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International

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MMP THESIS ABSTRACTS BOOKLET
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BOOK OF ABSTRACTS

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EDITORIALS

MPI Issue focussed on ALFIM and ICMP2019

Slavik Tabakov, MPI Co-Editor in Chief

This issue of the Journal, Medical Physics International (May 2019), has a focus on the countries from South and Central America and the Caribbean Region. The development of medical physics in this part of the world, and in Africa, is embedded in the IOMP plans during the past 10 years. The reason for this is the small number of medical physicists per million of inhabitants in these parts of the world. The support for the professional development in Latin America is easier, first because small number of languages are spoken by large groups of people, and second as the IOMP Regional Organization ALFIM exists for almost 35 years (ALFIM – Asociacion Latinoamericana de Fisica Medica : Latin American Medical Physics Association). This is the second IOMP Regional Organization, after the one in Europe – EFOMP. At the beginning of 2018 the IOMP Council selected Chile as the host for the International Conference on Medical Physics 2019 (ICMP2019).

The current MPI issue includes an invited paper from Brazil and a survey of medical physics status in Central America (commissioned at the ICTP College on Medical Physics). It also includes papers about the development of medical physics in Chile and in Jamaica, plus an address from the current ALFIM President. Additionally, the issue includes papers related to educational materials - GIF animations (from USA), practical measurements of DRLs (from Brazil), and the 30th Anniversary of the ICTP College on Medical Physics. Also included are brief reviews of 4 textbooks, which will be very useful educational resources. Speaking on historical note, the MPI issue also includes a paper about the John Cameron Memorial Lectures at the SEAFOMP Conferences. Continuing on the same subject, please see the Editorial from Prof. Sprawls about the coming Second MPI Special Issue related to the project “History of Medical Physics”.

Next month the current MPI issue will be updated with the selected Abstracts of presentations/posters for the ICMP2019 (plus addresses from IOMP, the Organizers and the Scientific Committee).

Editorial- Our Medical Physics History and Heritage

Perry Sprawls, MPI Co-Editor in Chief

Medical Physics is one of the sciences that has become a foundation of modern medicine with major contributions to the health of society in all countries of the world. Clinically applied medical physics and technology as we know it today is the result of a continuing series of research, developments, and innovations occurring for well over a century. Our profession is enriched with knowledge and appreciation for the many developments from our past. The IOMP Medical Physics History Project in collaboration with the AAPM is providing extensive resources for exploring our history and sharing it with colleagues and students to preserve and appreciate our heritage.

The articles resulting from this project are published in special editions of this journal, Medical Physics International. They are generally authored by medical physicists with extensive careers in the field that have been active in and experienced much of the history. A feature of all of the articles is extensive bibliographies with references and links to much of the literature on this history. This is a place to start for more in-depth study and research.

The articles published in the 2018 Special Edition of MPI (http://www.mpijournal.org/MPI-v06SIi01.aspx) were:
• X-Ray Tubes Development. By Rolf Behling
• Film-Screen Radiography Receptor Development: A Historical Perspective. By Perry Sprawls
• History of Medical Physics E-Learning: Introduction and First Activities. By Slavik Tabakov
The presentations at the History Symposium at the AAPM Annual Meeting are based on the articles from the IOMP History Project. For the 2019 MPI History Edition and AAPM Symposium these are:
• The Scientific and Technological Developments in Mammography:
A Continuing Quest For Visibility. By Perry Sprawls
• The Evolution of Fluoroscopy Science, Technology, and Clinical Applications. By Steven Balter

EDUCATIONAL TOPICS

ORIGINAL GIF ANIMATIONS TO SUPPORT THE TEACHING OF MEDICAL IMAGE RECONSTRUCTION

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Abstract — **Understanding the principles of 3D imaging and how measured data can be reconstructed into images is fundamental to the modern field of medical imaging. Visual representations of multi-step technological or mathematical concepts can aid their understanding, provide a resource for students in their education, and increase interest in the field. To help explain the basic principles of three-dimensional medical imaging, we developed a series of multi-frame gif animations and text that describe the foundational concepts of tomographic imaging, used in computed tomography (CT), positron emission tomography (PET), and single photon emission computed tomography (SPECT). The animation based-learning package is available online – viewable in a web browser, or as slides contained in a downloadable PowerPoint lecture. The material covers the principles of sinograms/image data storage, forward projection, PET/CT/SPECT acquisitions, and filtered back-projection. Moreover, the package is free and readily downloadable by anyone interested, such as teachers/students, clinicians, and engaged patients.**

Keywords — **image reconstruction, education, training, animation, e-Learning**

I. INTRODUCTION

The concept of *Medical Imaging* refers to the process of creating visual representations of the body's anatomical or functional interior to be used for clinical purposes, and is widely utilized in modern medicine for an abundance of applications in oncology, neurology, surgery, orthopedics, pharmaceutical trials etc.

Historically, medical images were two-dimensional (2D), static images printed on film, whereas many modern imaging systems produce three-dimensional (3D) digital images. Understanding the principles of 3D imaging and how measured data can be *reconstructed* into images is fundamental to the field of medical imaging. Clinicians, technologists, physicists, patients, students, and inquisitive minds all stand to benefit from greater comprehension of the supporting technologies. The collection of data through an imaging system (e.g. computed tomography (CT) scanner) and the subsequent reconstruction of that data into medical images involve much underlying technology and mathematical theory. These concepts can appear complicated and difficult to understand. However, imaging is by nature a graphical media, and image reconstruction is a serial process. These factors lend themselves to elegantly utilize animations as visual aids so that mathematical functions can be associated with intuitive spatial processes.

To help explain the basic principles of 3D imaging, we developed multi-frame animations that convey the concepts of tomographic imaging in CT, positron emission tomography (PET), and single photon emission computed tomography (SPECT). These animations help explain imaging concepts by visualization of spatial/temporal aspects of data collection and utilization. The series of free (gif) animations are accessible online and provide a multimedia introduction to the main concepts of image reconstruction.

Increased insight in the process of medical imaging and image reconstruction may help introduce imaging concepts to students and the greater public, hopefully expanding interest in the field, and possibly nurturing future innovators and further breakthroughs.

II. MATERIALS AND METHODS

Text and animations were created to convey the principles of analytic tomography in CT, PET and SPECT. The animation based-learning package is available online on the IAEA's Human Health Campus (humanhealth.iaea.org) [1], and our personal website (kesnersmedicalphysics.com) [2]. In addition, to accompany this article, a full PowerPoint lecture slide set is also hosted on the sites. All content is free for download or viewing for teachers, students, or anyone interested in the subject of image reconstruction. The file sizes of the animations range between 5-10 MB each, and combined are a total of ~64 MB. Depending on individual internet connection speed, the e-Package/webpage may take several minutes to fully download.

Kesner-Haeggstroem Fundamentals of Medical Image Reconstruction Explained with Animations Lecture: The full animation set, and bullet text is prepared in an Microsoft Office PowerPoint lecture format, and available for download on the sites. It consists of 13 slides (including a title and final slide). The main topics covered by the package are the following: principles of sinograms/image data storage, forward projection, principles of PET acquisitions, and filtered back-projection. A total of 9 animations were created and presented for scenarios with CT, PET, and digital phantoms. Static frames of two of the animations are seen in Figure 1 and 2.

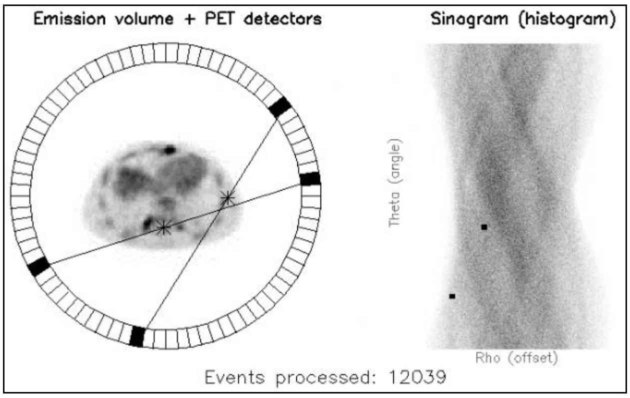

Figure 1. Static frame from one of the gif animations available in the learning content, visualizing the detection of annihilation photons in the PET scanner (left), and how those data are stored in the corresponding sinogram (right).

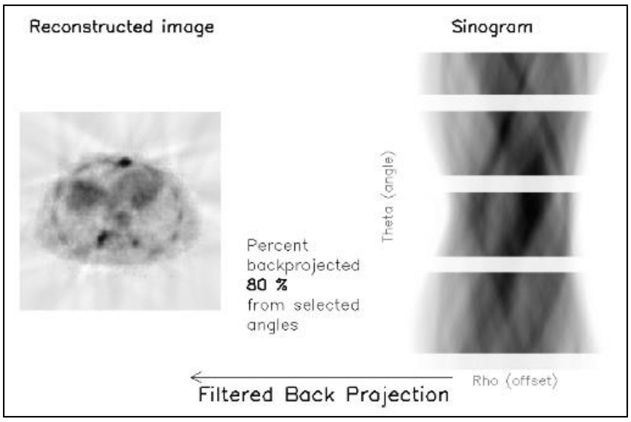

Figure 2. Static frame from one of the gif animations available in the learning content, visualizing the filtered back-projected image (left) resulting from only using a subset of the measured sinogram data (right).

III. RESULTS

Tutorial text and animations have been posted online, freely available to view or download. The material has been available online since 2014 (with animations added over time). In 2016, our conference abstract describing the animations placed as a finalist in the education tract AAPM conference award. Since first posting, we have collected positive feedback from a variety of users. The animations are presently in the first position in a google search of “image reconstruction animations”.

IV. DISCUSSION AND CONCLUSIONS

This animation based-learning package was developed aiming to increase the knowledge in medical tomographic imaging and image reconstruction.

We identified a need for improved teaching tools to help visualize the (temporally variant) concepts of image reconstruction and have shown that animations can be a useful tool for this aspect of education.

The choice to work with the gif (graphics interchange format) to create the animations was an intentional one. The format carries carry several advantages which we have found make them ideal for teaching media. They’re built simply as a sequence of image frames, and are relatively robust, easy to share and optimized file size. Gif animations are viewable universally across platforms, across web browsers, and slideshow presentations, and without the need for vendor supported plugins. In terms of long term durability, it is difficult to know what the favored file format in coming years will be, but we have seen the gif file format used over several decades and it continues to enjoy continued widespread utility across platforms.

Classically, over the last century, teaching has been limited to on what may fit on a printed page. The modern digital age, and particularly the advent of computers and the internet, has opened new possibilities for developing tools for learning and dissemination. When creating contemporary educational material, we should consider the opportunities we have for enhanced media formats [3]. In keeping up with modern technology, we believe the future of teaching imaging sciences should continue to take advantage of modern media – in this case digital animations and open distribution.

In our experience with this project, posting animations freely on the web has shown to be a good way to maximize their impact in the community, and well beyond their initial intended use for a single institution. In future endeavors, we hope to expand this animated content to cover principles of imaging, likely including iterative reconstruction, 4D imaging (3D+temporal), magnetic resonance imaging (MRI), as well as other phenomena relating to imaging.

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INTERNATIONAL COLLEGE ON MEDICAL PHYSICS AT ICTP –

30 YEARS SUPPORT FOR THE COLLEAGUES IN LOW AND MIDDLE INCOME COUNTRIES

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Abstract–The ICTP College on Medical Physics celebrated its 30th Anniversary during 2018. Over this period the College has educated c.1200 participants from over 100 developing countries. Many of the College past students have become professional leaders in their countries - in particular from Asia, Africa, Latin America and Eastern Europe. The success of the College on Medical Physics has triggered other medical physics activities at ICTP. The paper presents brief statistics and results of the College, showing its international impact.

In 2018 the College on Medical Physics at ICTP (the Abdus Salam International Centre for Theoretical Physics, Trieste, Italy) celebrated its 30th Anniversary. The first College on Medical Physics at ICTP was conducted in 1988. The purpose for establishing a College was to support colleagues from Low and Middle Income (LMI) countries (aka developing countries). It was originated by Dr Anna Benini (at that time IAEA expert) and was supported over the years by Prof. Luciano Bertocchi (at that time ICTP Deputy Director). Both continue to be at the heart of the College and other medical physics activities in the ICTP. The college was strongly supported by all ICTP Directors: from Prof. Abdus Salam, to Prof. Virasoro, Prof. Srinivasan and now Prof. Quevedo.

Since the start in 1988 the ICTP Medical Physics Colleges were held during 1990, 1992, 1994, 1996, 1999, 2002, 2004, 2006, 2008, 2010, 2012, 2014, 2016, and 2018. Over the years the College Directors included: A Benini, L Bertocchi, J Cameron, F De Guerrini , S Mascarenhas, R Cesareo, P Sprawls, J Chela-Flores, S Tabakov, G D Frey, F Milano, M DeDenaro. The faculty of lecturers included eminent specialists from many countries.

In 2001 the Coordinating Directors (P Sprawls and S Tabakov) modified the teaching programme to develop the participants as more effective educators in their institutions. This "Train-the-Trainer" approach had three components, as described later. This was of special value to colleagues from LMI countries— gradually building their knowledge necessary for the clinical application of digital medical imaging. The materials presented to each student after 2002 were enriched with purpose built e-learning materials. This facilitated the global dissemination of the knowledge from the College, as many of the College students used these materials for their teaching activities and organising courses in their countries. The new programme structure also allowed the College to be condensed in 3 weeks (from 2008) and to introduce to each College a different emphasis. This structure allowed introduction of laboratories with computer simulations, and further practical labs at the Trieste Hospital. These principles continue to be the backbone of the College and is highly appreciated by all students.

The materials from the ICTP College on Medical Physics were used for similar activities in India, in South-East Asia and in Latin America and Caribbean Region. All Colleges after 2002 also include a Workshop, where students present the main professional and educational activities in their countries. This exchange of experience facilitated the creation of professional networks, which they continue to support.

From 1988 to 2018 the College has had approximately 1200 students from over 100 countries, these were students with ICTP support plus self-funded attendees and ICTP associates and students. 31% of all students are women. The percentage of women grew from 15% at the beginning to 42% in recent years. In the period 2002-2018 the College students were c.700 from 89 LMI countries (Fig.1)

Many of the students from the ICTP College on Medical Physics became respected medical physicists and leaders in their countries who established Academic Departments and Societies; became Professors, Heads of Departments and Officers of their Societies; took active roles in the further professional development and healthcare provision in their countries; took part in various international projects, including the Multilingual Medical Physics Dictionary. Our data after 2002 shows that 35 men and 16 women, College students from 25 countries, have become professional leads in their countries and regions. Many other College students have later organised University programmes and short courses in their countries. Over the years the International College on Medical Physics at ICTP has become a real

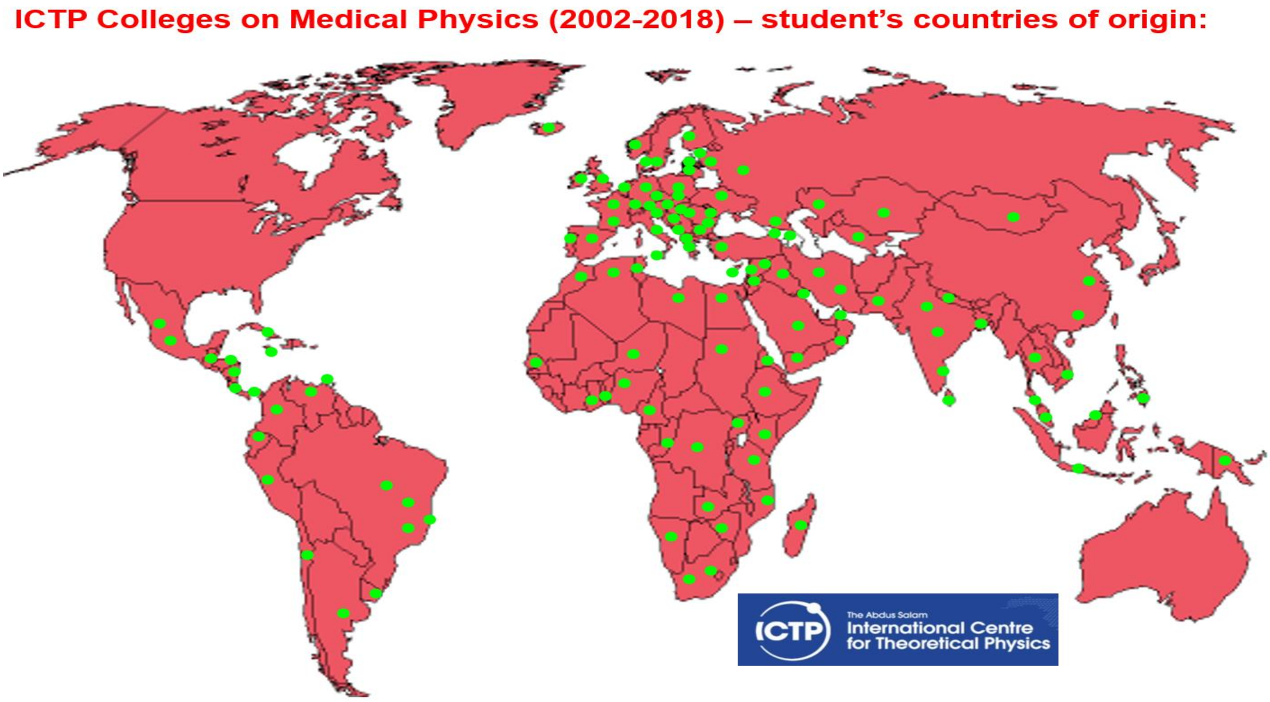

Fig.1 ICTP Colleges on Medical Physics (2002-2018) – students from: Albania, Algeria, Armenia, Argentina, Bangladesh, Belarus, Bosna, Brazil, Brunei, Bulgaria, Burkina Faso, Cameroon, P.R. China, Chili, Croatia, Columbia, Congo, Costa Rica, Cote D'Ivoir, Cuba, Czech Rep., Ecuador, El Salvador, Estonia, Ethiopia, Egypt, Eritrea, Georgia, Ghana, Guatemala, Honduras, Hungary, India, Indonesia, Iran, Iraq, Jordan, Kenia, Kuwait, Latvia, Lebanon, Lesotho, Lithuania, Libya, North Macedonia, Madagascar, Malaysia, Malawi, Moldova, Mongolia, Mexico, Morocco, Montenegro, Namibia, Nepal, Nicaragua, Niger, Nigeria, Oman, Peru, Philippines, Papua New Guinee, Panama, Pakistan, Poland, Romania, Russia, Serbia, Senegal, Slovenia, Slovakia, Sudan, Syria, Sri Lanka, South Africa, Tanzania, Trinidad and Tobago, Thailand, Turkey, Uganda, Ukraine, Uruguay, Uzbekistan, Venezuela, Vietnam, West bank, Yemen, Zambia, Zimbabwe (some College participants have come from High Income countries, where they have studied).

beacon of medical physics for colleagues from LMI countries. Its international impact has been particularly strong in the countries of Asia, Africa, Latin America and Eastern Europe.

