, time-of-flight (TOF) information (allowing for the positron annihilation point to be localized accurately) has been incorporated to improve the image reconstruction. The development of the digital silicon photomultiplier (SiPMs), connecting each scintillator crystal to a single detector pixel, has improved the PET scanner performance.

PET image quality and quantitation are dependent on the reconstruction algorithms, including parameters used, and the corrections applied.

The disposition of a computer tomography (CT) scanner in tandem or in line with a PET scanner has led to the PET/CT scanner, providing accurately aligned of anatomical and functional images. CT images are used for attenuation correction of the PET data, eliminating the need of rotating radioactive Ge sources around the patient and detection of the attenuated transmission signals. Conventional bed motion is stop and go, with overlapping bed positions due to the decrease in the axial sensitivity at the end of the field of view. The development of the continuous bed motion has improved protocols from bed planning protocols to organ specific examination protocols.

The combination of a magnetic resonance imaging (MRI) scanner with a PET scanner into a PET/MRI device has involved major modifications, especially in the PET detector technology. Different approaches have been proposed for the scanner configuration, including the two scanners mounted back-to-back to each other, similar to a PET/CT, a PET system within the MRI, and the two scanners mounted apart in the same or in a different room. Since the use of PMT in the magnetic field is excluded, scintillator detectors are coupled to position-sensitive avalanche photodiodes (APD) based detectors. In a PET/MRI scanner, tissue attenuation correction necessary for PET image reconstruction needs to be based on MR images. With that aim, different methods for attenuation correction have been developed.
Evolution

X-ray therapy for the treatment of cancer evolved immediately after Roentgen’s discovery of X rays in November, 1895: just two months later, Emil Grubbé treated a woman with breast cancer. It was not long after this, in 1899, that Stenbeck, in Sweden, delivered the 1st documented curative cancer treatment (basal cell carcinoma), using a grand total of 99 fractions! Why so many fractions? It was not because, as we learned much later, that treatments had to be fractionated in order to cure a cancer without exceeding normal tissue tolerance, but because outputs were so low and unpredictable. It was not until 1914, with the advent of the Coolidge hot-cathode X-ray tube, that high dose rates and controllable exposures became possible, and this sparked a debate on the need for fractionation, which was not resolved until 1932 when Coutard published his excellent results using fractionated radiotherapy. The Coolidge tube also sparked the evolution of X-ray machines of ever increasing energy in order to be able to treat deeper lesions, with energies rising to 1 MV by 1933. In the quest for even higher energies, new technologies were developed such as the Van de Graaff accelerator in 1937, the betatron in 1940, and the linear accelerator in 1953. The linear accelerator became the workhorse of radiotherapy by the end of the 1970s.

Convolution

Modern radiotherapy was sparked by three applications of computer technology in the 1980s and ‘90s: 3-D treatment planning, the use of computerized tomography in planning, and the advent of computer controlled linacs and multileaf collimators. Highly conformal radiotherapy became possible and this ultimately led to the development of IMRT, the CyberKnife, and Tomotherapy. At the same time, accurate targeting of treatments was evolving with real-time electronic portal, CT, PET and MRI imaging. The convolution of computerized delivery and sophisticated imaging is about to revolutionize radiotherapy.

Revolution

With the advent of flattening filter free linacs and the concomitant very high dose rates, combined with highly conformal treatments with tight margins and subsequent normal tissue sparing, the delivery of higher doses/fraction without excessive risk of complications is now possible. Such hypofractionation has been shown to be at least as effective as conventional fractionation for the treatment of several common cancers and, because it is so much more cost effective, it is likely to revolutionize radiotherapy within the next few years.
**SS07.2 – IUPESM Awardees Presentations**

**SS07.2.01 - IUPESM Award of Merit (Medical Physics): Cost-Effective Provision of Medical Physics and Medical Engineering Services in Healthcare**

**Author(s):** Peter H S Smith  
Aberdeen, UK

All healthcare services, in both developed and developing counties, are under increasing pressure. Growing use of technology is one the factors involved and medical physics and engineering services are one just more cost pressure and therefore it is essential that these services are provided in the most cost-effective way.

A number of factors will be examined including organizational aspects, staffing and research and development. The author’s experience of providing integrated engineering and physics services on a regional basis will be used to illustrate some of the issues, including the advantages and disadvantages of horizontally organized and integrated medical physics and engineering service.

The correct provision and deployment of professional, technical, administrative and other staff is essential and can raise difficulties: cultural, perceived job roles, professional barriers, supply and training. Should clinical engineers and physicists be involved in research? If so, who funds and what links to academic institutions are essential?

Manufactures of medical devices are a major influence on the deployment and maintenance of technology in healthcare and medical physicists and engineers can help ensure that appropriate technology is procured in accordance with defined needs and maintained in a cost-effective manner.

The contribution that can be provided by national, regional and international professional, governmental and UN organisations, to finding solutions to these issues will also be considered.

**SS07.2.02 - IUPESM Award of Merit (Biomedical Engineering): Improvement of Health Care Quality by Medical and Biological Engineering (MBE) with the collaboration of Academia, Industry, the Government and the People**

**Author(s):** Fumihiko Kajiya, M.D., Ph.D  
Special Appointed Professor, Kawasaki College of Allied Health Professions

The American Institute for Medical and Biological Engineering (AIMBE) has highlighted nearly 30 medical technologies since the Hall of Fame began in 2005. In subsequent years new technologies were added as the key innovations of the 20th century until now. For example, artificial kidneys, X-ray, ECG, pacemakers, cardiopulmonary bypass, antibiotic production technology and defibrillators up to the 1960’s, and since the 1990’s genomic sequencing and micro-arrays, PET, image-guided surgery and optical coherence tomography (see AIMBE home page). Virtually, every person has benefitted from these key technical innovations in receiving better health care. For instance, more than 2 million people have hemodialysis treatment in the world (3 hundred thousand in Japan). However, the development of each technology doesn’t progress in a straightforward way. As for artificial kidneys, it is well known that many crucial technological developments, such as dialysis-circuits, pumps, vascular access, anticoagulant measures and high performance membranes have been achieved. These are a result of fusion technology from many disciplines. Personally, I have been engaged as a co-chair (2004-13) in the Medical Engineering Technology and Industrial Technology (METIS) in Japan, i.e., Cooperative organization of academia, industry and government. The scope of METIS includes not only medical devices but also science and engineering in health care. From my small experiences, I would like to emphasize the possible improvement of health care quality by future contributions of MBE in the interdisciplinary fusion with the collaboration of academia, industry, the government and the people.
SS08 - THE FUTURE OF CLINICAL ENGINEERING EDUCATION