A major College objective is to develop the students as educators who can create within their countries effective programmes in medical physics (imaging and radiation safety). This is achieved through the combination of three specific activities:

(i) providing guidance on modern imaging methods and related radiation safety;

(ii) providing instruction on the process of learning and teaching and the development of appropriate educational programmes for their institutions;

(iii) providing students with extensive high-quality teaching materials/resources to be used in their courses.

The educational activities in the College have been innovative from the very beginning. Because of the College in 1995 the ICTP was included in the project EMERALD, that developed one of the first e-learning materials in the world. As a result in 1996 the College introduced in its curriculum e-learning, thus becoming the first educational activity in medical physics to embrace this new type of learning. Later all its students received full sets of lecture notes and Power Point presentations, plus copies of the above e-learning materials, which they could use in their countries. The Feedback collected from all College students shows that this was highly appreciated and most College participants have made plans during their stay at ICTP how to apply these materials in their practice.

The first major educational websites in medical physics www.emerald2.eu and www.sprawls.org were introduced in the College and the feedback was used for their updates. This early connection of the ICTP College with e-learning led to involvement of the applicants in other e-learning activities in their countries. The latest feedback questionnaires show that 66% of the students already apply e-learning in their teaching activities through the materials given to them at the College, and 27% plan to take part in further e-learning activities.

The needs of the ICTP College students for translation of some teaching materials into their own languages triggered in 2002 the development of the Multilingual Dictionary of Medical Physics Terms through the projects EMIT and EMITEL. A number of College participants took part in this activity, which is now freely available to all through its web site www.emitel2.eu (interlinked with the e-Encyclopaedia of Medical Physics).

Applications to the College (currently 300+ applications for 40–50 places) show its popularity amongst young medical physicists from LMI countries.

One particular strength of the College is the emphasis on Quality Control (QC) of X-ray Equipment – one of the most widely used medical technologies. The EMERALD protocols were of significant importance for this activity. These are still some of the most widely used parts of the whole EMERALD package in many LMI countries. Some of these protocols were used in the College as Computer Labs and from 2010-12 these were additionally strengthened by practicals in the Trieste Hospital. The QC practicals in Nuclear Medicine and practicals in Radiation Protection were also added to the College curriculum. This reflected in significant increase of students' knowledge in these fields – see the survey results in Fig. 2.

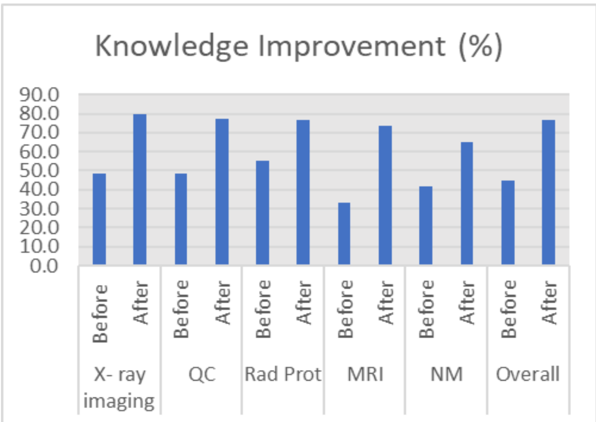

Fig.2 Student's own estimate of their knowledge (in %) before and after completion specific parts of the College curricula (max 100%): X-ray imaging; X-ray Quality Control; Radiation Protection; Magnetic Resonance Imaging, Nuclear Medicine Physics and Overall

These results are further supported by the overall 94% positive feedback from the College (mean 4.7, st.dev 0.2), where the students had to grade anonymously from 5 (excellent) to 1 (unsatisfactory) the following questions:

1.Are you satisfied with the organisation of the College?
2.Do you like the ICTP teaching facilities?
3.Do you find the topics useful for your future activities?
4.Do you exchange valuable information with your colleagues in the College?
5.Are the lectures accessible?
6.Did you find-the Computer labs useful?
7.Do you like the Teaching materials received?

The students who indicated that they have attended other medical physics courses before ICTP varies over the years from 25 to 44%. They all highly valued the College information, its detail and presentation, as well as the practical knowledge they have received at ICTP.

Another strength of the ICTP College is the inclusion of instructions on the process of learning and teaching. Special Workshops were introduced where College participants present and discuss the professional and education activities in their countries. These Workshops were associated with class discussions and exchange of expertise on the subject. This resulted in the introduction of many improvements in medical physics teaching, as well as establishment of new educational courses and forming stable links between lecturers from different countries. Some of these led to later formation of educational projects supported by the IAEA and other institutions. In 2016 the most innovative ideas and achievements were supported through the newly established Emerald Award.

The information from these Workshops was published in the book *Medical Physics and Engineering Education and Training – part I*, ISBN 92-95003-44-6, ICTP, Trieste, Italy 2011, (edited by S Tabakov, P Sprawls, A Krisanachinda, C Lewis). The book includes information about the educational activities in 27 countries (plus 9 Institutions and projects). A new book on the subject (part II) is in preparation at the moment. These publications present the vector of professional development not only in LMI countries, but also in the developed countries.

A most important impact of the College is that after their graduation more than 80% of the College students have clear ideas how to spread the knowledge from the College in their countries and how to boost the development of medical physics there. Indicatively, during the past 10 years the number of students who know other ICTP College participants in their countries has risen from 62% to 80%. While we could not establish the exact number of Professors, course Directors and Society Officers from LMI countries, who have studied at the ICTP College, our students report that many of their teachers or senior colleagues have participated at the ICTP College. At the other end of this scale are some College students from LMI countries, who inform that they are the first people in their countries to have some education in medical physics.

The College on Medical Physics 2018 introduced online teaching. This added significant value to the program by having live presentations and discussions by international experts from other countries directly with the students in the ICTP classroom. Also there was expansion of the practicals in Trieste Hospital, plus visits to the Udine Hospital, and introduced medical equipment management topics. This way the students could also learn how to organise medical physics departments and activities associated with maintenance of the equipment in their countries. The College lecturers and leads deliver for free their teaching and provide free access to all their educational and e-learning materials. This secures more resources for supporting the travel of some students to the College. We have to underline that the ICTP College do not charge participants with attendance fees and provides free accommodation for most students from LMI countries.

Over the years ICTP appreciates the College on Medical Physics as one of its very successful activities in the field of applied physics. In 2005 ICTP was Co-Organiser of the UNESCO World Conference on Physics and Sustainable Development (November 2005, Durban, South Africa). At this high-level international event the case of “Physics and Health” was presented by P Sprawls, D Van Der Merwe, S Tabakov and A Niroomand-Rad. Following this the Conference selected this area of applied physics to be one of the four main UNESCO Millennium Development Goals with special importance for the years ahead.

The success of the College on Medical Physics led to opening and supporting of other medical physics activities in ICTP – notably various IAEA Courses. In 2015 ICTP started a regular activity - School of Medical Physics for Radiation Therapy (in alternating years with the College). This School is headed by R Padovani, with the support from EFOMP, IOMP, AAPM, IAEA and ICTP. This School just had its 3rd delivery.

In 2004 the College Directors (S Tabakov, P Sprawls and L Bertocchi) discussed with the ICTP Director the idea of forming a regular post-graduate educational course in ICTP. This continued to be discussed and updated until in 2014, when ICTP formed an alliance with the University of Trieste, resulting in the first international MSc programme in Medical Physics, headed by R Padovani and R Longo. This MSc on Advanced Studies in Medical Physics, with IAEA support, has already produced several alumni and has the strong support of the Italian Association of Medical Physics. In 2016 IOMP (the International Organization for Medical Physics) provided International Accreditation for this MSc programme. At the end of this issue of the MPI Journal are the abstracts of the Master Dissertations of the students from the MSc graduation in December 2018.

The MSc students and College participants have a number of joint activities. Some young colleagues from both groups take part in research activities organised by ICTP – the Programme of Research and Training in Italian Laboratories (TRIL) and become ICTP Associate Members

The ICTP College was also the reason for the ICTP to host some other Medical Physics Conferences – Regional, EFOMP and International, including the first International Conference for Medical Physics Training (1998), the first International Conference for e-Learning in Medical Physics (2003) and the International Conference “Medical Physics Encyclopaedia” (2008).

The College students, and indirectly - their students, have become a very important part of the healthcare delivery in LMI countries. On the occasion of the 30th Anniversary of the ICTP College on Medical Physics a special Gratitude Folder was presented to the ICTP Directorate, which includes photos from all Colleges and other medical physics activities in ICTP, Trieste (Fig. 3). The Folder also includes appreciation and gratitude emails from College students from 42 countries (in the period 2010-2018), available from: http://indico.ictp.it/event/8296/material/3/

The education and training activities of the ICTP College on Medical Physics will be pivotal in the dealing with the current challenge confronting the profession – the global shortage of medical physics specialists, especially in many LMI countries and, related to this, the need of almost tripling the medical physicists globally by 2035. The ICTP College on Medical Physics students (and their students) have made the physics applied to medicine an inseparable part of the lives of millions of patients globally.

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Fig.3 ICTP College on Medical Physics 2018 presenting to ICTP Deputy Director Prof. S Scandolo a Gratitude Folder from students and College Faculty: R>L: R Padovani, P Bregant, M DeDenaro, F Milano, S Tabakov, S Scandolo, A Benini, L Bertocchi, S Radosic (missing Faculty on photo: P Sprawls, A Seibert, J Oshinski, M Stoeva, S Tipnis, Prof. F Quevedo)

PROFESSIONAL ISSUES

THE DEVELOPMENT OF THE MEDICAL PHYSICS PROFESSION IN THE CENTRAL AMERICAN REGION

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The development of the Medical Physics profession in the Central American region has been impressive, if we compare to the status existing 20 years ago. In year 1997, a sub-regional IAEA technical cooperation project for Central America and the Caribbean region (Fig.1), coded ARCAL XXX, estimated that the number of physicists working in hospitals were less than 10 in all countries, devoted only to Radiotherapy, and most of them lacked a postgraduate education in the field. At that time, they were only few cobalt machines for teletherapy and low dose brachytherapy sources; none or very basic dosimetry equipment were available and only a 2-D TPS was used in Panama, which later was involved in the accident of overdose.

Currently, according to a recent ALFIM/IOMP survey, there are 91 medical physicists in the region, half of them with a MS level in Medical Physics. Only in Costa Rica there are 2 MS programs in Medical Physics and there is a BS program in Nicaragua. Although there are still many problems related with the recognition of the profession, the lack of locally certified clinical training programs, the weakness or inexistence of national medical physics associations, emigration of professionals due to low salaries, etc., it should be recognized the great effort made by different institutions, entities and individuals, specially the IAEA, PAHO and ICTP, in order to improve quantitatively and qualitatively the Medical Physics profession in the Central American countries.

Fig.1 Map of Central America and Carribean Region

STATUS OF MEDICAL PHYSICS IN CENTRAL AMERICA

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***Abstract*— "Status of medical physics in Central America" is a study from data collection and additional resources from each country available until the year 2018. The study is based in the incidence of patients with cancer diagnosis, the number of diagnostic and treatment centers, the number of equipment according to use and modality, the professional personnel in medical physics working in the areas of Radiotherapy, Diagnostic Radiology, Nuclear Medicine and Radiation Protection, and the demand projection of professionals for the upcoming years. The information used was obtained from recent national and international studies available in each country; data provided from personnel working in national entities such as hospitals, health ministries and statistical ministries who have relation in the application of radiation to diagnose and treat. The objective of the study is to attain an update of the status of the medical physics specialty in Central America with the most recent available resources. Hence, introducing an estimate of the demand of such profession for the following years. The results shown are complete in most countries. However, in case of lack of information, this data was included in the study as: No Data Available (NDA), thus requiring a more in to depth study.**

***Keywords*— Medical Physics, Central America, status, update, cancer, diagnosis, treatment.**

I. HISTORY OF MEDICAL PHYSICS IN CENTRAL AMERICA

On November 8, 1895, Wilhelm Conrad Röntgen (1845 to 1923) discovered a mysterious new ray that he later called the "x-ray" [1]. After the discovery, the development in the application of the x-rays for medical science began to be implemented around the world, and with this flourished the need of a medical physics profession that now a days is increasing gradually.

Central America is a region between North America (from Mexico) and South America (until Colombia) and is comprised of seven countries: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama.

Medical physics in Central America started with the implementation of x-rays machines for medical diagnose by reproducing the experiment that took place to the discovery. The first equipment used in the Central America´s region and second one in Latin America was in Guatemala in November 1896, just one year after the discovery of W. Röntgen [2]; this was achieved thanks to the reconstruction of an x-ray tube, with the help of Ph.D. Darío Gonzalez. Ph.D. Darío Gonzalez, of Salvadoran origin, and an associate professor in the Faculty of Medicine at the university (Universidad de San Carlos de Guatemala), initiated the radiological practice in the region [3] with the use of the reconstructed x-ray tube at such institution. In the next years the use of X-ray machines was later developed throughout countries of Central America.

By 1897 with the help of M.D. Miguel Ángel Ugarte, the first equipment for x-rays was acquired from Germany; this marked the beginning of the radiology in Honduras [2].

In Nicaragua the first x ray machine was acquired in 1902 by Ph.D. Rosendo Rubí Altamirano [2], who also was the first radiologist in the national hospital in Nicaragua.

With the studies of M.D. Carlos de Cespedes about the evolution of the radiology as a medical specialty during the XX century, documented in the year 1904. This date marked the beginning of the radiology in Costa Rica followed by the purchase of the first X-ray machine by Professor José Brunetti Félix, of Italian origin [2].

In 1907, the first equipment was installed in El Salvador with the help of M.D. Alfonso Quiñonez Molina. Molina was responsible for acquiring the first bone and thorax radiography in that country [2].

The first x-ray equipment that worked in Panama was brought by M.D. Pedro Obarrio, installed in the ancient hospital Santo Tomás in 1912 [4]. In Belize the information is not public available.

Since the first time of the implementation of an x-ray generator machine, medical physics has been growing at different levels in each country. Some other historical dates in the development of medical physics are shown in a timeline summary of Central America in Table 1. A description of the status of medical physics in Central America is available in the next sections. This has been done according to the demographical and territorial indices, the number of new cases in cancer diagnose during the 2018, the professional source, the technology available for diagnosis and treatment and a projection of professional demand to cover in the next years.

Table 1. Timeline of medical physics in Central America.

Year – Event
1896 - First X-rays in Central America (Guatemala) [2]
1897 - 1912 First X-ray in the rest of Central America [2], [4]
1921 - First Brachytherapy in Guatemala [3]
1956 - First Brachytherapy in Nicaragua [5]
1957 - First Radio Oncologist in Guatemala [3]
1960 - First Brachytherapy in Honduras [2]
1960 - 1969 First Cobalt-60 Unit in Guatemala, Honduras, Nicaragua, Panama, Costa Rica and El Salvador [2],[6],[7]
1975 - First Brachytherapy in El Salvador [8]
1975 - First Medical Physicists in Costa Rica [7]
1980 - First Radio Oncologist and Medical Physics in Honduras [9]
1985 - First CT in El Salvador [2]
1986 - First Radiotherapist Oncologist in Costa Rica [7]
1993 - First MR in El Salvador [2]
1994 - First MR in Honduras [2]
1996 - Accident with Cobalt-60 Unit in Costa Rica [10]
1998 - First LINAC in Guatemala [3]
1999 - First LINAC in Costa Rica [7]
2000 - 2001 Accident with TPS in Panamá [11]
2008 - First CT in Honduras [2]
2009- First Rapid Arc in Latin America (Guatemala) [3],[12]
2011 - First Nuclear Medicine Center in Nicaragua [5]
2011 - First Nuclear Diagnosis in Nicaragua [5]
2013 - First Cyclotron in Central America (Panama) [13]
2014 - First IGRT in Costa Rica [7]
2015 - First Advance Technique in RT in El Salvador [8]
2015 - First Advance Technique in RT in Nicaragua [5]
2016 - First Nuclear Diagnosis in Honduras [9]
2018 - First Brachytherapy in Honduras [9]
2018 - First LINAC in Nicaragua [5]
2019 - Robotic Radiosurgery with CyberKnife in Costa Rica) [14]

II. DEMOGRAPHY AND GEOGRAPHY FEATURES

The official language spoken throughout Central American countries is Spanish with the exception of Belize, where the official language is English. The central American region has a territory of 522 thousand square kilometers with an estimated population of 48 million.

All the countries are members of the Atomic International Energy Agency (IAEA). The description of population, geographical area, growing population, Gross Domestic Product (GDP) and type of income group is shown in Table 3 according to each country [15].

III. INCIDENCE OF CANCER IN CENTRAL AMERICA

In order to understand the demand of equipment and professionals in medical physics is described a reference of the number of new cases diagnosed per year. The number of new cancer cases per year in a given population is obtained from the national population statistics, which is based on the cancer registry according to the oncology centers. In most cases in Central America this information is not publicly available for national centers; in private centers there is less possibility to have access to such information. This data is used as a statistic per working year progress because there is no journal/registry in the national health ministry that provides detailed description of the analysis or information for new cancer cases. Thus, the best estimation of the new cases is taken from the International Agency for Research on Cancer (IARC).

The incidence of cancer in Central America during the year 2018 is taken from the data base of IARC with Global Cancer Observatory Globocan-2018 [16]. Table 2 shows the percentage of cases according to the gender for all ages, and the total number of cases during this year.

The percentage of most frequent cancer case types diagnosed in the 2018 in Central America are shown by gender in Figure 1, for males containing: prostate, stomach, liver and lung cases. In Figure 2, for females containing: breast, cervix, stomach, liver and lung cases.

Table 2. Incidence of cancer in Central America during the year 2018.

Country	Percentage Distribution		Total
	Male	Female	
Belize	48.6%	51.4%	358
Costa Rica	50.0%	50.0%	12957
El Salvador	40.0%	60.0%	10326
Guatemala	43.5%	56.5%	16332
Honduras	44.3%	55.7%	9942
Nicaragua	45.7%	54.3%	7956
Panama	50.7%	49.3%	8244

Table 3. Demography and Geography features of Central America.

Country	Belize	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama
Population (thousands)	374.68	4,905.77	6,377.85	16,913.50	9,265.07	6,217.58	4,098.59
Geographical Area (km^2)	22,970.00	51,100.00	21,040.00	108,890.00	112,490.00	130,370.00	75,420.00
Population Growing Rate (%)	2.04%	1.19%	2.50%	1.93%	3.90%	1.06%	1.53%
Gross Domestic Product, GDP (Billion US$)	1.863	57.286	24.805	75.62	22.979	13.814	62.384
Income group	Upper middle income	Upper middle income	Lower middle income	Upper middle income	Lower middle income	Lower middle income	High income

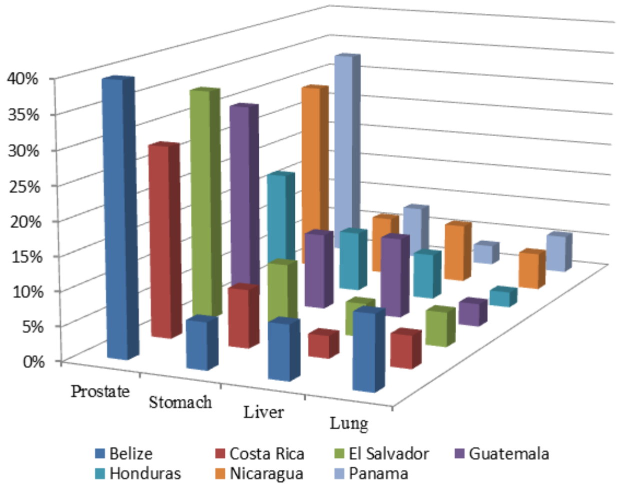

Fig. 1 Percentage of incidence of the most frequent types of cancer in Males in Central America, 2018.

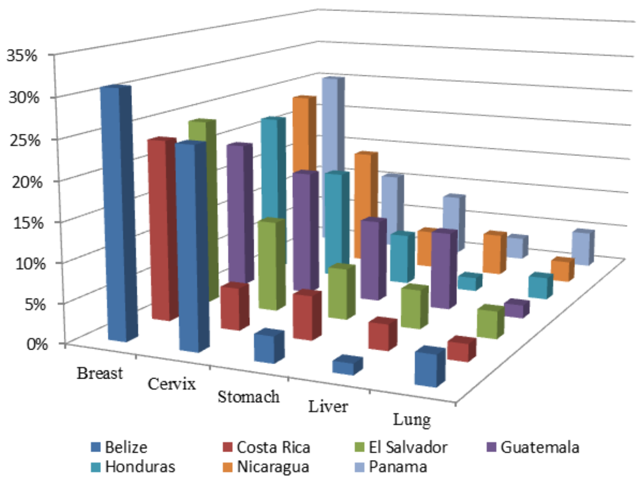

Fig. 2 Percentage of incidence of the most frequent types of cancer in Females in Central America, 2018.

IV. Professional status and medical physicist recognized in Central America

The Central American countries, although they share cultural and historical aspects, they presently have broad differences in human and scientific development at different stages. These differences are found in the requirements that each country requests for the professional practice of medical physics, and in some cases, it is adjusted to the academic resources. For this reason, there is no Central American norm that integrates, homogenizes and regulates the exercise of the profession for medical physicists in the region. The following paragraphs describe the necessary requirements for the practice of medical physics in each country of the Central American region.

Belize doesn't have Medical Physicist.

Costa Rica for professional practice the following is a requirement: master´s degree in medical physics, a certification proving they have planned and accomplished 50 treatments in radiotherapy (2D, 3D-CRT or IMRT). A license is given with validity for Radiotherapy and Superficial X-ray therapy. To work on radiation protection, it is necessary to have courses in shielding calculation. The license for brachytherapy is obtained by demonstrating that 50 patients have been planned [7].

El Salvador for professional practice the following is a requirement: Degree in Physics (must include courses of ionizing radiation) [8].

Guatemala for professional practice the following is a requirement: master´s degree or PhD degree in medical physics, this should be accredited by the national university; the recognition is evaluated by a board in medical physics, the medical physicist is registered in the College of Engineers of Guatemala. A minimum of two years training in of the specialty with the approval of a recognized medical physicist.

Honduras for professional practice the following is a requirement: Degree in Physics (must include courses of ionizing radiation) or grade in Biomedical Engineer [9].

Nicaragua to be able to practice the profession the following is a requirement: Master's degree in medical physics. The master's degree must be accredited by a national university and must comply with the sanitary code from the Ministry of Health, clinical practice license, medical and psychological fitness, inscription in the official newspaper and a two-year experience [5].

Panama the information is not available.

Table 4. Academic Offer to produce medical physicist per country of Central America.

Country	Bachelor degree	Master's degree	PhD
Belize [18]	-----	-----	-----
Costa Rica [7]	*Bachelor in physics*	• Professional Master's degree in Medical Physics • Academic Masters' degree in Medical Physics	-----
El Salvador [8]	*Bachelor in physics*	-----	-----
Guatemala [17]	*Bachelor in physics*	-----	-----
Honduras [9]	• *Bachelor in physics* • *Biomedical engineer*	-----	-----
Nicaragua [5]	*Bachelor in physics* with mention in medical physics	-----	-----
Panama [19]	*Bachelor in physics*	-----	-----

Table 5. Professionals working in medial physics according to specialties in Central America.

	Belize [18]	Costa Rica [7]	El Salvador* [8]	Guatemala [17]	Honduras [9]	Nicaragua [5]	Panama [19]
Radiotherapy	0	18	11	7	3	3	9
Nuclear Medicine	0	5	2	2	1	0	NDA
Diagnostic Radiology	0	2	0	4	1	1	1
Radiation Protection	0	4	3	3	1	2	NDA
Medical Physicist Recognized	0	NDA	1	7	3	5	15
Physicist Working in the Area	0	23**	13	7	3	5	15

*Physicist not recognized.
**Radiotherapy plus nuclear medicine physicist, real data is not available.

In order to ensure the academic training of medical physicists, each country offers different academic programs according to the requirements necessary to practice the profession. Guatemala and Nicaragua, however, are an exception to that rule since a degree in medical physics is required even though such career does not exist in the country. Table 4 shows the academic offer in each country in Central America.

Even with the mentioned difficulties there is an existing number of medical physicists specialized in the region, such number of professionals is increasing on a yearly basis. In most cases the formation of such professionals is carried out in foreign countries such as Argentina, Mexico, Italy amongst others, thanks to international programs' acceptance of the Latin American community and worldwide. The actual status of physicist working in the area of medical physics is shown in Table 5. Note, the total representation of the medical physicist may no match in some cases with the total staff working due to differences in internal normative for recognition.

V. DIAGNOSTIC AND TREATMENT CENTERS

There are not enough diagnostic and treatment centers in Central America, hence the need for more centers to treat all cancer diagnosed patients on a yearly basis. In most cases the diagnostic centers are distributed in the region according to the population concentration distribution. Many at times without meeting the normative for safety issued from the government that provides the regulatory requirements recommended by the IAEA. Within the recommended IAEA's requirements failure to abide is in terms of staff training, adequate documentation for standard operating procedures (SOP's), quality control or preventive maintenance of the equipment. The latter, related to fulfilling the growing demand of the services by the population and resulting in little or no time for preventative or regular maintenance of equipment; the end consequence then, is no dosimetry audits or any growing control over the operational services.

Therapy centers in most of the cases are centralized in the capital city of each country despite the difficult access this represents for rural areas due to distance, accommodation and or travelling expenses. These centers are however, more organized in regards to the regulations stipulated by the government. In the Central American region every country with the exception of Belize, has at least one governmental or non-governmental organization for radiotherapy center. In most countries, however, the private centers provide services to more than half of the population. The previous being a major setback for patients with low incomes. The quantity of centers that give the services for diagnosis and therapy are shown in the Table 6.

Table 6. Diagnosis and Treatment Centers in Central America.

Service Type	Belize [18]	Costa Rica [7]	El Salvador [8]	Guatemala [21]	Honduras [9]	Nicaragua [5]	Panama**
Brachytherapy	0	1	3	4	2	1	2
Nuclear Medicine	NDA	6	3	2	2	2	5
Radiotherapy	0	3	5	4	5	1	4
Based in x-ray modalities	NDA	NDA	200	12*	200	50	NDA

*Public Institutions in 2012 [19].
** Information obtained from [19] and [20].

Table7. Equipment according to modality in Central America.

Equipment type	Belize [18]	Costa Rica [22]	El Salvador [8]	Guatemala [21]	Honduras [9]	Nicaragua [5]	Panama [20]
LINAC	0	5	4	5	3	1	6
CO60	0	1	2	1	4	2	0
Magnetic Resonance	NDA	12	10	NDA	4	NDA	NDA
Mammography	NDA	NDA	40	97	50	--	NDA
Computed Tomography	NDA	NDA	30	95	8	--	NDA
Conventional X ray	NDA	NDA	100	327	50	--	NDA
Fluoroscopy	NDA	NDA	20	77	15	116**	NDA
PET	NDA	2	0	0*	1	0	NDA
SPECT/Gamma camera	NDA	9	3	2*	1	2	NDA

*Data from the year 2012 [19].
**Number that corresponds to equipment for radiology diagnosis and intervention.

VI. Equipment

The number of centers described in the previous sections indicate the possibilities of a patient to be diagnosed or treated. Each center contains different number of equipment in terms of the demand and recurrence of the diagnostics of their population. A radiotherapy center in each country contains at least one LINAC or Co60 and in some cases a low or high dose rate brachytherapy for therapy.

The diagnostic equipment in each country is distributed amongst centers; in some countries in Central America there is no data control making it difficult to have accurate information. The found data for existing equipment by country is summarized in Table 7.

VII. Estimating demand

There exists different ways to estimate the demand of medical physicist as described in [23]: i) range of applications of physics in medicine, ii) scale of organizational and management responsibilities (number of hospitals, population served), iii) the amount and complexity of equipment and procedures used in related clinical specialties, iv) number of patients examined and treated in the relevant modalities and the complexities of these examinations or treatments, v) the load for formal teaching and training, vi) the level of participation in research, development and clinical trials vii) the number of supporting staff (e.g. technical and radiographic).

According to the information in this article, the quantity of whole time equivalent (wte) medical physicists along with the necessary equipment for Radiotherapy, Diagnostic Radiology and Nuclear Medicine are estimated as follows:

1. Medical Physics in Radiotherapy:

- 1 high energy LINAC: 0.8 wte physicist.
- 1 major item equipment (Co60, TPS for LINAC, Brachytherapy service): 0.4 wte physicist.
- 1000 patients in radiotherapy: 1.2 wte physicist.

2. Medical Physics in Nuclear Medicine:

- 1 SPECT/CT or Gamma Camera: 0.75wte physicist.
- 1 PET/CT: 0.25 WTE physicist.
- Up to 5000 examinations per year and 50 treatments for year in a Nuclear Medicine Center: 0.75 wte physicist.

3. Medical Physics in Diagnostic Radiology:

- Population of 500,000: 1 wte physicist.

Table 8. Medical Physicist demand according to specialty in Central America.

	Belize**	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama
Radiotherapy*	0	15	13	18	12	7	13
Nuclear Medicine	0	11	4	3	2	2	4
Diagnostic Radiology	1	10	13	34	18	12	8
Total Medical Physicist	1	36	30	55	32	21	25
According to Italian system	5	67	87	232	127	85	56

*Patients in radiotherapy estimated as a 50% of the total [25].
**No radiotherapy and Nuclear Medicine services.

The estimation of the total number of medical physicists is summarized in Table 8. Such information is taken as a reference for minimum staffing for the few parameters used. These values acquired can be compared with a developed medical physics system, similar to that of the Italian, where in the year 2017 it was calculated a mean number of medical physicists being: 13.7 medical physicist per million of habitants [24], including all the specialties of the entire country.

The estimation of staff in radiation protection is not calculated due to the fact that this figure is not restricted to a physicist, in some Central American countries can also be a physician or a professional in another area with knowledge in radiation.

VIII. Discussion

Historically the Central American region has used ionizing radiation applied to medicine shortly after its discovery by Röntgen in 1895. Since the first decade of XX century, x-rays were used in diagnosis as shown in Table 1. With the implementation of new technologies involving radiation sources such as Co-60 and subsequently the LINAC, the region has failed to adapt. One of the reasons is largely due to development and socio-economic issues as shown in the Table 3. Central American countries have the lower GDP values of the American continent similar to the Caribbean ones.

These unfortunate realities result in limited or no access to healthcare, even with the high incidence of cancer in the region. In 2018, 66,115 new cases of cancer were reported in the region, with the predominance of prostate cancer among men and breast cancer among women as seen in the Figures 1 and 2. There is an equivalent rate of incidence among men and women as shown in the Table 2. To deal with this situation, the region needs to incorporate medical physicists in the public and private hospitals. The requirements for the qualification of a medical physicist depend on the academic resources that each country can offer. Costa Rica is currently the only country that can satisfy their own requirements, as they benefit from their own masters programme in medical physics. In the other countries, only bachelor's degrees in physics exist, with additional courses orientated to ionizing radiation as shown in the Table 4. In order to solve this issue, professionals migrate to satisfy academic necessities. An example of this high demand, is the master programme in medical physics of the ICTP in conjunction with the Università degli studi di Trieste, in Italy. This programme has contributed to the development of the medical physics practice in Central America [26].

As shown in Table 5, radiotherapy is the most developed specialty in Central America, even though there exists a large number of diagnostic equipment (Table 7). This disparity between available equipment and clinically trained physicists creates a great need for specialists in the area of diagnosis and nuclear medicine (Table 6). An estimation of the number of medical physicists needed for Central America was made in Section VI. Utilizing the criteria set forth by EFOMP, it was determined that 200 physicists are needed to satisfy the minimum requirements of the region. A further calculation was done using the Italian system, to provide a more ideal number, for which the region should aim in the future.

The training of such professionals should be organized together with the heads of government of each country. Collaborations of this nature will produce better environments to implement correct practices in each center of diagnose and treatment, better application of radiation to medicine, and improved attention to the patients that need healthcare. The challenge that the Central American countries must face in the coming years, involve education, health and scientific plans.