SS08.1 - Clinical Education at University of Connecticut
Author(s): Frank R. Painter
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The clinical engineering graduate educational program at the University of Connecticut is in its 41st year. Dr. JosephBronzino started the program in 1973 at Trinity College and the Hartford Graduate Center in Connecticut, USA. In 1995 the program moved to the University of Connecticut. Dr. Bronzino retired in 2000 and Frank Painter assumed responsibility for the program under the guidance of Dr. John Enderle.

The program provides students with a two year clinical engineering internship experience as well as seven academic courses which focus on various aspects of clinical engineering. A successful student will graduate from UCONN with an MS BME degree.

There are 20-24 students in the program in most years. Each year 30-50 students apply for the CE internship program. Normally there are ten to twelve openings each year in the 17 participating internship locations. A few more students are selected to interview than the number of openings available. These candidates are then invited to come to the Southern New England area and in a four day period, as a group, they interview at all hospitals who have internship openings. In the interview the hospital's CE director and several of their staff, including the current interns, interview each candidate. During the end of the interviews the CE directors are asked to select their five preferred candidates and the candidates their five preferred hospital locations. A meeting of the directors is then held to match the choices and the candidates are informed of the outcome.

Starting in late August, the interns spend two full academic years in the program. They are required to work in the hospital 20 hours per week and spend an additional 10-15 hours per week in the hospital working on their class projects, homework, clinical observations, research, reading and studying. Additionally the students take the following clinical engineering focused course work over the four semester program. Clinical Engineering Fundamentals focuses on how a CE department is managed, Engineering Problems in The Hospital focuses on utility systems in the hospital which support medical equipment, Human Error and Medical Device Accidents focuses on the risks of healthcare technology, Medical Instrumentation in the Hospital focuses on high end medical systems, including imaging and therapy, Clinical Systems Engineering focuses on medical device integration and interoperability and Clinical Rotations focuses on observing clinician-technology-patient interface in the clinical environment.

The program is the result of a partnership between the hospitals and the University. The clinical engineering directors greatly contribute to the program a success. Each hospital signs a contract with the university and pays a yearly fee to finance the graduate student stipend and program administrative fees. Every hospital in the program has hired a program graduate and many have hired several.

The majority of the second year students receive multiple clinical engineering job offers before graduation. Most of the program graduates end up in a career working directly for hospitals. All of the remaining students work for companies either providing services or products to the healthcare technology community.

SS08.2 - The Future of Clinical Engineering Education in the Western Hemisphere: USA and Peru
Author(s): Thomas M. Judd1, Luis Vilcahuaman2, Rossana Rivas3, Herbert F. Voigt4
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It is undeniable that engineers have played an important role in the delivery of modern health care. The boots on the clinical floors have been filled with BMETs, clinical engineers (CEs) and biomedical engineers (BMEs), the mix of which has been uniquely formulated in thousands of clinical environments globally. It is interesting that although educational opportunities to train BMETs are common, training of CEs at the undergraduate and graduate level is virtually non-existent in the Western Hemisphere.

In fact, there are only a few CE MS programs (some with no internship opportunities) and no CE Ph.D. programs in the western hemisphere. There is an urgent need to provide highly qualified, certified CEs at all levels, BMET, BS, MS and Ph.D. level. Many Universities that provide biomedical engineering undergraduate education do not offer clinical engineering internships, local or international, that are so important for training CEs. In addition, the clinical environments in developed countries offer very different challenges than those in developing countries. For certification purposes, this is likely to result in different weighting of the factors important in the various environments. This session will address the need for new clinical engineering programs at various educational levels to serve the current and future health system needs.

The CE profession is changing in ways that significantly impacts US and global healthcare. In addition to the historic CE medical device lifecycle management function (called health technology management or HTM), there is (1) the emerging integration of medical devices into electronic health records (also called Health IT or CE-IT), and (2) other key topics in which CEs help drive changes in clinical workflows at health organizations: planning, policies, acquisition, management, strategies, investments, risk, design of clinical environments and others. This is accomplished through the interoperability of devices and EHRs so that care everywhere (inpatient, clinician-based and mobile health) profoundly allows redesign of care delivery.

The profession needs practitioners with new skillsets - both for emerging graduates and people at all stages of their careers. These requirements are outlined in a White Paper by Sloane, Welsh, and Judd: New Opportunities for BME/CE Health IT Education, May 2014, (http://ceitcollaboration.org/docs/NewOpportunitiesBME_CEHealth_IT_Education.pdf). This session will address the pertinence and impacts of exploring more opportunities to grow Clinical Engineering Education in the U.S.A. and promote this specialty in developing countries and globally moving forward.

The Future of Clinical Engineering in the Western Hemisphere, which is a model for CE globally, will be addressed in oral presentations, followed by a Panel Discussion.
SS09.1 - Functionalized gold nanoparticles for point-of-care nucleic acid detection

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Gold nanoparticles (AuNPs) have been extensively investigated for colorimetric detection of nucleic acid. This is enabled by the unique interparticle distance-dependent optical property of AuNPs. The solution color for monodispersed particles appears red (for widely used 13 nm AuNPs) but turns purple upon aggregation due to a red-shift in the surface plasmon resonance absorption band. Until now, all the reported platforms are not practical for point-of-care testing. To address this, our group developed a new platform by incorporating 11-mercaptooundecanoic acid-modified AuNPs (MUA–AuNPs) into loop-mediated isothermal amplification (LAMP). When added into the LAMP reaction mixture, MUA–AuNPs aggregated as a result of ion-templated chelation between the carboxyl groups and magnesium ion (Mg2+), which plays an indispensable role in LAMP reaction as an enzyme cofactor. The solution color changed from red to purple. In the presence of a specific target DNA sequence, the LAMP reaction occurred and pyrophosphate ion (P4−) was generated as a reaction by-product. The chelated Mg2+ was then extracted by P4−, leading to the deaggregation/redispersion of the MUA–AuNPs and the solution color turned red. This new platform possesses all the ideal features for point-of-care testing, including simple preparation and operation, low cost, high sensitivity, and worry-free carryover contamination control.