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Annex

The following is the translation of the form used for data acquisition.

Status of medical physics in:__________________

Fill in the below table with the information requested as accurate as possible:

I) Educational programs for medical physics

Bachelors level			
University			
Degree			
Duration time			

In case of clinical training acquired, indicate the quantity of hours necessary.

Master level			
University			
Degree			
Duration time			

In case of clinical training acquired, indicate the quantity of hours necessary.

II) Qualifies to be recognized as a medical physicist in the country

Academic level	
Quantity clinical experience years	
Others	

III) Quantity of medical physicist in the different areas of work in the country

Radiotherapy	
Nuclear Medicine	
Diagnostic Radiology	
Radiation Protection	
Total number of medical physicists in the country	

In the absence of medical physicist professionals indicate the profile of the person that works in the roll of medical physicist:

IV) Services and Equipment for diagnose and treatment

Quantity of centers where radiotherapy is practiced	
Quantity of centers that deliver studies of diagnosis based on x-ray modalities (Tomography, mammography, CT, fluoroscopy, etc.)	
Quantity of centers where nuclear medicine is practiced	

Equipment type	**Quantity**
LINAC and Co60	
Magnetic Resonance	
Mammography	
Computed Tomography	
Conventional X ray	
Fluoroscopy	
Brachytherapy services	
Nuclear Medicine treatment	
PET	
SPECT	
Gamma Camera	

V) In the following table some historical information about the evolution of medical physics in the country is required. Provide dates and a brief description.

Event	**Year and Description**
First equipment for Radiotherapy installed	
First radiotherapy treatment delivered	
First Radio-oncologist	
First medical physicist	
First brachytherapy delivered	
First diagnose in nuclear medicine	
First radiotherapy treatment with an advanced technique delivered	
Another important event	

TEN YEARS OF MEDICAL PHYSICS EDUCATION AND CONTINUING PROFESSIONAL TRAINING IN JAMAICA

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***Abstract*— Caribbean countries and Jamaica face several challenges in the use of radiation medicine. Most provide diagnostic services, but few offer radiotherapy treatments. Training opportunities are limited, and primarily delivered by overseas institutions. The Medical Physics education and professional training in Jamaica was implemented in three phases. The first step introduced the Bachelor of Science (BSc) degree in Medical Physics, and the second phase implemented the postgraduate education with MS and PhD programmes in Medical Physics. The third phase of the medical physics programme comprised of postgraduate diploma and certificate courses, as well as of short professional courses on radiation safety and protection. The PhD programme provides opportunities for professional development at higher levels, solving research problems in the fields of radiotherapy and nuclear medicine. Currently Jamaica is the leading country in the IAEA regional project "Strengthening Human Capacities of Caribbean Countries in Radiation Medicine" which aims to improve radiation medicine services in the Caribbean, as well as to identify centres of excellence in diagnostic radiology, nuclear medicine and radiotherapy for clinical training in the region.**

Keywords— **Jamaica, medical physics, training, education, medical imaging, diagnostic radiology, nuclear medicine, radiotherapy, UWI, UHWI, IAEA, ICTP.**

I. INTRODUCTION

Jamaica is the third largest Caribbean island and the largest English-speaking one. The population has increased on average by 3% over the past years and currently is estimated to 2.9 million, with a median age of 26 years. The island is divided into three counties – Cornwall, Middlesex and Surrey – which are subdivided into 14 parishes.

National health services are administrated by four Regional Health Authorities (RHA) - South East, Southern, North East and Western RHA, shown in Figure 1. The Regional Health Authorities have direct management responsibility for the delivery of public health services within its geographically defined area. Services are provided through a network of 24 hospitals, including 6 specialist institutions and 316 health centres.

Caribbean countries, including Jamaica, face several challenges in the use of radiation medicine. Most provide diagnostic services, but few offer radiotherapy treatments. Training opportunities are limited, and primarily delivered by overseas institutions.

Fig.1. Map of Jamaica showing the parishes and health regions.

The Medical Physics education and professional training programme in Jamaica was introduced in 2009 with a Bachelor of Science (BSc) degree in Medical Physics, and it was implemented in three phases. After the first step, bringing medical physics to undergraduate university standards, a postgraduate MSc and PhD programmes in Medical Physics were introduced in 2011. To-date, over 140 students have graduated with BSc degrees in Medical Physics and 38 with Master's and PhD degrees. Among graduates are students from Jamaica, Trinidad and Tobago, St. Lucia, Dominica, Bahamas and Nigeria.

The increased use of ionization radiation for diagnostic and therapeutic purposes, as well as the high radiation doses delivered by interventional procedures, have raised serious safety and health concerns for both patients and medical staff. The public health providers in Jamaica conducted over 450,000 diagnostic imaging studies in 2017, with an average increase of 30% [1]. The third phase of the medical physics programme included postgraduate diploma and certificate courses, as well as delivery of short professional courses on radiation safety and protection. Courses are delivered by local and overseas experts of the International Atomic Energy Agency.

II. MEDICAL PHYSICS AND RELATED EDUCATIONAL RESOURCES IN RADIATION MEDICINE

Jamaican Medical Physics education and professional training programme is under continuous development to respond to emerging needs of the country on radiation medicine. The IAEA has recently published a guidance document on development of national strategies for education and training in radiation, transport and safety [2]. Following these guidelines, a Joint Interfaculty Steering Committee was established in 2018 at the University of the West Indies to coordinate the continuing professional and clinical training in radiation medicine with participation from the Faculties of Medicine and Science & Technology, Ministry of Health, University Hospital of the West Indies and International Centre for Environmental and Nuclear Sciences. The committee developed a new BSc degree programme in Biomedical Radiation Science to support the biomedical research and radiation protection needs of the country.

The curriculum of the postgraduate Masters' programme in Medical Physics (Fig.2 and Fig.3) was developed using the AAPM guidelines "Academic Program Recommendations for Graduate Degrees in Medical Physics" [3], which will enable students to achieve professional accreditation by relevant national/international institutions.

The programme is delivered as evening and weekend classes and offers the flexibility of attending part- or full-time according of the work schedule of students. The MSc course has a modular structure consisting of core (Level I), professional (Level II) and speciality & practical (Level III) courses. Level I courses include Basic Radiation Physics, Medical Electronics, Anatomy, Physics of the Human Body, Radiation Biology, Biostatistics and Informatics. The Level II courses focused on specialization areas of the Qualified Medical Physicists and includes Diagnostic Imaging, Nuclear Medicine, Radiotherapy, as well as Nonionizing Radiation Imaging (MRI an US) and Environmental & Industrial Radiation Health Physics. Level III includes six months research project in Medical Physics and graduate seminar presentations. The research topics include quality control in diagnostic imaging, customised phantom development, image processing, radiation safety in medical and dental X-ray facilities. Ethics approval is obtained through the UWI Ethics Committee based in the Faculty of Medical Sciences.

The Postgraduate Diploma option (PgDip) requires completion of Level I and Level II courses and is suitable for personnel working in the health care sectors and seeking to obtain additional certification in diagnostic imaging or radiation safety and protection services. Individual courses of the programme are also delivered to "specially admitted students" as postgraduate certificate course (PgCert) in ionising/nonionizing imaging modalities, radiotherapy or environmental and industrial radiation health studies.

Other educational resources in radiation medicine in Jamaica include the following:

*Bachelor of Science in Diagnostic Imaging (Radiography) delivered by the School of Medical Radiation Technology, Faculty of Medical Sciences, University of the West Indies, Mona.

**Doctor of Medicine (DM) in Radiology, offered by Faculty of Medical Sciences, University of the West Indies, aiming to train medical professionals in the specialty of general diagnostic radiology.

III. OUTCOMES

Cancer care delivery in the public health system has been advanced with establishment of two new National Cancer Treatment Centres at Cornwall Regional Hospital in Montego Bay, and in St Joseph's Hospital in Kingston. The centres are equipped with state-of-the-art Linear Accelerators (LINAC) supplied by Varian Medical Systems. Medical physicist employed in both centres are graduates from Jamaican Medical Physics MS programme.

Jamaica's effort to fight cancer and chronic diseases has received a major boost with the re-establishment of a Nuclear Medicine Centre at the University Hospital of the West Indies (UHWI) (4). It is expected that the facility will be fully operational in mid-2019. The IAEA has contributed with delivery of equipment and technical expertise, as well as with the fellowship training of a medical physicist, a nuclear pharmacist, a nuclear medical physicist and a nuclear technologist.

The PhD programme in Medical Physics provides further opportunities for professional development at higher levels. Five medical physics staff members are currently enrolled in the PhD programme, carrying out research in the fields of radiotherapy and nuclear medicine. One staff member is currently completing the ICTP's Master of Advanced Studies in Medical Physics (MMP) programme, specializing in clinical radiation oncology. Research findings of MSc and PhD students were published in local and international peer-reviewed journals, as referenced [5-9].

The International Atomic Energy Agency (IAEA) started a four-year project to help Caribbean countries improve radiation medicine services in the region. Jamaica is the leading country in the IAEA regional project "Strengthening Human Capacities of Caribbean Countries in Radiation Medicine" with participation of Antigua and Barbuda, Bahamas, Barbados, Belize, Guyana, Haiti, Jamaica, Saint Vincent and the Grenadines, and Trinidad and Tobago, and experts from Cuba, Saint Lucia and Surinam. The aim of the project is to strengthen radiation medicine in the region, is to improve professional skills through training, with the objective of ensuring safe and effective diagnosis and treatment of patients.

IV. ACKNOWLEDGEMENTS

I would like to acknowledge the continued support of the International Atomic Energy Agency thought TC projects, workshops, experts visit and fellowship training in medical physics. Special thanks to the ICTP College on Medical Physics and related programmes, and personally to Prof. S Tabakov, for their support for the development of medical physics in Jamaica.

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Fig.2 First graduates of MSc Medical Physics and Physics staff, University of the West Indies, Kingston, Jamaica, 2013

Fig.3 MSc students at LINAC Cancer Centre in Kingston, Jamaica, 2018

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THE CHILEAN SOCIETY OF MEDICAL PHYSICS NOWADAYS

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Sociedad de Física Médica Chilena.

Abstract— **Here we describe the foundation and work of the Chilean Society of Medical Physics. Since its origin in 2014, this society has contributed to different areas related to the pacific use of ionizing radiation, in particular to the applications of physics in medicine.**

Keywords— **Chile, medical physics, scientific society, education, radiotherapy, medical imaging, nuclear medicine.**

I. INTRODUCTION

The Chilean Medical Physics Society (SOFIMECH hereafter) is a nonprofit association that affiliates medical physicists, or entities related to medical physics, whose academic and professional activities are developed in Chile.

The creation of SOFIMECH was associated to multiple historical and social developments that happened in Chile at the beginning of the current century: the construction of new linear accelerators facilities, the promulgation of technical protocols related to equipment quality assurance (developed by the Ministry of Health), the arrival of several foreign medical physicists, and the creation of new master programs in medical physics.

On March 2008; the first Master program of medical physics was offered by *Universidad de La Frontera*, at the south part of the country. The initial goal of this program was to train professionals who could satisfy the needs of the country in this matter. Four years later, on March 2012, *Pontificia Universidad Católica de Chile* opened admissions for its own medical physics master program, led by a new group of researchers with Ph.D. in medical physics. This program is offered in Santiago, Chile's capital. Today, there are more than 60 medical physicists graduated from these programs.

The objectives pursued by the SOFIMECH, are: to increase the recognition of the specialty within the clinical field; to disseminate the principles and scientific basis that allow medical physicists to contribute to the prevention, diagnosis and treatment of different diseases; to promote the preparation of training programs in the area of medical physics; and to collaborate with public and private institutions, based on the pacific use of ionizing radiation, in all matters concerning the specialty.

II. DEVELOPMENT OF THE SOCIETY

SOFIMECH was legally constituted on April 8th, 2014, by a group of 21 men and women working on medical physics. As shown by Figure 1, medical physicists are distributed across various regions throughout the country, but with almost a 50% of them concentrated in Chile's capital city, Santiago. As of 2019, SOFIMECH has 41 active members, both Chileans and foreigners. This represents approximately a 40% of all medical physicists actively working in Chile; and several new membership applications are in process.

Fig. 1 Medical physicists' distribution throughout Chile. Red stars indicate the places where medical physicists are working in clinical and academic activities.

Fig. 2 Part of SOFIMECH members that participated in the 2019 Ordinary Assembly celebrated in April 13th in Santiago.

Despite its short history, SOFIMECH has supported several scientific events related to radiotherapy, nuclear medicine, medical imaging and radiation protection. It has also promoted the celebration of the *International Day of Medical Physics*. Last year, for instance, this date was commemorated with an academic seminar joint with the *Instituto de Salud Publica de Chile*, the government institution responsible for assuring the quality in the clinical area. Another important contribution of the society was the organization of the 1st *Chilean Congress of Medical Physics*, where around 40 abstracts were received from hospitals, clinics, and universities; and around a hundred people participated last September.

Nowadays, SOFIMECH is also part of the *Council of Civil Societies of the Chilean Nuclear Energy Commission*, an advisory council for the design, execution, and evaluation of public policies related to nuclear energy. Moreover, based on international recommendations, such as those stated by the IOMP and IAEA training guidelines, SOFIMECH developed a list of requirements for the clinical medical physicists. This profile was introduced in the design and implementation of the *National Cancer Plan,* which defines the public policies for prevention, diagnosis and treatments of that disease for the next years.

III. CONCLUSION

This article describes how the work performed *ad honorem* by professionals and scientists who are passionate about the use of applied sciences for the benefit of human beings and the environment, can contribute to the recognition of the specialty, the dissemination of the scientific developments of medical physics field, the prevention, diagnosis and treatment of different diseases, and the assurance of quality in the training and education of new medical physics. All this, through active collaboration with public and private institutions.

While there is still a lot of work to be done, in order to achieve international standards, the challenge of being the host country (and part of the International Conference on Medical Physics 2019 - ICMP2019 organization committee) make us proud and motivate us to keep working for our colleagues and future generations.

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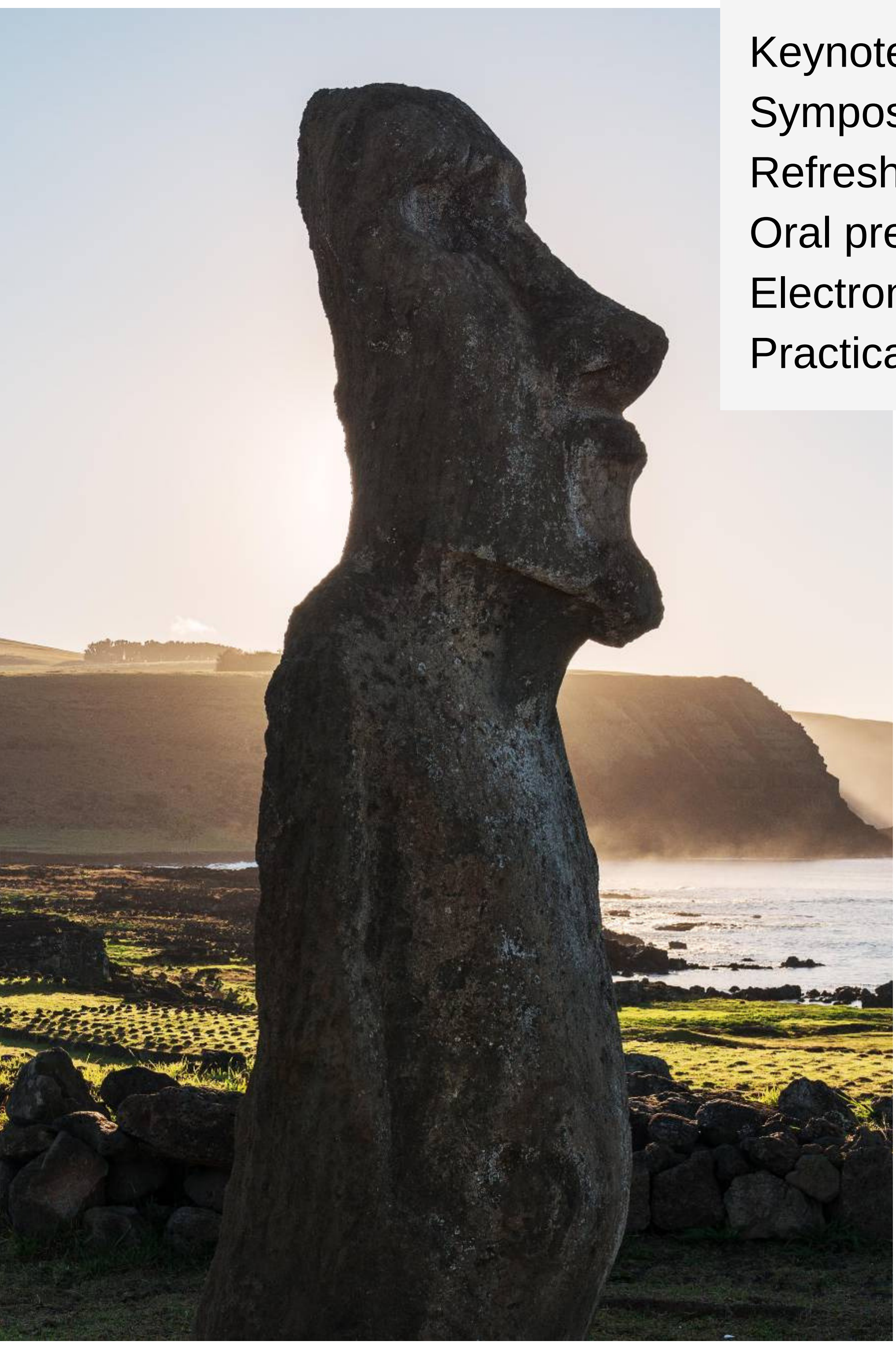

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INVITED PAPER

PANORAMA OF DIAGNOSTIC RADIOLOGY IN BRAZIL

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I. INTRODUCTION

The history of X-ray imaging in Brazil has started in 1896, when Dr. Adolpho Carlos Lindenberg, physician, published the first thesis about radiology in Brazil, which cover's translation is [1]:

“DISSERTATION
MEDICAL PHYSICS CHAIR

ABOUT X-RAY
IN THE POINT OF VIEW OF MEDICAL-SURGICAL

PROPOSITION
Three about each one of the chairs of the medical and surgical sciences

THESIS
PRESENTED TO
Faculty of Medicine of Rio de Janeiro
In 5th of November of 1896

By
ADOLPHO CARLOS LINDENBERG
Natural from the State of Rio de Janeiro
IN ORDER TO OBTAIN THE DEGREE OF DOCTOR IN MEDICINE”.

The Medical Physics Chair, as mentioned in the thesis cover, was established in 1832 by the law of 3rd of October of 1832, by the Emperor D. Pedro II. This law regulated the Faculties of Medicine in Brazil and created 14 permanent Chairs, where Medical Physics was the first Chair [2].

In 1897, Dr. José Carlos Ferreira Pires, physician, bought the first X-ray machine in Brazil and installed in the city of Formiga, Minas Gerais. The first public demonstration of a radiography was in 1898, a foreign body in the hand of a Minister. This X-ray machine is in the International Museum of Surgical Science, in Chicago, Illinois, USA [3].

An important contribution from Brazil to the diagnostic radiology worldwide was in 1936, when a Brazilian radiologist, Dr. Manoel Dias de Abreu, developed a revolutionary method for mass tuberculosis screening. It was miniatures of chest X-ray (about 50 to 100 mm size), named by him as Roentgengraphy. In 1939, the 1st National Congress of Tuberculosis changed the name of this technique to Abreugraphy, in his honor [3].

Diagnostic radiology in Brazil has started right after the X-ray discovery, despite that, the development of Medical Physics in this area had the official first steps in 1977 [4]. Nowadays, the number of Clinically Qualified Medical Physicists (CQMP) in diagnostic radiology is yet very small all over the country.

II. CURRENT STATUS

Brazil is the largest Latin American country in terms of territory and it is divided in five regions: Midwest, Northeast, North, Southeast and South (Fig. 1). The total population estimative in July of 2018 is 208,494,900, according to IBGE (Brazilian Institute of Geography and Statistics). Table 1 shows Brazil's population and territory distribution in Brazil. The most populous region is the Southeast and the largest in territory is the North, corresponding to 45% of the national area [5,6].

Fig. 1 Map of Brazil divided by regions.

Table 1. Population and territory distribution in Brazil.

	Area (km²)	%	Population	%
Total	8,515,759	100%	208,494,900	100%
North	3,853,841	45%	18,182,253	9%
Northeast	1,554,291	18%	56,760,780	27%
Midwest	1.606.234	19%	16,085,885	8%
Southeast	924,609	11%	87,711,946	42%
South	576,784	7%	29,754,036	14%

The National Cancer Institute estimates, for the year of 2018, more than 630,000 new cases of malignant neoplasms

[7]. Besides the several diseases that relies on X-ray imaging to be detected, this data demonstrates the importance of excellence in diagnosis and cancer therapy in Brazil, which makes the CQMP increasingly necessary all over the country.

According to the National Registry of Health Facilities (CNES – Cadastro Nacional de Estabelecimentos de Saúde, in Portuguese), there are 137,074 diagnostic imaging equipment available in the country, including nuclear medicine. The data from CNES states that 94% of the equipment is operating and less than 30% is disposable to the public healthcare. Furthermore, the number of high complexity imaging systems is very small for the entire country. For example, there are less than 5,000 Computed Tomography (CT) scans and only 2,034 to assist the public healthcare [8].

Table 2 shows the number of equipment per imaging modality. The reason why the operating equipment is lower than to the total number is not described in the CNES database. A probable justification is the health facilities' insufficient funds for proper equipment maintenance. Some hospitals and/or clinics, especially in the public healthcare, remain with a broken equipment for years. In these cases, the machine usually finishes its lifetime without the possibility of repairing.

Table 3 shows the number of diagnostic imaging equipment per 100,000 inhabitants for each region in Brazil. Despite the elevated number of equipment for a low-income country, due to the large population and territorial extension, the diagnostic imaging resources are insufficient. Furthermore, film-screen radiology is still largely used in Brazil. According to CNES, there are 2,721 film processor systems exclusively dedicated to mammography and the public healthcare possess 2,065 of these systems.

Table 2. Number of equipment in Brazil, divided by imaging modality.

Image Modality	Total	Operating	Public Healthcare
PET/CT	72	71	38
MAMMOGRAPHY W. STEREOTACTIC SYSTEM	913	869	355
MAMMOGRAPHY (FILM-SCREEN/DIGITAL)	5,505	2,409	1,130
INTERVENTIONAL RADIOLOGY	906	875	335
GAMMA CAMARA	976	936	356
MAGNETIC RESSONANCE	2,544	2,475	961
BONE DENSITOMETRY	2,325	2,279	808
FLUOROSCOPY SYSTEMS	1,723	1,541	556
COMPUTED TOMOGRAPHY	4,735	4,578	2,034
X-RAY (CONVENTIONAL AND PORTABLE)	24,267	23,092	9,964
ULTRASSOUND	40,420	38,871	12,957
DENTAL X-RAY	53,183	49,068	7,346
TOTAL	137,074	129,482	37,970

III. MEDICAL PHYSICS IN DIAGNOSTIC RADIOLOGY

The education for the CQMP in diagnostic radiology follows the steps described in the diagram below (Fig. 2). The first program of Bachelor´s degree in Medical Physics in Brazil appear in the year of 2000 and currently there are 11 programs [9].

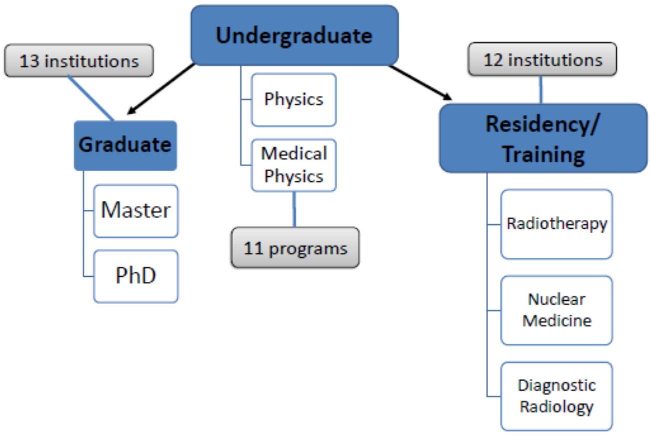

Fig. 2 Diagram of CQMP education in Brazil.

Residency programs in diagnostic radiology have started in 2013. Brazilian law requires they have a minimum of 1153 hours of didactical instruction in classroom and at least 4608 hours of practical training. There are 12 institutions with Residency programs and they offer approximately 34 positions, nine of them are in diagnostic radiology.

The low number of diagnostic imaging equipment, especially considering the population and territory extension, combined to the few clinical training programs, are a big challenge to increase the number of CQMP in diagnostic radiology.

IV. PROFESSIONAL REGULATION

The profession of Physicist and Medical Physicist was not regulated up to 10th of July of 2018. This process started in 11th of May of 2005, when a Senator proposed the bill to the professional regulation request by a group of physicists. The legal process lasted 13 years with large interaction of the Brazilian Society of Physics and the Brazilian Association of Medical Physics. This is a important step to the Medical Physics in Brazil development.

V. CURRENT CHALLENGES

Diagnostic radiology in Brazil is expanding and developing very fast. Figure 3 shows the increase of diagnostic imaging equipment in the last 10 years. In 2008, there was 82,669 equipment in Brazil and 38 CQMP certified in diagnostic radiology by the Brazilian Association of Medical Physics. Nowadays there are 137,074 equipment and 91 CQMP certified.

Table 3. Number of equipment each region in Brazil per 100,000 inhabitants.

	NORTH	NORTHEAST	SOUTHEAST	SOUTH	MIDWEST
PET/CT	1,1	2,6	3,9	5,0	3,1
INTERVENTIONAL RADIOLOGY	28,0	27,8	51,5	55,1	50,4
FLUOROCOPY	29,1	33,5	121,0	104,9	66,5
GAMMA CAMARA	37,9	30,1	52,4	51,8	51,0
BONE DENSITY X-RAY	66,0	79,1	134,2	126,0	126,8
MAGNETIC RESSONANCE	83,0	75,2	144,1	154,9	149,8
FILM PROCESSOR FOR MAMMOGRAPHY	100,1	121,2	126,9	159,6	121,2
COMPUTED TOMOGRAPHY	155,6	150,8	260,1	279,3	300,9
MAMMOGRAPHY	185,9	222,9	307,6	302,5	302,1
X-RAY	738,1	806,5	1318,3	1197,1	1272,5
DENTAL X-RAY	1158,3	1389,7	3060,6	3055,0	1951,4
ULTRASSOUND	1246,3	1561,1	2039,7	2215,2	2027,9
Total	3809,8	4488,0	7589,7	7686,0	6399,4

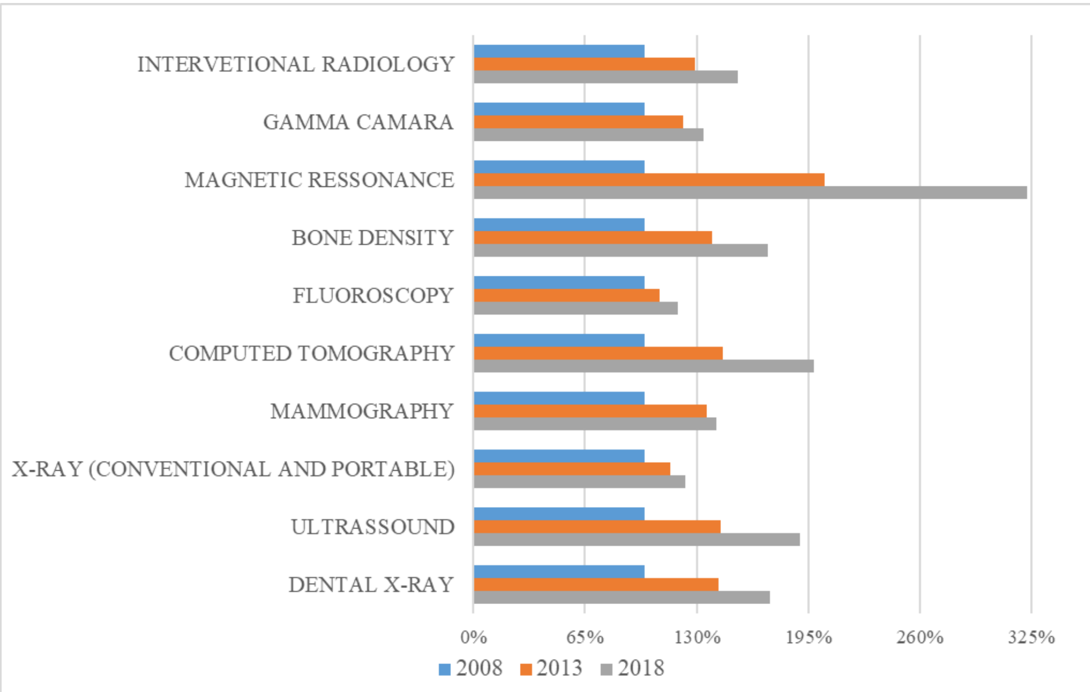

Fig. 3 Increasing of diagnostic imaging equipment in Brazil in 10 years.

Although the recent regulation of the profession, there is no national Council yet. Consequently, there is no database about the number of professionals working as CQMP. In general, Medical Physicists in diagnostic radiology work at private companies that perform quality control and radiation survey for hospitals and clinics, as requested by law since 1998. However, there are other professions performing these activities, such as radiology technicians and technologists, because of the practice directives absence.

Another issue is the lack of job positions at hospitals and clinics for CQMP in diagnostic radiology. Since 2012 there were 55 new positions created in Federal University Hospitals [10]. Nevertheless, most of the private hospitals does not have the knowledge of the CQMP roles and responsibilities, thus there are not many job positions for it. In general, when a CQMP is hired, he/she also assumes the responsibilities of Radiation Protection Officer.

VI. WAY FORWARD

Brazil has a promising perspective for the development of the Medical Physics and medical imaging. The achievements chronology (Fig. 4) indicates the evolution towards to the goal of increasing the Medical Physics workforce in Brazil and possibly to contribute to the whole Latin America. There were 1,256 Medical Physicists in Latin America and Caribbean in 2017 [11], mostly in radiotherapy.

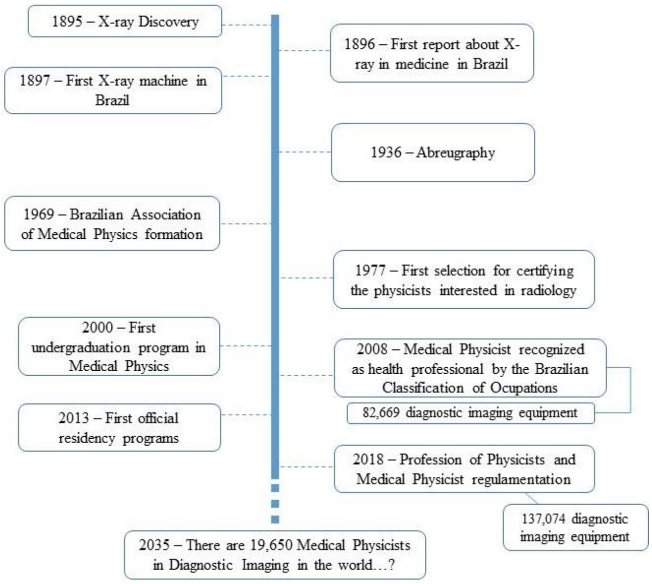

Fig. 4 Chronology of the diagnostic imaging and Medical Physics in Brazil

As the medical imaging technology in Brazil is expanding, the high technologies as Positron Emission Tomography with Magnetic Resonance Imaging (PET/MRI), hybrid operating rooms of interventional radiology, dual energy CT scans, among others are already a reality in the country. The importance of having trained physicists to be CQMP in diagnostic radiology is rising together with this technology expansion. The CQMP needs to be inside the hospitals and clinics to support an appropriate Quality Assurance Program and to guarantee the radiation safety and proper diagnosis for each patient.

Conflict of Interest

The authors declare that they have no conflict of interest.

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HOW TO

METHOD TO DETERMINE A REGIONAL DIAGNOSTIC REFERENCE LEVEL FOR INTRAORAL RADIOGRAPHS IN THE STATE OF SANTA CATARINA, BRAZIL

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Abstract—**This study aimed to describe a method for the determination of a Regional Diagnostic Reference Level (RDRL) for intraoral radiographs in the State of Santa Catarina, Brazil. The incident air kerma at the exit of the X-ray tube was measured from 990 intraoral radiographic devices, and Entrance Skin Dose (ESD) was estimated. Bootstrap resampling was applied, with a population mean of 2.87 mGy, producing a sample mean of 2.86 mGy. The RDRL for the incident air kerma rate at the exit of the X-ray tube is approximately 9.9% lower than the value recommended by the current Brazilian legislation. From a general perspective, approximately 89.09% of the equipment analyzed are below 3.5 mGy and only 10.91% are above that. Two RDRLs were established for incident air kerma at the exit of the X-ray tube and another for ESD.**

Keywords— **Regional Diagnostic Reference Level, Kerma, Intraoral Radiograph, Entrance Skin Dose, Dentistry.**

I. INTRODUCTION

Radiographs are a crucial tool for dentists for the diagnosis, planning, follow-up or treatment of lesions. However, no exposure to ionizing radiation can be considered completely risk-free, being the dentist the one responsible for the safety of patients, the public and other professionals involved in the process (1).

ICRP Publication 60 (ICRP, 1991) has issued recommendations for the optimization of medical exposure by adopting values called dose constraints and reference levels (2). In ICRP 73 (ICRP, 1996), the term Diagnostic Reference Levels (DRLs) was introduced, revealing the agency's objective of having a dose value that could reflect a level of reference to identify unjustified exposures (3).