SS09.2 - Hemodynamic function of Fontan circulation mechanical assistance in Fontan circulation animal experimental model

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Fontan procedure is selected the final palliative surgical operation in pediatric patients with serious congenital heart diseases. After Fontan procedure, there is non-pulsatile flow in the pulmonary circulation called Fontan circulation. We focused on the additional pulsatility in the Fontan circulation for the pulmonary flow assistance for congenital heart failure patients. In order to promote the pulsatility in the flow that infuses the lungs, we implemented an original mechanical contractile device which promotes flow pulsatility. Then we have been developing a circulatory support device with the function of peristaltic contraction for the promotion of an efficient assistance for Fontan circulation using shape memory alloy fibers. The structure of the device was a mechanically contraction from the outside of the extracardiac conduit. The device was consisted the 16 units of the shape memory alloy actuators in parallel arrangement. In this study, we developed the animal experimental model for in vivo examination of the Fontan circulation assist device for the pre-clinical research. And also, we examined the hemodynamics function in the device driving by the animal experimental model. The animal experimental model was constructed in four adult goats (45.8±15.6 kg). The right heart bypass of inferior vena cava (IVC) to pulmonary artery (PA) was constructed by using extracardiac conduit (Dacron, D = 18mm, Boston Scientic Corporation, USA). The vascular tape was indwelling in IVC and right atrium (RA) anastomosis for clamping. And the left ventricular assist device (LVAD, Gyro Pump C1E3, Kyocera Medical Corporation, Japan) was connected to the apex to reduce the left ventricular load. Rotational speed of the LVAD was set to 1400rpm. The right heart bypass circulation could be created by the IVC-RA clamping. IVC and PA pressure rose to 15mmHg during clamping. The device could be mounted easily to the conduit in the thoracic cavity. The pulsatile flow could be generated in the pulmonary circulation by the device contraction. In the faster peristaltic contractile speed, the device could be generated larger pulsatile flow waveform. The animal experimental model could be constructed to reproduce the hemodynamic of Fontan circulation by using LVAD. In our model, it was represented to steady flow in the bypass circulation. In the pulmonary circulation of the experimental model, the flow fluctuation was included by heart beat and respiratory variation. For the further investigation to more effective assistance, it is considered to require the control method including synchronization with the heart beat or respiration. We examined the function of the device in the animal experimental model. And it was indicated that the pulsatility by the device could be generated pulsatile flow in device implantation.

SS09.3 - Biomedical Engineering at the Nanoscale: the Inspiration We can Draw from Endogenous Systems Interactions to Design the Nano-Bio Interface

**Author(s):** James C.Y. Kah
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Nanomedicine can be described as biomedical engineering on the nanoscale where we seek to apply intelligent design to tackle health challenges. The last decade has seen tremendous growth in this field as studies on the various applications of nanotechnology in medicine and biotechnology form a sizeable aspect of modern day research. Biomedical applications of these nanoparticles have been reported in four major areas, namely, drug delivery, disease diagnostics, imaging and therapeutic applications as an outcome of man’s ingenious design on the nanoscale. Nature’s intelligent design has also created a range of endogenous biomolecules that exist in the same size regime as nanoparticles. In biology, however, there are numerous examples of biomolecular systems that far surpass any man-made machine in terms of efficiency, precision, and complexity. Natural endogenous biomolecules such as DNA and proteins often self-assemble, or interact with other biomolecules in order to perform their naturally intended function. Most often, these interactions between biomolecules are useful, if not critical, to the survival of the organism. In a similar manner, nanoparticles also demonstrate a high propensity to interact with other biomolecules to form the nano-bio interface. Intelligent design of this nano-bio interface is therefore crucial to the functionality of nanoscale systems in biology. In this talk, I will show how we can draw inspiration from nature and design appropriate nano-bio interface formed from DNA, proteins and peptides to probe and control biology in at least four ways: (1) to enhance efficiency of protein translation in vitro; (2) tune cellular response; (3) to enable loading and trigger release of drugs; and (4) to develop a cost-effective and instantaneous biomolecular assay. I will also be sharing some of our current research that involves understanding and engineering the nano-bio interface in molecular and cell biology.

SS09.4 - High Frequency Ultrasound Elastography and its Biomedical Applications

**Author(s):** Chih-Chung Huang
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It is well known that the mechanical properties of soft tissues, such as elasticity, viscosity, and mechanical impedance, change depending on the conditions of tissues, for instance disease and age, hence
the mechanical properties may give useful information in medical diagnosis. Several ultrasound elastographs have been proposed to measure the mechanical properties of tissue quantitatively, such as sonoelastographic image, shear wave image, and acoustic radiation force impulse image. However, the image resolutions of above elastographs are insufficient due to their operational ultrasound frequency. It remains difficult to estimate the mechanical properties of smaller organs and tissues using current elastographs. Therefore, the high frequency ultrasound elastographs based on acoustic radiation force impulse imaging and shear wave imaging were proposed in our Lab to assess the mechanical properties of some micro-structure tissues, such as cornea, plaque, and vessel wall. In cornea study, a 50 MHz high frequency acoustic radiation force impulse (ARFI) imaging system were built for mapping the hardness of cornea. A dual frequency ultrasonic transducer was designed for this objective. The outer 10 MHz element was used to push the fibers in cornea and the inner 50 MHz element was used to detect the displacement of cornea. The experiments were carried out using artificial porcine cornea and a new algorithm for high frequency ARFI imaging was established. In plaque study, a 40 MHz shear wave imaging system was built for measuring the elastic properties of blood clots. Furthermore, we applied our high frequency ARFI imaging and shear wave systems into intravascular ultrasound (IVUS). A concept of combining the high frequency AFRI and shear wave technology on IVUS for assessing the mechanical properties of thrombus and vessel was proposed in present study.