DRLs do not provide a dividing line between good or bad practice, so it is inappropriate to use them as dose limits or restrictions because they are applied only in medical practices and therefore are unsuitable for public and occupational exposures. DRLs are adopted by agencies for good practice recommendations and radiological protection in dental radiology (4).

In DRL determination, values can be derived from national, regional or local data using the third quartile, given that the remaining 25% are derived from exceptional cases that may underestimate dose distributions to estimate DRLs (5). In Brazil, there is neither a national nor a regional DRL in the field of intraoral radiology. As Brazil is a country with a large territorial extension, the determination of a regional level is an excellent practice to aid in dose optimization. In view of that, the present paper aimed to describe in detail the method used to determine a Regional Diagnostic Reference Level (RDRL) for intraoral radiographs in the State of Santa Catarina, Brazil.

II. METHOD

According to the International Atomic Energy Agency (6), DRL estimations should draw on data from a specific type of examination (e.g. for adults or children) or procedure. For example, in the case of chest X-ray examinations for a typical adult patient, the first step is to verify how many tests were performed within a certain time interval and avoid months with atypical movements in order to estimate the sample size. The second step is to verify the technical parameters adopted in the clinical routine – if the work is done by more than one person, the research should be individualized and consider mean values to obtain the data.

In the present case, the sample needs to be representative of the intraoral radiographic procedures practiced in the State of Santa Catarina, Brazil. Therefore, it is necessary to know how many machines are available in the State. In such cases, official sources must be consulted.

Brazil has the National Register of Healthcare Facilities (CNES), which to date counts 2,520 machines available, but only 2,439 in use.

Once the population is known, it is possible to estimate the sample size (n) (7) by adopting the following ratio (1):

$$n = \frac{N \cdot n_0}{N + n_0}, where \quad (1)$$

N is the population size and n_0 is the first approximation of the sample size given by ratio (2):

$$n_0 = \frac{1}{E_0^2}, where \quad (2)$$

E_0 is the tolerable error of the sample.

There is no optimal or recommeded value for E0, therefore it was considered to be the percentage variation between the existing machines and those in use, according to the CNES database:

$$E_0 = \frac{(2{,}520 - 2{,}439)}{2{,}520}.100$$

$$E_0 = 3.2\ \%$$

Substituting this value into Equation 2:

$$n_0 = \frac{1}{(0.032)^2}$$

$$n_0 = 976.56$$

Finally, Equation 1 was used to calculate the sample:

$$n = \frac{(2{,}439\ \times 976.56)}{(2{,}439 + 976.56)}$$

$$n = 697$$

Therefore, the sample estimated for RDRL determination should be at least 697.

The decision of using a specific procedure and examination should be based on clinical and practical criteria. It is necessary to ask the team (physicians, technicians, technologists and biomedical professionals) for information and tips about procedures that need to be evaluated and optimized. It is worth mentioning that keeping the team committed will contribute to greater adherence to the project. One can choose to compare one's results with other reference levels previously established or with provisions of the local legislation.

To adjust the machine to the desired radiographic technique, it is recommended to personally consult the operator in charge, who preferably shall select it on the control panel. One should avoid using lists of techniques attached near the machines, as each technician may have their own particularities, and using online forms or email is not a good option, as one cannot guarantee the origin of the answers, or the provision of further information. If there is automatic exposure control (AEC), then the clinical routine should be followed in order to map the values.

In the present case, a reference value was chosen for an incidence in an upper molar of a typical adult patient. This choice was based on three facts:

- ✓ There are other established reference levels.
- ✓ It is the most usual incidence.
- ✓ In the Brazilian state where this study was carried out, there is a dose limit stipulated by the current legislation.

A peculiarity of intraoral radiography machines is that they have only a fixed voltage value, so in order to obtain the radiograph the operator has to select only the exposure time. There are some machine models with fixed exposure menus, that is, the dentist selects the type of incidence based on the patient's biotype and the equipment suggests the exposure time. In the present study, when the machine had selectable exposure times, the dentist was asked about the value that he/she had selected. In machines with preset menus, the interviewed dentist was asked to indicate which option they used, since the commands do not discriminate the type of incidents, as shown in Figure 1.

Figure 1: On the left, a Gnatus machine with selectable times. On the right, an Astex machine with a preset menu

Data collection requires that validated standards be followed and that the same experimental arrangement be maintained. For example, if the object of study is mammographic dosimetry, and if the guidelines in the literature indicate that measurements should be taken at 6 cm from the chest wall, at 4.5 cm high from the Buck, and using a compression plate, one should attempt to keep such architecture. The present study adopted the method of the International Atomic Energy Agency (IAEA), described in document TRS 457 (8). This document recommends that kerma values be collected at the exit of the focusing cup. This way, regardless of the machine analyzed, the experimental arrangement adopted was the one shown in Figure 2.

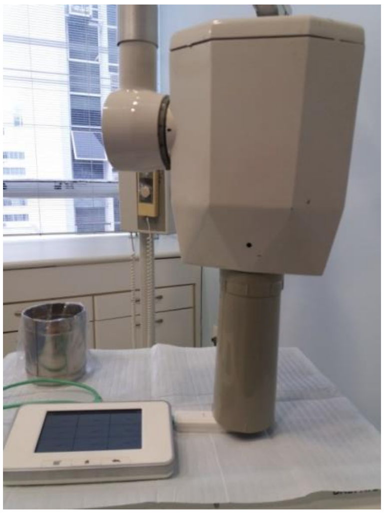

Fig. 2 Experimental arrangement adopted. Solid-state detector positioned at the exit of the X-ray tube.

The readings were taken using these six radiation detectors: Radcal Corporation 9096 with 10X6-6 Ion Chamber sensor; Radcal Corporation Accu Gold with AGMS-D+ sensor; RaySafe X2 with R/F sensor; Electronic Control Concepts, Model 890, Dose Meter; Unfors 407L; and RTI Electronics Piranha. It is of the utmost importance that the machines used for dosimetry be certified with valid calibration.

After the readings in the detector, Equation 2 was adopted to estimate the incident air kerma at the exit of the tube:

$$K_i = \bar{M} N_{K,Q_o} K_Q K_{TP} \pm u_{c,} \text{, where} \quad (2)$$

$\bar{M}$ is the mean of the readings obtained with the radiation detector, N_{K,Q_o} is the calibration coefficient of the dosimeter, [1]K_{TP} is the correction factor for temperature and pressure and the term u_c is the expanded uncertainty for a confidence interval (K = 2) obtained by Equation 2.

Without this method, there is no way to quantify the reliability of the measured results. In an experiment, there are numerous factors of error, so it is up to the researcher to identify and quantify them. In the present case, data were collected in a real environment and during clinical routine, which made it impossible to control and quantify all the sources, therefore two inevitable errors were considered. One of them is associated with the radiation detector - Type B[2], and the other is associated with fluctuation in the measured values - Type A[3], as shown in Equation 3.

$$u_c = \sqrt{(u_A^2 + u_B^2)} \quad (3)$$

where u_A is the standard deviation of the mean of the readings from the detector, and u_B is the uncertainty provided in the calibration certificate for the radiation detector (8).

Finally, Entrance Skin Dose (ESD) was estimated using Equation 4, which was adapted from the ARCAL XLIX document, considering the term BSF (backscatter factor) a constant linked to backscattering (9).

$$ESD = K_i \, BSF \quad (4)$$

where: BSF[4] = 1.2, and K_i is the incident air kerma at the exit of the X-ray tube.

III. RESULTS AND DISCUSSIONS

From January 2016 to December 2018, data were collected from 990 intraoral dental machines – a quantity that is higher than the estimated sample size, so the data are sufficient to determine a regional DRL. However, the collected data do not account for all the machines, so it is necessary to verify if the values for the air kerma rate are representative of the entire population. To do this, the Bootstrap resampling procedure was used, as shown in Table 1. It was observed that there are no significant discrepancies in the means, standard deviations and confidence interval, so the sample of the present case is representative of the entire population.

[1] Some detectors consider the factor according to the reading displayed or require the user to enter the value in the detector's memory.

[2] Methods that do not depend on analyses of series of observations.

[3] Methods involving statistical analyses of series of observations.

[4] Factor by which the patient radiation dose is increased by the dispersed radiation of the body (15).

Sample (n = 990)		Mean	SD	95% Confidence Interval
		2.3903	1,598	2.312 – 2.463
Number of Resampling	10	2.3998	1.337	2.331 - 2.411
	15	2.4001	1.425	2.335 - 2.437
	100	2.3925	1.334	2.316 - 2.461
	325	2.3871	1.335	2.312 - 2.454
	1000	2.3924	1.344	2.316 - 2.458
	6525	2.3888	1.333	2.312 - 2.461
	10000	2.3886	1.339	2.312 - 2.463

Table 1: Resampling

In the first clinic used for data collection, the intraoral radiograph machine was Gnatus Times 70C. The radiation meter RaySafe X2 with R/F sensor was used for collecting the following parameters, as described in Table 2.

Table 2: Values measured in the first case

Tube Voltage (kV)		Exposure time provided by the operator (ms)		Source-detector distance measured (cm)	Detector's output reading (mGy)
Nominal	Measured	Nominal	Measured	Measured	Measured
70	68.3	1000	999.9	20	2.01
	68.2		999.8	20	2.00
	68.2		999.8	20	2.00

The instrument has a valid calibration certificate issued by the LabProSaud Laboratory of the Federal Institute of Education, Science and Technology of Bahia (IFBA), Brazil. The calibration certificate provides that for the voltage and quality range RQR 5 (70 kV), the correction factor is $N_{KV} = 1.00$ with an uncertainty of 1.6%, therefore the voltage must be corrected by adopting Equation 5.

$$KV_c = KV_m \, . N_{KV} \qquad (5)$$

where KV_m is the measured value.

To estimate uncertainty, Equation 3 was used, where u_B is 1.6% and u_A is the standard deviation of the measured values for the 6% voltage.

$$u_c = \sqrt{(u_A^2 + u_B^2)}$$

$$u_c = \sqrt{(5.77^2 + 1.6^2)}$$

$$u_c = \sqrt{35.85}$$
$$u_c = 5.98\ \%$$

Therefore, the measured voltage mean is (68.3 ± 4) kV
The same is valid for the other measured values, except for the value of mA since the measurement instruments used do not allow estimating it. For the exposure time in the calibration certificate, the uncertainty provided is 1.9%; since there is no correction factor, only uncertainty must be estimated:

$$u_c = \sqrt{(u_A^2 + u_B^2)}$$

$$u_c = \sqrt{(5.77^2 + 1.9^2)}$$
$$u_c = \sqrt{36.90}$$
$$u_c = 6.07\ \%$$

Therefore, the exposure time mean is 999.8 ± 60.6 ms. The ruler used has a calibration certificate provided by the metrology laboratory of the Foundation Centers of Reference in Innovative Technologies (CERTI) and provides an absolute value, so the source-detector distance mean is 20 cm $\pm$ 0.04.

Table 3 in Appendix A shows, in a simplified way, the measured exposure parameters (kV and exposure time), the nominal mA for each manufacturer and model, the incident air kerma at the exit of the X-ray tube, and the ESD estimation. The voltage mean value was 61.96 ± 3 kV, in that the lowest value was 37.2 ± 2 kV measured by a Gnatus XR 6010 device, and the highest value was 76.4 ± 4 kV measured by a 70X Ion Proton. Regarding exposure times, the mean was 727.22 ± 14.4 ms, with the lowest limit of 60 ± 1.2 ms measured by a Sirona Heliodent Plus high frequency device, and the highest one of 5001.2 ± 100.2 ms measured by a Dabi Atlante Spectro 70X single phase device. The ionization current values described by the manufacturers are between 2 mA to 11 mA with an average of 8 mA, the lowest value being the one measured by a Micro Image Diox 602 and the highest one by a Procion IonX10 device.

Equation 2 was used to obtain the incident air kerma at the exit of the tube, with the calibration factor for RQR 5 (70 kV) being $N_{K,Q_o} = 0.974$, a uncertainty = 1.8%, and K_{TP} = 1:

$$K_i = \bar{M}.N_{K,Q_o}.K_{TP} \pm \sqrt{(u_A^2 + u_B^2)}$$

$$K_i = 2.00\, mGy\, .0.974\ \ .1\, .\ \ \pm\ \sqrt{(1^2 + 1.8^2)}$$

$$K_i = (1.978 \pm\ 0.039\ )mGy$$

The value in Equation 4 was substituted to obtain ESD:

$$ESD = (1.978\ \pm\ 0.039\ )\ mGy\ .1.2$$

$$ESD = (2.374\ \pm 0.047)\ mGy$$

The remaining 889 readings underwent the same procedure taking into account the calibration and uncertainty factors of the relevant radiation detector adopted.

As previously mentioned, the DRL is represented by the values in the third quartile of the sample. The values for the incident air kerma at the exit of the tube ranged from 0.21 ± 0.004 mGy to 21.77 ± 0.43 mGy with the third quartile of 2.84 ± 0.07 mGy, being the lowest value obtained by a digital imaging system and the highest value by an analog one. In the estimation of the ESD that represents the RDRLs for the incident air kerma at the exit of the X-ray tube, the value is approximately 9.9% lower than that recommended by the current legislation in Brazil, as shown in Table 2. Overall, approximately 89.09% of the devices analyzed are below 3.5 mGy and only 10.91% are above that.

For ESD, the range was 0.26 ± 0.005 mGy at 26.13 ± 0.53 mGy with the third quartile of 3.05 ± 0.06 mGy, as shown in Table 2. In the present study, that value was compared with seventeen studies, and in ten of them the values were lower. In NCRP 72 (10) and UKR (11), DRL is approximately 50% of the value stipulated in the present study, and in the 1996 IAEA it is more than double that, as shown in Figure 2 (12,13 and 14).

Table 4: Statistical Analysis

Dosimetric measurement (mGy)	Sample size	Limit Below	Limit Above	Mean	First Quartile (25%)	Third Quartile (75%)
Air Kerma	990	0.21 ±0.004	21.27± 0.43	2.11	1.68	2.84
ESD		0.26 ±0.005	26.13± 0.53	2.52	2.02	3.05

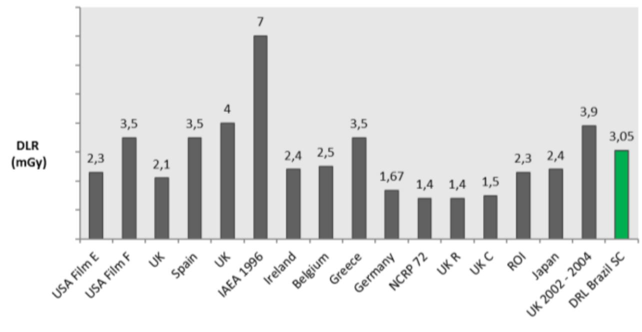

Fig. 2 Comparison between DLRs obtained in Brazil and in other countries.

The State of Santa Catarina, Brazil, has the Normative Resolution No. 002/DIVS/SES (16) which recommends a reference level for air kerma at the entrance of the skin in intraoral procedures. In an upper molar of an adult patient, the reference level is less than or equal to 3.5 mGy for incidences. The mean for the air kerma rate was 2.11 mGy with the third quartile of 2.84 mGy, so the RDRL for the incident air kerma rate at the exit of the X-ray tube is approximately 9.9% lower than the value recommended by the current legislation, as shown in Table 3. Overall, approximately 89.09% of the analyzed devices are below 3.5 mGy and only 10.91% are above this value.

III. CONCLUSIONS

With the method tested, it was possible to establish two Regional Diagnostic Reference Levels (RDRL) for incident air kerma and another for ESD. The data obtained confirmed that patients subjected to intraoral radiography in the State of Santa Catarina, Brazil, will not be exposed to limits above that recommended in the current normative resolution. As Brazil's large territorial extension impedes data collection, this study suggests that each State of the country should establish its own value and gather data to stipulate their own reference level regionally.

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Note from the Editors: The paper is supported with an Appendix A of 24 pages. It includes real data from the practical measurements, described in the paper (see below a sample from Appendix A - Table 3). In case of need the Appendix can be requested directly from the corresponding author.

Appendix A

Table 3: Exposure parameters

Mean of the measurements of tube voltage (kV)	mA nominal	Mean of the measurements of the exposure time (ms)	Mean of the measurements of the source-detector distance measured (cm)	Mean of the measurements of the detector's output reading (mGy)	ESD (mGy)
68.2	8	998.9	20	2.00	2.40
48	10	835	18	2.42	2.90
70	8	500	20	1.46	1.75

……. Etc.

HISTORY AND HERITAGE

THE JOHN CAMERON MEMORIAL LECTURE – CELEBRATING THE LEGACY OF A GREAT PIONEER

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"If anything is worth doing, it is worth doing it badly" - John Cameron, citing G. K. Chesterton

"It doesn't have to be perfect, just get it to work!" More than once this was enough to spur on his students to "just do it" and not worry about perfection. Perfection could always come later if it is necessary.

The John Cameron Memorial Lecture was inaugurated by the South East Asian Federation of Organizations for Medical Physics (SEAFOMP) in 2004 in honour of the late Professor John Cameron, University of Wisconsin [1], USA. Professor John Cameron dedicated his entire life to improving the medical physics profession in the US and many developing countries. He is well known for his original, forward thinking, and thought provoking ideas on scientific subjects.

Excerpt from 'In Memoriam: John Cameron' Health Physics Society [2]:

John died on 16 March 2005 at age 82 in Gainesville, Florida, where he lived during the winter months and served as a Visiting Professor in the Department of Radiation Oncology at the University of Florida. John, born in northern Wisconsin in 1922, was raised on a farm and experienced firsthand the Depression years. In 1937 his parents moved to Superior so that he and his seven siblings could attend college. After enrolling at UW-Superior, John's education was interrupted by service in the U.S. Army Signal Corps from 1941 to 1946. After the war, he enrolled at the University of Chicago and received a BS degree in mathematics in 1947.

Subsequently John moved to Madison and received his PhD in physics in 1952, with the thesis title "Elastic Scattering of Alpha Particles by Oxygen". Despite John's protestations about the usefulness of his thesis research, these cross sections are still used today in ion beam implantation work. As an assistant professor at the Universidad de São Paulo in Brazil, John established many lifelong friendships. After a brief stint of post-doctoral work at UW-Madison, he became an assistant professor at the University of Pittsburgh (1956-1958). Finally, in 1958 John joined the faculty of the Department of Radiology at Madison, accepting an assistant professor position, with a joint appointment in the Department of Physics.

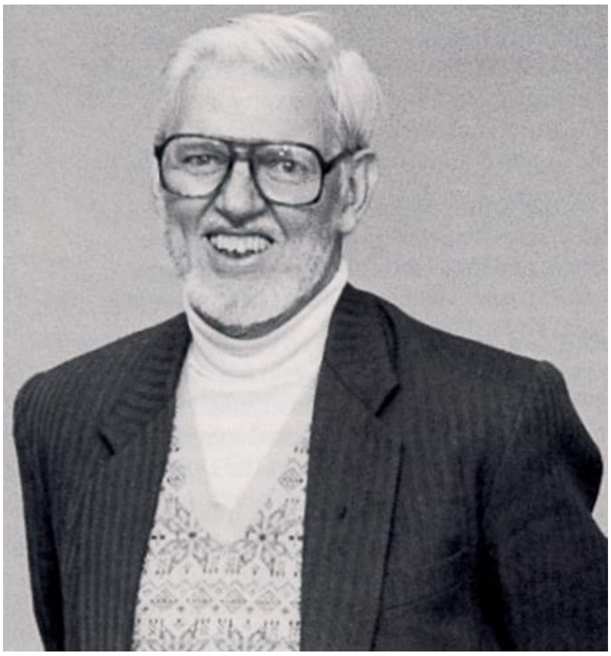


Fig. 1 A classical photo of Prof. John Cameron.

Thus began an illustrious career in medical physics. For the next three decades, John guided the UW Medical Physics Program from a "one physicist" operation to one of the largest and most productive in the world. Presently there are 21 faculty and 8 postdoctoral appointees training 86 students. Since its founding in 1958, the program has awarded more than 185 PhD and 156 MS degrees. Graduates and trainees have become leading medical physicists—a source of great personal pride for John. The program was awarded departmental status in 1981, the first medical physics program to receive departmental status in the United States. John served as chair until his retirement in 1986.

John is widely recognized for several innovative and seminal contributions to medical physics. He investigated and advanced thermoluminescence dosimetry, establishing most of the principal characteristics needed for wide applicability. This technology became the standard for personal radiation monitoring, eventually largely replacing traditional film densitometry.

At about the same time, John invented bone densitometry, which uses precise radiation measurements to determine the mineral content of bone. Since the radiation doses were very small, his graduate students often used family members (and each other) as "research subjects." A small change in a lactating mother's bone mineral was easily observed. One of his early bone densitometry publications (Invest. Radio. 3:141; 1968) was listed as its single most cited article on the 25th anniversary of Investigative Radiology. Many useful clinical applications of highly accurate bone densitometry became evident and a number of companies developed bone densitometers. Lunar Radiation (now GE-Lunar) arose directly from early work done in John's "bone mineral lab." The number of bone densitometers in the world now exceeds 20,000.

John was deeply concerned with excess radiation exposures in diagnostic radiology. He developed simple test tools and techniques to measure radiation and to evaluate the quality of x-ray images. These efforts led to the creation of Radiation Measurements, Inc. (RMI), a pioneering manufacturer in quality-assurance measurements, materials, and devices. This also led to product developments by several companies and to several standard techniques for radiation measurement and image quality assurance.

John founded Medical Physics Publishing, a nonprofit corporation whose initial objectives were to provide reprints of useful but out-of-print books. That company now publishes a wide spectrum of original books and is a major source of material relating to health physics and medical physics.

John was interested in developing new applications of physics to medicine. He preferred to hire new faculty whose research was not in the mainstream at the time. John started a program for radiation physics measurement that with federal funding became the Midwest Center for Radiation Physics. His foresight led to the early development of significant programs at UW-Madison in applications that eventually became "mainstream," including ultrasound, positron imaging, and digital angiography, to name but a few. He also helped initiate a program in magneto-encephalography, looking at the magnetic signals emitted by the brain. After his retirement, his interests spread into still more areas, including imagination and creativity.

While an outspoken advocate for reductions in diagnostic radiation exposures, John was equally concerned about the excess and unwarranted concerns about near-background levels of radiation exposure. In recent years he devoted himself to educating the public accurately about the benefits and risks of radiation used in medicine. He was especially concerned about the fear caused by low-level radiation and analyzed much data to illustrate that these fears probably are unfounded. He argued this aspect by talking about longevity being a measure of health effects of radiation (Radiology 229:14-16; 2003). Indeed, he argued (convincingly) that radiation might be a beneficial "trace element" at very low doses (Physics and Society October 2001).

John received numerous honors for his contributions to medical physics, including the Coolidge Award from the AAPM in 1980. In 1995 he was one of only four recipients of a Roentgen Centennial Medal Award from Radiological Society of North America. In 2000 John received from the International Organization for Medical Physics the Madam Curie Award for activities in medical physics education in developing countries.

For all of his research and professional contributions, John's greatest legacy is the many students, trainees, and young faculty whose budding careers were nurtured in the UW Medical Physics Program. He was a caring and generous man who went out of his way to ensure that all of these young people had the best opportunity possible to develop their careers in medical physics. He was full of optimism and had a great sense of humor, catching many students by surprise as he taught them. Every graduate or trainee of the UW Medical Physics Program owes a debt of gratitude to John for his efforts on behalf of them and of the UW program.

Among his many attributes, John is legendary for two others. John took great pride in his Scottish frugality and would demonstrate it in a humorous manner. Also John had a philosophy that he used to inspire his students and others. He would always quote in the middle of a trying time during an experiment, "Anything worth doing is worth doing poorly," meaning, "It doesn't have to be perfect, just get it to work!" More than once this was enough to spur on his student to "just do it" and not worry about perfection. Perfection could always come later if necessary.

Fig. 2 John with his wife, Lavonda (Left); The author with Prof. John Cameron, 1996 (Right).

JOHN CAMERON MEMORIAL LECTURES

Table 1 A List of the first thirteen lectures. The lecturers cover an international geographic distribution, 5 from Asia, 3 from Oceania, 2 from Europe and 3 from the USA.

No	Year	Lecture Title	Lecturer	Affiliation
1	2004	Recent Developments in Volume CT Scanning	Willie Kalender	Institute of Medical Physics, University of Erlangen, Germany
2	2007	Medical Physics in 2020: Will we still be relevant?	Kwan Hoong Ng	University of Malaya, Kuala Lumpur, Malaysia
3	2008	Frontiers of Medical Physics	Barry Allen	St George Hospital Cancer Care Centre, NSW, Australia
4	2009	Role of Medical Physics in the Design and Construction of the Colorado Translational Research Imaging Center: Legacy of Pioneers in Quantitative Imaging	Gary Fullerton	University of *Texas* Health Science Center, San Antonio, Texas, USA
5	2010	Education and Training of Medical Physicists, Biophysicists and Bioengineers in SE Asia: 2010 and Beyond	Brian Thomas	Queensland University of Technology, Brisbane, Australia
6	2011	Quality Control and Dosimetry in Diagnostic Medical Physics- An Overview	Joel Gray	DIQUAD, LLC Illinois, USA
7	2012	The Convergence of Imaging and Therapy	Thomas Kron	Peter MacCallum Cancer Centre. Melbourne, Australia
8	2013	From Evolution to Revolution - Multi-Modality Imaging Comes of Age	David Townsend	National University of Singapore, Singapore
9	2014	The Growth in Medical Physics Research: The Indonesia Case	Djarwani Soejoko	University of Indonesia, Jakarta, Indonesia
10	2015	The Potential Impact of Computer-Aided Diagnosis in Medical Imaging	Kunio Doi	University of Chicago, Chicago, USA
11	2016	Advances in Image Guided Radiation Therapy	Geoffrey Ibbot	The University of Texas MD Anderson Cancer Center, Houston, USA
12	2017	Optimization: the Role of Medical Physicist in Diagnostic Radiology	Anchali Krisanachinda	Chulalongkorn University, Bangkok, Thailand
13	2018	The role of the ICRP in Medicine: Past, Present and Future	Colin J Martin	Committee 3 International Commission of Radiological Protection, UK

1st 2004 3rd SEACOMP Kuala Lumpur, Malaysia
"Recent Developments in Volume CT Scanning"
Willie Kalender, PhD

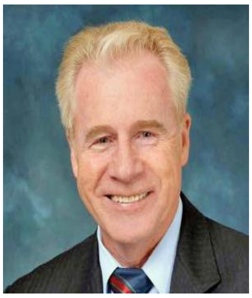
Whole body scanning within a breath hold period and truly isotropic high-resolution CT have become routinely available with the latest multi-slice spiral CT (MSCT) scanners. What is the state of the art? What are the challenges for future developments? The talk shall focus on two core issues: on scanner and detector technology and on considerations of patient dose. Several detector designs are presently available, such as isotropic and non-isotropic or adoptive arrays. Systems on the market offer the simultaneous acquisition of up to 64 slices. The underlying technical concepts will be described. The cost and the size of the detector electronics are still a problem; however, there are no physical limits. Wider arrays will become available; the use of flat panel detectors originally designed for digital radiography is under evaluation for CT imaging. Respective developments including comments on reconstruction algorithms, will be reviewed in part one of the talk. Patient dose issues are of increasing concern in Europe and worldwide. The availability of submillimetre isotropic 3D spatial resolution spurs the request for more scans and for larger scan volumes. Higher resolution has immediate implications for noise and potentially for patient dose as will be explained. However, there are also innovative approaches for reducing dose and for optimizing the CT application with respect to dose. An automatic exposure control (AEC) for CT is the challenge. The respective concepts and results will be presented and discussed; typical patient dose values will be given.

2nd 2007 5th SEACOMP Manila, Philippines
"Medical Physics in 2020: Will we still be relevant?"
Kwan Hoong Ng, PhD

From the time when Roentgen and other physicists made the discoveries which led to the development of radiology, radiotherapy and nuclear medicine, medical physicists have played a pivotal role in the development of new technologies that have revolutionized the way medicine is practiced today. Medical physicists have been transforming scientific advances in the research laboratories to improving the quality of life for patients; indeed, innovations such as computed tomography, positron emission tomography and linear accelerators which collectively have improved the medical outcomes for millions of people. In order for radiation-delivery techniques to improve in targeting accuracy, optimal dose distribution and clinical outcome, convergence of imaging and therapy is the key. It is timely for these two specialties to work closer again. This can be achieved by means of cross-disciplinary research, common conferences and workshops, and collaboration in education and training for all. The current emphasis is on enhancing the specific skill development and competency of a medical physicist at the expense of their 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 of medical physicists to respond to new technologies. In addition, in the background loom changes of tsunami proportion. The clearly defined boundaries between the different disciplines in medicine are increasingly blurred and those between diagnosis, therapy and management are also following suit. The use of radioactive particles to treat tumors using catheters, high-intensity focused ultrasound, electromagnetic wave ablation and photodynamic therapy are just some areas challenging the old paradigm. The uncertainty and turf battles will only explode further and medical physicists will not be spared. How would medical physicists fit into this changing scenario?

We are in the midst of molecular revolution. Are we prepared to explore the newer technologies such as nanotechnology, drug discovery, pre-clinical imaging, optical imaging and biomedical informatics? How are our curricula adapting to the changing needs? We should remember the late Professor John Cameron who advocated imagination and creativity - these important attributes will make us still relevant in 2020 and beyond. To me the future is clear: "To achieve more, we should imagine together."

3rd 2008 6th SEACOMP Ho Chi Minh City, Vietnam
"Frontiers of Medical Physics"
Barry J Allen, PhD, DSc



Medical Physics has a rather unbalanced profile, with most medical physicists attached to radiotherapy departments for cancer therapy and to a much lesser extent to Nuclear Medicine departments. As such, many medical physicists find themselves some way from the frontiers of Medical Physics

Frontier 1 There are many medical physicists involved with the implementation of new external radiation beam technologies for the therapy of cancer and imaging of cancer and other diseases. Most would say that this is the frontier today. Imaging techniques continue to resolve smaller tumours, and the development of SPECT and PET has had a major impact on the management of disease. However, subclinical disease cannot be observed and tell us where micro-metastases lie. External beam radiotherapy can target well defined volumes, achieving local control, but can never eliminate systemic disease. Such high technology and expensive equipment cannot serve rural communities in most developing countries. These limitations suggest that there are other frontiers of medical physics that must address these important issues.

Frontier 2 New advances in Immunology and the development of exquisite targeting vectors allow the systemic targeting of cancers. Radioisotopes that decay by alpha or beta rays are used to label monoclonal antibodies for systemic radio-immunotherapy. However, high LET alpha radiation is superior to betas in terms of efficacy and lower adverse events. The key objective is the control of systemic disease by targeted alpha therapy, leading to improved survival for systemic cancer patients

Frontier 3 A discipline that ignores the plight of two thirds of the world's population is not really doing its job. For rural populations in developing countries, cancer patients present at the incurable end-stage. Palliative therapy is required to reduce pain and increase quality of life.

The new frontiers for medical physics are therefore:

- High cost technology for medical imaging and external beams for local, curative cancer therapy;
- Internal high LET targeted therapy for systemic cancer;
- Low cost imaging and radiotherapy for palliative therapy in developing countries.

4^{th} 2009 7^{th} SEACOMP Chiang Mai, Thailand

"Role of Medical Physics in the Design and Construction of the Colorado Translational Research Imaging Center: Legacy of Pioneers in Quantitative Imaging"
Gary Fullerton, PhD

The growing importance of in vivo quantitative measurement in human subjects to evaluate drug delivery, drug response and treatment efficacy has increased demand for the use of imaging as a source of critical biophysical data. A growing number of translational research imaging centers have been created to provide improved quality of research information. This presentation reviews the process of creating the Colorado Translational Research Imaging Center C-TRIC at the University of Colorado in Denver. The planning process used input from visiting experts, site visits to centers of excellence and presentations from corporate imaging manufacturers to create a new center of excellence for 21th century research needs. The C-TRIC has six operational cores. Translational research begins within the Animal Imaging Core where basic science studies use the tools created by the Image Analysis Core to provide the basis for more complex studies in the Human Imaging Core. The data from both animal and human imaging is maintained and integrated with information from other sources using resources of the Imaging Bioinformatics Core to allow long term data mining and advanced meta-analysis methods to be applied. The most important new molecular processes of the Molecular Imaging/ Radiochemistry Core require on-site cyclotron and radiochemistry capacities to label critical bio-molecules to decipher molecular processes important to human health. Finally the growing complexity and multi-specialty knowledge demands require educational programs from Imaging Education Core to educate research scientists, post- doctoral fellows, graduate students and professional research assistants concerning the strengths, weakness and potential of research imaging data. The combined use of MRI, PET, SPET, US and optical methods in micro-formats suitable for rodent models but extending to large animal and human formats provides continuity for translation of genomics and microbiological concepts to the resolution of human disease for improved health care.

5^{th} 2010 8^{th} SEACOMP Bandung, Indonesia

"Education and training of medical physicists in SE Asia-accomplishments and challenges."
Brian J Thomas, PhD

John Cameron made significant contribution to the field of Medical Physics. His contribution encompassed research and development, technical developments and education. He had a particular interest in the education of medical physicists in developing countries. Structured clinical training is also an essential component of the professional development of a medical physicist. This paper considers aspects of the clinical training and education of medical physicists in south east Asia and the challenges facing the profession in the region if it is to keep pace with the rapid increase in the amount and technical complexity of medical physics infrastructure in the region. The paper was presented for the 5th John Cameron Memorial Lecture at the 8th SEACOMP conference in Bandung, Indonesia, 2010.

6th 2011 9th SEACOMP Manila, Philippines

"Quality Control and Dosimetry in Diagnostic Medical Physics- An Overview"

Joel E. Gray, PhD

Diagnostic medical physics has been a very dynamic field since the invention of the first computed tomographic scanner in 1972. Diagnostic imaging has seen major changes in technology and image quality, requiring the medical physicist to continually support these new modalities.