SS10 - IFMBE Awardees Presentations

SS10.1 - IFMBE Otto Schmidt Award: Neuro-engineering for navigation, intervention and implementation in neurosurgery

Author(s): Karin Wårdell
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Neurosurgery and neuro-intensive care are clinical areas in which highly specialized interventional, navigational and monitoring techniques are imperative for patient care and improved health in the society. The overall aim of our research is to develop and evaluate new methods and techniques for radical improvement of navigation, intervention and monitoring in neurosurgery. Topics of special interest are deep brain stimulation (DBS), optical techniques for intraoperative neuronavigation, brain microcirculation as well as the integration and translation of the new tools and methods for clinical use. In the DBS research we have developed a patient-specific modelling and simulation concept for investigation of the electric field around active DBS-contacts. This allows for visualization of the relative electric field changes in relation to the patient’s anatomy by using MRI together with superimposed atlas structures. The simulation method has proven useful for clinical evaluations of movement and speech in Parkinson’s disease and is now also introduced for new DBS-indications and brain targets. During the talk examples of both optical application in neurosurgery as well as projects related to DBS will be presented.

SS10.2 - IFMBE Vladimir Zworykin Award: Microfluidic Technologies for Disease Diagnosis, Therapeutics and Personalized Medicine

Author(s): Chwee Teck Lim
Provost’s Chair Professor, Dept of Biomedical Engineering &Mechanobiology Institute, National University of Singapore

Our blood comprises ~5 billion cells in one cubic milliliter with red blood cells (RBCs) accounting for >99% of all cellular components suspended in protein-rich plasma. Besides blood constituents, pathogenic microorganisms or diseased cells can also be present in blood for certain diseases, which can present possible routes for disease detection, diagnosis and therapy. However, the presence of the large number of RBCs complicates removal of pathogens in blood as well as makes disease diagnosis such as detection of rare circulating tumour cells (CTCs) in blood of cancer patients extremely challenging. Here, we address these issues and demonstrate that physical biomarkers such as the unique size and deformability of diseased cells can be effectively used for their detection and separation from blood by using microfluidics. We do this by leveraging on the many inherent advantages of microfluidics such as high sensitivity and spatial resolution, short processing time and low device cost. We developed a suite of microfluidic biochips that exploit the principles of cell size/deforability-based separation as well as inertial focusing to perform high throughput continuous detection and separation of diseased cells. These simple, efficient and cost-effective microfluidic platforms will be imperative in realizing point-of-care (POC) diagnostics and invaluable for many downstream clinical and biological applications as well as personalized treatment.
Over the past half century engineers have made enormous contributions to both an increased understanding of biology and biological mechanisms and to improvements in clinical treatments. For these many contributions by engineers and physical scientists, there is much to celebrate. From the study of blood flow, to the role of hemodynamics in atherosclerosis and the role of the vascular endothelium, to the development of new medical devices, to regenerative medicine and stem cell technology, the contributions of the medical and biological engineering community have had a major impact. This includes everything from advances in pacemakers to continuing efforts to understand “the rules of life” that determine cell function. As one further envisions the future, although the application of engineering to the medical area will continue to be important, such new areas as energy, the environment, and food will be an expanded part of medical and biological engineering. Already we are seeing an industrialization of biology with the biomanufacturing of chemicals today becoming a significant element of the economy. The International Federation of Medical and Biological Engineering (IFMBE) has had a major leadership role, and in the world of the future, IFMBE will have to evolve its role in order to provide the leadership necessary for the global community.

Machine learning approaches to biomedical image analysis are gaining popularity encouraged by successes in the sister field of computer vision and increasing availability of large clinical and biological image databases. This talk will describe how we are applying machine learning in ultrasound image analysis, an area where quantification by traditional image analysis methods is very hard due to the wide range of data qualities met in real world applications.

A major application area of interest is “womb-to-cot” imaging – imaging in pregnancy and early life. I will describe progress towards developing machine learning based solutions for ultrasound-based biomarker estimation and quantification. These solutions are designed to be “accessible” – or easy to use – by a clinical end-user, and hence suitable for application in community care and to support healthcare delivery in the developing world.

The Bio-Unions Cluster of the International Council for Science (ICSU) consists of 11 of the 32 International Scientific Unions that are Union-members of ICSU, of which the IUPESM (the International Union for Physical and Engineering Sciences in Medicine) www.iupesm.org/ is one. “The principal objective of IUPESM is to contribute to the advancement of physical and engineering sciences in medicine for the benefit and well-being of humanity.”

ICSU’s website states, “The International Council for Science (ICSU) is a non-governmental organisation with a global membership of national scientific bodies (121 Members, representing 141 countries) and International Scientific Unions (32 Members). ICSU’s mission is to strengthen international science for the benefit of society. To do this, ICSU mobilizes the knowledge and resources of the international science community to:

- Identify and address major issues of importance to science and society.
- Facilitate interaction amongst scientists across all disciplines and from all countries.
- Promote the participation of all scientists—regardless of race, citizenship, language, political stance, or gender—in the international scientific endeavour.
- Provide independent, authoritative advice to stimulate constructive dialogue between the scientific community and governments, civil society, and the private sector.”

The ICSU member unions fall into four clusters, one of which is the Bio-Unions Cluster. Since 2010, the Bio-Unions Cluster has been meeting among themselves to plan interdisciplinary activities, including:

- a presence at each other’s congresses,
- the joint sponsorship of meetings, and
- joint sponsorship of teaching activities.

In 2013, the Bio-Unions Cluster met in Paris a day before the ISCU Unions meeting. At that meeting additional decisions were made. They decided:

1) To meet at least once a year.
2) To create a school that meets in conference facilities on a Greek island.
3) To consider supporting satellite conferences in conjunction with a World Congress of one of the ICSU members.
4) To organize a session(s) at one of the Bio-Union Cluster’s World Congress
5) To build into the Unions’ budget money to support the Bio-Union Cluster’s activities. ($5,000 – $10,000/year)

Our activities here today at IUPESM’s WC 2015 demonstrate a continuing commitment made by the Unions in the Bio-Unions Cluster to uphold these activities. But there are additional opportunities related to long-term programs that involve ISCU.
Two of ICSU’s relatively new, long-term programs are: 1) Health and Wellbeing in the Urban Environment and 2) Future Earth (Global Sustainability). IUPESM has resources and capacity to be helpful in both of these programs. For example, Future Earth, is a 10-year international research initiative “sponsored by the Science and Technology Alliance for Global Sustainability comprising the International Council for Science (ICSU), the International Social Science Council (ISSC), the Belmont Forum of funding agencies, the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP), the United Nations University (UNU), and the World Meteorological Organization” (Future Earth Website). Biology is essential to Future Earth and therefore the Bio-Unions Cluster must establish a role for itself in this complex activity.

**SS11.2 - The International Council for Science (ICSU) Bio-Unions Cluster**

**Author(s):** Nils Chr. Stenseth¹, Herbert F. Voigt²

¹Université Paris Sud XI, IUBS, Orsay/FRANCE, ²Health Technopole CENGETS PUCP, Pontifical Catholic University of Peru, Lima/PERU

The Bio-Unions Cluster of the International Council for Science (ICSU) consists of 11 of the 32 International Scientific Unions that are Union members of ICSU. This session will be an introduction to some of the ICSU Unions making up the Bio-Unions Cluster. It will include speakers, primarily Officers, from several of the Unions within the Bio-Unions Cluster, who will address their Unions’ Mission and their Interactions with ICSU and other Unions within the Bio-Unions Cluster. The Session Chair is Nils Stenseth, Chair of ICSU Bio-Union Cluster and President, International Union of Biological Sciences (IUBS). Other speakers are: K.Y. Cheung, President-Elect, International Union for Physical and Engineering Sciences in Medicine (IUPESM); Elaine Faustman, Secretary General, International Union of Toxicology (IUTOX); Pingfan Rao, Past-President, International Union of Food Science and Technology (IUFoST); Walter Boron, Secretary General, International Union of Physiological Sciences (IUPS) and Herbert Voigt, President, International Union for Physical and Engineering Sciences in Medicine (IUPESM). The session will end with an open discussion regarding the future activities of the ICSU Bio-Unions Cluster.

**Bio-Unions Cluster/ICSU**

ICSU’s website states, “The International Council for Science (ICSU) is a non-governmental organisation with a global membership of national scientific bodies (121 Members, representing 141 countries) and International Scientific Unions (32 Members). ICSU’s mission is to strengthen international science for the benefit of society. To do this, ICSU mobilizes the knowledge and resources of the international science community to:

- Identify and address major issues of importance to science and society.
- Facilitate interaction amongst scientists across all disciplines and from all countries.
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- Provide independent, authoritative advice to stimulate constructive dialogue between the scientific community and governments, civil society, and the private sector.”

The ICSU member unions fall into four clusters, one of which is the Bio-Unions Cluster. Since 2010, the Bio-Unions Cluster has been meeting among themselves to plan interdisciplinary activities, including:

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- the joint sponsorship of meetings, and
- joint sponsorship of teaching activities.

**11 ICSU Unions in the Bio-Unions Cluster:**

1. IBRO (International Brain Research Organization) [www.ibro.info](http://www.ibro.info)/ Pierre Magistretti, President pierre.magistretti@epfl.ch

2. IUBS (International Union of Biological Sciences) [www.iubs.org](http://www.iubs.org)/ Nils Chr. Stenseth, President n.c.stenseth@bio.uio.no

3. IUFoST (International Union of Food Science and Technology) [www.iufost.org](http://www.iufost.org)/

Rickey Yada, President lfs.dean@ubc.ca

4. IUIS (International Union of Immunological Societies) [www.iuisonline.org](http://www.iuisonline.org)/

Jorge Kalil, President jkalil@usp.br

5. IUMS (International Union of Microbiological Societies) [www.iums.org](http://www.iums.org)/

Yuan Kun Lee, President micleeyk@nus.edu.sg

6. IUNS (International Union of Nutritional Sciences) [www.iuns.org](http://www.iuns.org)/

Anna Larthe, President aalartey@ug.edu.gh

7. IUPAB (International Union for Pure and Applied Biophysics) [www.iupab.org](http://www.iupab.org)/

Zi-He Rao, President raozh@xtal.tsinghua.edu.cn

8. IUPESM (International Union for Physical and Engineering Sciences in Medicine) [www.iupesm.org](http://www.iupesm.org)/

Herbert F. Voigt, President hfv@bu.edu

9. IUPHAR (International Union of Basic and Clinical Pharmacology) [www.iuphar.org](http://www.iuphar.org)/

S. J. Enna, President IUPHAR@kumc.edu

10. IUPS (International Union of Physiological Sciences) [www.iups.org](http://www.iups.org)/

Denis Noble, President denis.noble@dpag.ox.ac.uk

11. IUTOX (International Union of Toxicology) [www.iutox.org](http://www.iutox.org)/

Herman Autrup, President ha@mil.au.dk

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SS16 - ADDRESSING GLOBAL CHALLENGES

SS16.1 - Bioengineering in the 21st Century
Author(s): Robert M. Nerem
Mechanical Engineering, Georgia Institute of Technology, Atlanta/GA/UNITED STATES OF AMERICA

Bioengineering in the 21st Century
Robert M. Nerem
Georgia Institute of Technology

In the last half century the field of bioengineering has evolved from its beginnings with the medical device industry to one that is much broader today and will be even broader as we move further into the 21st century. In this span of more than 50 years, there has been a technological revolution in healthcare and also an educational revolution. In the 1950s as the medical device industry began to develop, engineers at universities in the traditional fields began to apply their expertise to problems in medicine. With the advent of the biological revolution, however, what subsequently emerged is an engineering discipline based on the science of biology, i.e. bioengineering. As this new discipline has evolved, the medical device industry has expanded and continues to be important; however, there are major trends in public health that are influencing and will continue to influence the development of bioengineering. These include a shift from acute to chronic disease, an aging population, the disparities in healthcare, emerging and re-emerging diseases, and the escalation in healthcare costs. In this there will be a transformation of medicine and there will be a need for the development of new innovative technologies. These are technologies that reduce healthcare costs, also ones that allow for imaging at the molecular level, and in addition technologies that will drive science just as science drives technology. There also will continue to be a focus at the cell and molecular level and the application areas of regenerative medicine and stem cell technology. Here engineers can take the lead in developing new, innovative enabling technologies. This includes high-throughput screening techniques, improved culture and differentiation systems, and in vitro models engineered to be more physiologic. The last of these include organ-on-a-chip models and engineered in vitro tumor models that can lead to a better understanding of cancer. Finally, for cell-based biomanufacturing there is a need for further advances in scaleup, techniques for real-time monitoring, and for process automation. It is clear that the engineering approach with its quantitative, systems-based thinking can contribute much more to advancing medicine than it has to date. Engineering analysis can be used to identify the components of highly complex biological systems and provide an understanding of how these components work together. Furthermore, computational models will be increasingly important in our efforts to achieve a better understanding of complex biological systems. For all of these areas it is the bioengineers that will create the reality of the 21st century age of biotechnology.

SS16.2 - ICT for Prevention of Non-Communicable Diseases
Author(s): Niilo Saranummri
Health, VTT Technical Research Centre of Finland, Tampere/FINLAND

Non-communicable diseases (NCDs) – such as heart disease and stroke, cancer, diabetes, and chronic lung disease kill more people globally than infectious diseases and are responsible for about two-thirds of deaths worldwide. Six out of the seven most important risk factors for premature death (high blood pressure, high cholesterol, high Body Mass Index, inadequate fruit and vegetable intake, physical inactivity, and excessive alcohol consumption, smoking excluded) are related to diet and physical activity.

Our lifestyle choices combined with our social, built, and economic environments influence the way our genes express in our dynamic phenotype and interactively contribute to health or disease. NCDs can to a large extent be prevented by following current health guidelines on diet, alcohol, physical activity, and smoking. Therefore, NCDs are often called lifestyle diseases.

Current thinking still views much of health promotion and prevention as relying on public health awareness campaigns to increase health literacy, education, feedback and support, as well policy and regulatory activities to decrease unhealthy behavior (e.g., regarding smoking, intoxicants, package labeling, and urban planning). Health statistics, however, show that the prevalence of NCDs is increasing around the world and that these efforts are only modestly effective in preventing disease and reducing the overall disease burden and health expenditure.

We need novel solutions to prevent disease and promote health, as well as to better manage NCDs while they occur. What is needed is an approach that engages individuals to manage their everyday health-related behaviors. Empowering people to manage their health and wellness and, if present, chronic diseases requires that two challenges are met.

The first is a disruption in the way health services are delivered and incentivized. The current illness-centered healthcare model needs to be replaced with a proactive health and wellness-centered model where people together with healthcare professionals manage their health and illness.

The second is to engage people to manage their health with innovative services and tools that people want to use and that provide them with the ability to respond wisely in health related situations. The new approach might be achieved with the following steps:

- Harness emerging mobile and ubiquitous digital technologies (sensors, mHealth apps, Internet of things (IoT), etc.) to collect comprehensive datasets on personal behavior in context while maintaining the required level of personal privacy and security;
- Liberate existing data; not just health or illness data but also data that are being already collected for various business purposes, such as loyalty cards in shopping for food and other items, credit cards telling a lot of our behavior, mobile phone use and location data etc.;
- Use data mining and systems modeling to build predictive models of personal behavior;
- Deploy these models combined with knowledge from systems medicine and behavior science to predict and anticipate personal behavior; and
- Provide users with personalized feedback at opportune moments that engages them to manage their health related behaviors.

Author(s): Robert Mathews
Office Of Scientific Inquiry & Applications, University of Hawai‘i, Honolulu & Hilo/HI/UNITED STATES OF AMERICA

Canadians and Americans have both been steadfast advocates for personal privacy since the birth of the two nations on the North-American Continent. However, in the 21st Century, the rate of digital technology proliferation, the widening range of technology adoption, and uses, all without a sufficiently broad and systematic construal, or comprehension, has produced a decay of long evolving frameworks for civil liberties, and the desecrations of more founded personal privileges. Nowhere has this decay been more conspicuously grand more recently than in the area of Healthcare practices within the United States. Will it be possible to arrest this decay? Are the ‘loss of privacy’ expansions reversible? How can Globally Interoperable Healthcare Services ever be a reality at all, where Patient’s personal safety and security cannot be properly assured?

SS19.2 - Social Implications of Technology

Author(s): Luis G. Kun
Private, Consultant, Vienna./VA/UNITED STATES OF AMERICA

Wireless technologies and remote sensing when combined with social networks and geographical information systems are having a prominent role in the coordination, communication, planning, response and management to some of the most devastating disaster scenarios we have witnessed in the last few decades. On the other hand many issues we routinely experience with respect to solving health care or public health problems, such as medical errors, occur and are perpetuated because of our silos or stovepipes of information. The scientific community recognizes intimately that preparing for the provision of health care, and erecting our public health system of tomorrow, is not just a matter of converging heterogeneous technologies and science but of people and processes as well. As society prepares to shift the current systems into some where wellness and disease prevention will be the focus, society will face some major challenges. Many changes can affect positively medical and cost effective outcomes as well as the reduction and or elimination of medical errors and patient safety for example and yet privacy and security of personal medical information continue to be a major hurdle. Information Technology acting as a catalyst for change when combined with discovery and advances in research and development of new devices, and new drugs offers a multitude of avenues that were hard to imagine just a few decades ago. The convergence of science and technology open some doors of opportunity that may help diminish the polarization among the developed and under-developed nations. Society needs a systems approach and having a holistic view of the problem; to be able to see the whole and not just discrete pieces; and help determine, for example unintended consequences which are absent. Integration of multidisciplinary and interdisciplinary orientations and activities when trying to understand the problem and moving toward generating potential solutions are needed; yet present approaches are grossly insufficient in this respect. A new Global Health strategy where the public and private sectors work together will be presented as well as a wide range of opportunities that can start at the cellular, molecular and genetics levels and go as far as population health. A Global Economy that will be pushed to integrate surveillance and epidemiology for better protection against environmental threats and food borne diseases through the use of remote sensing data and a worldwide food enterprise architecture will also be discussed. The access to new services such as home healthcare delivery and public health safety are generating a “new digital divide” discussion between those that have the means and those that don’t. The current Internet Neutrality debate must incorporate these concepts in order to address new social challenges posed by the new technologies.
Demographic changes, where the expected lifetime of people is increasing and many suffer from not one but several chronic diseases, are challenging our healthcare system. There is a clear need for wearable and distributed health monitoring systems, allowing people to continue their normal activities independent of location; at home, at work or in hospital. Monitoring of changes and trends in health status can facilitate early intervention and prevent severe conditions to develop, and new technology enables simultaneous monitoring of multiple physiological parameters. Hence, this can prevent suffering for patients and also means large savings for society. Moving the point-of-care from hospitals to homes is a trend that will increase in the future. The recent development of embedded sensor systems, the rapid development in wireless technology, and the ability to include intelligence in small, embedded sensor systems are all key enablers to achieve ambient monitoring of health conditions. To successfully address these issues, holistic system approaches are necessary, including not only sensor and hardware expertise, but also software expertise. The current workshop will bring together experts in these areas, and will address the need and potential in using embedded sensor systems for monitoring of health conditions in home environments, including the use of Internet, Wi-Fi, and smart phones. A keypoint addressed will be the starting point from clinical needs, thus the involvement of clinical experts is essential throughout the whole development process. Also the user-friendliness of the systems is essential. If not easy to use, there will be a large resistance against using the systems. Topics to be addressed in the workshop are sensor system applications, signal processing, intelligent decision support, and infrastructure. Further, decision support distributed in the system will be included, together with safe and secure transport and storage of physiological data, to ensure personal integrity of the persons being monitored.

Growing populations and shortages of healthcare workers paired with the explosive growth of mobile communications infrastructure over the last decade has sparked growing interest in the provision of health services through mobile and wireless technologies. This Workshop will address the use of mobile systems and devices such as smartphones, tablets, and laptops to address the unmet healthcare needs in rural/urban marginalized areas of the resource-limited regions of the world, where health conditions and vital signs data acquired from geriatric, pediatric and infirm patients have to be communicated in a timely manner to adequately trained and qualified caregivers. The Workshop will bring together experts to assess the clinical needs to be fulfilled, to review some innovative solutions that are ready to be implemented and to identify benefits from implementation of such mobile systems by overcoming barriers and matching patient needs with solutions. These experts will address and demonstrate new devices (hardware and software) that provide improved healthcare at the point-of-care, will review communication aspects and telemedicine (sending data to and from remote experts for consultation, diagnosis and prescription), and will discuss how to assure continuum of care and remote support to improve the utilization and maintenance of existing equipment.

Specific topics to be addressed include: The state of TeleHealth, TeleMedicine, and mHealth; implementation, barriers and policy issues in industrialized and resource-limited regions; telecommunications, interoperability, regulatory and legal issues; telemedicine challenges and opportunities; development of new mobile-centric hardware to detect health conditions; development of healthcare applications using facilities and functions available in modern mobile devices; quality of service assessment; and evaluation of maintenance and sustainability issues. Following the formal presentations, there will be an open discussion between the audience and the Workshop participants, from which final conclusions and recommendations will be drawn.
SS25.1 - Challenges and Benefits of Clinical Engineering Peer Review

Author(s): Jean Ngoie1, Michael J. Capuano2
1Biomedical Engineering, Niagara Health System, St. Catharines/CANADA; 2Biomedical Technology, Hamilton Health Sciences, Hamilton/CANADA

Clinical engineering departments in Canada have the opportunity to be reviewed based on the CMBES Clinical Engineering Standards of Practice (CESOP). The process is designed to affirm well established programs, provide recognition of excellence in Clinical Engineering, and to provide programs with a baseline for improvement and knowledge exchange. The CMBES Peer Review Committee coordinates and approves all requests for review and assigns the reviewers (surveyors) to the requesting facility. Peer review requires the clinical engineering program to complete a pre-survey questionnaire and to provide information about the program including policies and procedures, organizational structure, explanation of processes, and demographics. A physical on-site visit is arranged lasting several days depending on the size of the organization and involves an equipment/work audit, interviews with staff and clients including senior management, tours of the facility, and review of department records. A summary report is provided after the review accompanied by a certificate of successful completion. This presentation will cover all of the above mentioned steps as well as past experiences and thoughts. Perspectives from the survey team and the reviewed will be presented including the benefits of Peer Review and the most challenging aspects of the process.
PL01 - WOMEN IN BIOMEDICAL ENGINEERING AND MEDICAL PHYSICS

PL01.1 - Engaging Women and Men for a Better Future Worldwide
Author(s): Monique Frize
Systems And Computer Engineering, Carleton University, Ottawa/ON/CANADA

From the three approaches suggested by Londa Schiebinger to harness the power of gender analysis, this part of the presentation deals with the first two: “Fixing the number of women” and “fixing the institutions”. Women and men can generate and participate in activities that lead to an increased participation of women in biomedical engineering and medical physics. Evidence also exists, demonstrating that there are economic benefits and more complete solutions created by gender balanced design teams and an increased number of women in decision-making bodies such as corporate boards, management teams in industry, government, and universities. It is critical to collect sex disaggregated data on undergraduate post-secondary enrolments and graduations in science and engineering, as well as to understand the gender participation in the workplace in these fields. Examining the issues that limit women’s participation at all levels is a first step, which can then be followed by the development and implementation of strategies that help eliminate gender bias and provide the necessary support for women to have a successful career in these fields.

PL01.2 - Gendered Innovations in Health & Technology
Author(s): Londa Schiebinger
Stanford University, Stanford/UNITED STATES OF AMERICA

How can we harness the power of gender analysis to discover new things? Schiebinger identified three major approaches to gender in science research, policy, and practice: 1) “Fix the Numbers of Women” focuses on increasing women’s participation; 2) “Fix the Institutions” promotes gender equality in careers through structural change in research organizations; and 3) “Fix the Knowledge” or “gendered innovations” stimulates excellence in science and technology by integrating sex and gender analysis into research. This talk focuses on the third approach. Gendered Innovations: 1) develops state-of-the-art methods of sex and gender analysis for scientists and engineers; and 2) provides 24 case studies as concrete illustrations of how sex and gender analysis leads to new ideas and excellence in research. Several case studies will be discussed, including stem cells, assistive technologies for the elderly, and osteoporosis in men. All case studies can be found at: http://genderinnovations.stanford.edu/. To match the global reach of science and technology, this project was developed through a collaboration of over sixty experts from across the United States, Europe, and Canada (and has now extended to Asia). Gendered Innovations was funded by the National Science Foundation, the European Commission, and Stanford University.

PL03 - URBAN HEALTH AND FUTURE EARTH / GLOBAL HEALTH CHALLENGES

PL03.1 - The Changing Urban Environment and Health in a Future Earth
Author(s): Gordon Mcbean
Western University, London/ON/CANADA

Around our planet there have been increasing numbers of disasters due to floods, storms, earthquakes and other natural hazards. Although earthquakes are most horrific when they happen, climate-related events cause about three-quarters of all disasters and as the climate warms, these hazards are increasing. There is also the migration to people to major cities, often on coasts of the oceans or major rivers. The result is the intersection of the effects of the major issues of climate change, disaster risk reduction and sustainable development. In all cases we need to look to the future and takes actions now to reduce losses in the future.

In 2015, nations will negotiate a revised framework on action on disaster risk reduction, a possible Paris-protocol on climate change and Sustainable Development Goals to be attained by all countries by 2030. The draft list of SDGs includes: end poverty and hunger; attain healthy life for all at all ages; secure water and sanitation; and build inclusive, safe and sustainable cities and human settlements. For the global science community, the challenge is providing the scientific basis for definitions and approaches, including how to achieve these goals and the criteria for measurement of progress.

This presentation will bring together these issues in the context of the new international research programs Future Earth: Research for Global Sustainability; Integrated Research on Disaster Risk; and Health and Wellbeing in the Changing Urban Environment: A Systems Analysis Approach; with a Canadian-funded project, Coastal Cities at Risk: Building Adaptive Capacity for Managing Climate Change in Coastal Megacities. The Future Earth program is adopting an approach to involve the stakeholder community in the research program from the beginning to co-design and co-produce the research based on the logic that this will make the research most directly relevant to societies needs to address these issues. The Coastal Cities research project is integrating across social-natural-economic-engineering and health sciences to develop a systems approach to quantifying urban resilience and then undertake “what if” experiments to identify the most effective approaches to improving resilience and reducing impacts, recognizing the complex interactions across these elements of society.

The International Council for Science is leading the Science and Technology Major Groups to input to these UN processes and will endeavour to bring these scientific principles to the negotiations. Working with UN agencies such as UNESCO, UNU and WMO, and non-governmental partners such as the Inter-Academy Medical Panel, the Council will continue in the coming decades to assert the importance of scientific bases for these international agreements and national actions. We need to have the full support of medical physicists and biomedical engineers engaged in supporting health care in diverse environments in order to achieve these societal objectives, consistent with the Council’s Mission to strengthen international science for the benefit of society - all societies and all people.
PL04 - EVIDENCE AND HEALTH INFORMATICS

PL04.1 - Academic Biomedical Informatics: Synergies and Challenges at the Interface with Industry
Author(s): Edward Shortliffe
College Of Health Solutions, Arizona State University, Phoenix/UNITED STATES OF AMERICA

Academic biomedical informatics has achieved great successes through research contributions and education of professional informaticians over several decades, now reflected in a thriving commercial marketplace for electronic health records and other informatics tools. That very success, coupled with changes in the ability of governments to support research at past levels, is forcing a reconsideration of the directions and emphases for faculty members in informatics academic units. In this presentation Dr. Shortliffe will discuss those forces and propose areas of emphasis that will strengthen the academic discipline as it continues to evolve. He will distinguish the roles of academic informaticians as practitioners of informatics, as researchers, and as educators. He will also stress the necessary synergies between academic informatics and the health information technology industry, arguing that both will be strengthened by more fertile relationships and joint efforts.

PL04.2 - Cognitive Challenges for Safe Human Computer Interaction
Author(s): Vimla Patel
The New York Academy of Medicine and Columbia University, New York/UNITED STATES OF AMERICA

Given the complexities of modern medicine, delivery of safe and timely care is an ongoing and recognized challenge. Errors, misunderstandings, and inaccuracies—large and small—are routine occurrences in healthcare delivery. Health information technology (IT) has undoubtedly reduced the risk of serious injury for patients. However, its true potential for preventing medical errors remains only partially realized. Unfortunately, such systems may even give rise to hazards of their own. There is a growing recognition that many errors are attributable neither solely to lapses in human performance nor to flawed technology. Rather they develop as a product of the interaction between human beings and technology. In our view, errors are the product of cognitive activity in human adaptation to complex physical, social, and cultural environments. How well the design of health IT complements its intended setting and purpose is critically important for safe and effective performance. In this presentation, I will discuss the cognitive challenges we face in understanding human-computer interaction (HCI) that make the integration of computing and clinical practice a difficult task that, improperly addressed, can lead to threats to patient safety.