This presentation will discuss the history of quality control (QC) in diagnostic imaging starting with the first QC publication in 1976. Although QC should be an integral part of every imaging department, it is not in many facilities. This has been partially overcome by requirements of governments or insurance companies for QC. Some imaging equipment includes software for QC making the task much easier and, in some cases, transparent to the facility.

Radiation dosimetry has made significant gains in techniques and technology in the past 40 years. Ionization chambers were the only choice 50 years ago, with their inherent weaknesses, i.e., partial volume effect. These have been mostly replaced by solid state dosimetry systems. Thermoluminescent dosimeters (TLDs) were the standard for radiation dosimetry requiring laborious annealing, sorting, heating curves, nitrogen heating chambers, and record keeping. TLDs are being replaced by optically stimulated luminescent (OSL) materials which can be read out in seconds after exposure and do not require any of the tasks normally associated with TLDs.

This presentation will provide an overview of both quality control and radiation dosimetry in diagnostic medical physics over the past 40-50 years. The challenge for the future is to clearly define the role of the medical physicist in diagnostic imaging and assure that we have the necessary tools, techniques, and training programs available for our profession.

7th 2012 10th SEACOMP Chiang Mai, Thailand

"The Convergence of Imaging and Therapy"

Tomas Kron, PhD

Introduction: Due to the increasing complexity of the work environment for most clinical and biomedical physicists subspecialisation has become common for medical physicists and many consider themselves either a therapy or diagnostic physicist. Most therapy physicists work in radiation oncology while diagnostic physicists are often further subdivided into nuclear medicine and radiology medical physicists. However, several recent developments challenge this approach and provide rationale for broadening the scope for medical physics practice again.

The situation in radiotherapy: Many major improvements in radiotherapy planning and delivery are associated with medical imaging. This ranges from better target definition due to more sophisticated imaging to the ability to visualize the target every day of treatment with the aim to reduce uncertainty and the amount of normal tissue irradiated. As functional changes often precede anatomical ones, imaging modalities such as Positron Emission Tomography and Magnetic Resonance Imaging emerge as tools to assess response to treatment early and as such adapt the treatment approach. Be it high quality, motion resolved or longitudinal imaging, the increasing availability of a large variety of diagnostic tools allows for much improved customization of treatment for each patient and provides new challenges for image handling and quality assurance that must be met by medical physicists.

The situation in medical imaging: Imaging has become increasingly dependent on computers. The resulting image quality and variety of contrast options has the potential of greatly enhancing the capacity of radiologists and nuclear medicine physicians to diagnose disease and help patients. However, it also often comes with a confusing array of technical options, possibly higher radiation dose and need for quality assurance. While the small number of well-trained diagnostic physicists is probably the greatest problem at present, the higher doses given and the increasing use of diagnostic equipment during medical interventions move diagnostic physicists closer to therapy. This is compounded by an emerging trend for use of radionuclides for targeted therapy of a variety of cancers.

Outlook: The presentation explores the challenges associated with the convergence of imaging and therapy from the perspective of a radiotherapy physicist. While the huge scope of the work practices and the need for a combination of broad and in-depth training are major concerns, the medical physics profession is in a good position to succeed as lifelong learning, adaptation to change and multidisciplinary engagement have always been defining characteristics.

8th 2013 11th SEACOMP Singapore

"From Evolution to Revolution: Multi-Modality Imaging Comes of Age"

David W Townsend, PhD

The first decade of the 21st century has seen the introduction of hybrid imaging technologies such as PET/CT and SPECT/CT into clinical practice. The adoption of these technologies, and in particular PET/CT, has been surprisingly rapid. Over the past few years, the clinical benefit to the patient of combined anatomical and functional imaging compared with either modality alone has been extensively documented. The advent of the second decade of this century saw the introduction of the latest design of hybrid imaging devices, combined PET and MR. However, the clinical role of PET/MR has yet to be established and adoption has been slow, largely due to the significant cost. Both PET/CT and PET/MR designs have benefitted from the advances in PET detector technology. Compared with just a few years ago, PET images can now be acquired routinely in less time and with lower injected dose, and even within a 3T magnetic field environment without artifacts. Parallel advances have been seen in CT technology where considerable emphasis has been placed on dose reduction, a benefit of PET/MR since the relatively-high radiation dose associated with CT is eliminated. However, advances in CT dose-reduction techniques now results in PET/CT studies with a total radiation dose as low as 5-7 mSv. Further effort has also focused on quantitative image accuracy and the reproducibility of studies for evaluating treatment response. Consequently, with over a decade of experience, PET/CT has become the primary clinical imaging modality for staging malignant disease and monitoring response to therapy. SPECT/CT, after almost a decade of clinical experience, is widely recognized as an advance compared with SPECT alone; finally, the clinical role for simultaneous PET/MR is still being explored after only three years of availability. This presentation will review these advances that suggest multi-modality imaging is finally coming of age.

9th 2014 12th SEACOMP Ho Chi Minh City, Vietnam

"The Growth of Medical Physics Research: The Indonesian Case"

Djarwani S. Soejoko, PhD

Medical Physics in Indonesia gained late attention, in terms of education and research. Physics Department, Faculty of Mathematics and Sciences, University of Indonesia started undergraduate and graduate program on Medical Physics in 1998 and 2002, respectively. This late start causes this field development needs enhancement, one of which in term of research. To illustrate the developing process, several examples research results, in the subfield related with Radiotherapy, Diagnostic Radiology, and Nuclear Medicine, are shown. All examples were the research results of student final projects. Advance technology develops equipment and technical procedures in imaging and radiotherapy treatment to become more and more complex, and of course affecting the growth of Medical Physics research as well. However the quality of research is still limited, since most research are performed according to the availability time of students, 6 - 12 months. Therefore in order to increase the research quality, doctorate program should be available at this department in the near future. Since the successful of Medical Physics research will be greatly influence by close cooperation with user research infrastructure at hospitals, therefore the growth of research culture at hospitals should also be induced.

10th 2015 13th SEACOMP Yogyakarta, Indonesia

"Potential Impact of Computer-Aided Diagnosis in Medical Imaging"
Kunio Doi, PhD

Computer-Aided Diagnosis (CAD) has become one of the major research subjects in medical physics and diagnostic radiology. Many different types of CAD schemes are being developed for detection and/or characterization of various lesions in medical imaging, including conventional projection radiography, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound imaging. Organs that are currently being subjected to research for CAD include the breast, chest, colon, brain, liver, kidney, and the vascular and skeletal systems. Commercial systems for detection of breast lesions on mammograms have been developed and have received FDA approval for clinical use. It has been reported that more than 10,000 commercial CAD systems have been used at many hospitals, clinics, and screening centers in the United States and in Europe for assisting radiologists in their task of detecting breast cancers. It has been reported also from prospective studies that CAD has provided a gain of approximately 10-20% in the early detection of breast cancers on mammograms. CAD may be defined as a diagnosis made by a physician who takes into account the computer output as a "second opinion". The purpose of CAD is to improve the quality and productivity of physicians in their interpretation of radiologic images. The quality of their work can be improved in terms of the accuracy and consistency of their radiologic diagnoses. In addition, the productivity of radiologists is expected to be improved by a reduction in the time required for their image readings. The computer output is derived from quantitative analysis of radiologic images by use of various methods and techniques in computer vision, artificial intelligence, and artificial neural networks (ANNs). The computer output may indicate a number of important parameters, for example, the locations of potential lesions such as lung cancer and breast cancer, the likelihood of malignancy of detected lesions, and the likelihood of various diseases based on differential diagnosis in a given image and clinical parameters. Because the basic concept of CAD is broad and general, CAD is applicable to all imaging modalities, and to all kinds of examinations and images. In this lecture, the basic concept of CAD is first defined, and the current status of CAD research is then briefly described. In addition, the potential impact of CAD in the future is discussed and predicted.

11th 2016 14th SEACOMP Bangkok, Thailand
"Advances in Image Guided Radiation Therapy"
Geoffrey Ibbot, PhD

The introduction of image guidance in radiation therapy has revolutionized the delivery of treatments. Modern imaging systems can supplement or even replace the historical practice of relying on external landmarks and laser alignment systems. Rather than depending on markings on the patient's skin, image-guided radiation therapy (IGRT) using techniques such as computed tomography (CT), cone- beam CT, MV on-board imaging (OBI), and kV OBI allows the patient to be positioned based on the internal anatomy. These advances in technology have enabled more accurate delivery of radiation doses to anatomically complex tumor volumes, while sparing surrounding tissues. While these imaging modalities provide excellent bony anatomy image quality, magnetic resonance imaging (MRI) surpasses them in soft tissue image contrast for better visualization and tracking of soft tissue tumors with no additional radiation dose to the patient. However, the introduction of MRI into a radiotherapy facility carries with it a number of complications including the influence of the magnetic field on the dose deposition, as well as the affects it can have on dosimetry systems. The development and introduction of these new IGRT techniques will be reviewed and the benefits and disadvantages of each will be described. Clinical examples of the capabilities of each of the systems will be discussed.

12th 2017 15th SEACOMP, IloIlo City, Philippines
"Optimization: the role of medical physicist in diagnostic radiology"
Anchali Krisanachinda, PhD

The optimization should be applied to all categories of exposure: occupational, public and medical. The practical information will include in the workplace. The emphasis throughout is on the integration of radiation protection into the more general system of work management, and on the involvement of management and workers in setting up a system of radiation protection and in its implementation. The presentation will cover the radiation doses in imaging individual patient per procedures such as the dose in radiography is 0.001-1.5 mSv, diagnostic fluoroscopy 3-8 mSv, CT 2-15 mSv, interventional radiology 5-60 mSv, nuclear medicine 0.2-12 mSv for Tc-99m, dental of <0.2 mSv. As there is no dose limits prescribed for patients, the diagnostic reference levels, DRL, had been developed by ICRP for the standard size of patients. DRL would be changed with time as technology develops. DRL is one step in optimization while the other step would be the image quality consideration. The image quality scoring criteria should be set up. Going beyond person of standard size, the patients should be divided into various weight groups or into clinical indications. The acceptable quality dose, AQD, could be determined for local, regional and national situations for self-comparison. AQD can be used prospectively in adjusting parameters of patients whose estimated dose indicator is likely exceeding AQD+ SD. Therefore, the image quality should be primary while the radiation dose should be secondary which all patient weights could be covered. Every examination using ionizing radiation should be justified and optimized, in simple words, right examination, right dose.

The vision of optimization of radiation safety for patients and staff in medical imaging, the ideal goals are:

- No radiation induced skin injuries;
- Every examination is justified and that applied to recurrent examinations;
- Every examination is performed at radiation dose needed to get desired information and no more;
- Every patient is satisfied that examination was performed with minimum radiation dose needed for the purpose and there should be no worry about carcinogenic effect;
- No high dose examination.

The challenges are:

- Confidence building in patient on safety of medical radiological examination;
- Cutting down inappropriate referrals for radiological examinations that use ionizing radiation;
- Development of imaging equipment that minimize and optimize radiation exposure automatically for achieving clinical purpose;
- Avoidance of radiation induced skin injury in patients and radiation cataract in staff;
- Development of equipment that can provide safe imaging for patients that justifiably require few tens of imaging procedures in life time;
- Development of biological indicators of radiation dose;
- System for tracking of radiation exposure history of patient;
- Transition from dose to a representative phantom to dose to individual patient.

13th 2018 16th SEACOMP, Kuala Lumpur, Malaysia
"The Role of the ICRP in Medicine: Past, Present and Future"
Colin J Martin, PhD

The International Commission on Radiological Protection (ICRP) is a body made up of experts in radiological protection from around the world. The commission makes recommendations on protection in the application of radiation in a variety of fields, prepares guidelines for users of radiation, and has developed a system of dosimetry for evaluation of radiation hazards, including the recommendation of dose limits.

The International X-ray and Radium Protection Committee, the forerunner of ICRP, was established in 1928 to address concerns about effects observed in radiologists and the committee produced the first recommendations on occupational protection in medicine in July 1928. As other applications of radiation developed, the field of radiological protection broadened and the commission was renamed the ICRP in 1950. Several committees were established within ICRP at this time, dealing with different types of radiation, routes of exposure, and radioactive waste, and the first official ICRP report was published in 1958. During the 1960s the potential for reducing doses to patients began to be recognised, culminating in Publication 16 entitled "Protection of the patient in X-ray diagnosis" in 1970. ICRP Committee 3 "Protection in medicine" was established in 1977 and a series of reports on protection of the patient in different areas were prepared during the

1980s. Facilitating the understanding of radiation dose and the link to potential harm by non-specialists has always been a problem, and ICRP have attempted to address this through the introduction of protection quantities such as effective dose. Committee 2 “Doses from radiation exposure” works with Committee 3 to derive coefficients that allow organ and effective doses to be calculated for a wide range of radiopharmaceuticals for use by the medical community. ICRP felt that early reports produced by Committee 3 giving practical guidance were not reaching the medical community, so their impact was limited, and the emphasis has been changed to production of shorter concise reports on specific topics.

Since 2000, 24 reports have been prepared giving guidance and recommendations on areas relevant to medicine. However, a major source of ICRP income is from purchase of reports and this places a barrier to many potential users. Therefore, to mark the 90th anniversary of the founding of ICRP, the commission has launched a funding campaign with the aim of making reports available free through the internet. ICRP hope that if this step can be achieved, it will make a major difference in implementation of good radiological practice across the world.

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BOOK REVIEWS

"PROBLEMS AND SOLUTIONS IN MEDICAL PHYSICS – DIAGNOSTIC IMAGING PHYSICS" : A BRIEF OVERVIEW

Tabakov, S.[1,2],

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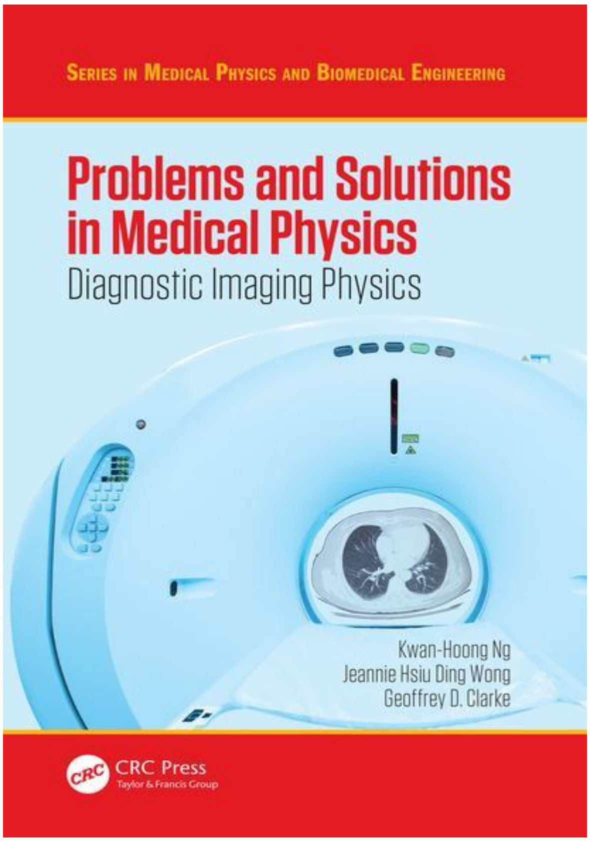
Abstract— **This article is a brief review of the CRC textbook "Problems and Solutions in Medical Physics - Diagnostic Imaging Physics" by Kwan Hoong Ng, Jeannie Hsiu Ding Wong and Geoffrey D Clarke, 2018, CRC Press (Series in Medical Physics and Biomedical Engineering), ISBN-13 978 1 4822 3995 9**



The book "Problems and Solutions in Medical Physics – Diagnostic Imaging Physics" is a publication in support of medical physics education. It comes as part of the CRC Series in Medical Physics and Biomedical Engineering.

The book includes 133 problems with their solutions. These problems are distributed in 11 chapters: Basic Physics; X-ray Production; Screen Film Radiography; Digital Radiography, Image Quality; Mammography; Fluoroscopy; Computer Radiography; Magnetic Resonance Imaging; Ultrasound; Radiation Protection and Radiobiology. Each chapter includes specific sub-chapters with educational problems.

The problems in the textbook are well chosen, illustrated with diagrams and images. A solution follows each problem, some illustrated and supported by mathematical explanation. The book includes 80 illustrative diagrams. The problems are based on real examples from clinical practice and are in line with the traditional medical physics lectures in University courses and other similar activities.

There are other books related to problems and solutions, which are complemented by the present book. This subject is important as the problems and solutions could be includes as Quizzes alongside the lectures, also as part of Examinations. The book can be useful by all colleagues teaching medical physics, but also by students who would like to test their knowledge. Some problems could also be used for advanced students in radiography.

The authors are educators from the University of Malaya and University of Texas. The authors succeeded to make the book useful both for students from Low and Middle Income Countries, and from High Income countries, by including a good selections of problems (e.g. for Screen Film Radiography and for Digital Radiography). The solutions to the problems are presented in a clear way, understandable for both groups of potential users. Such books with problems are always useful for lecturers, as a source of ideas for developing further educational questions and answers.

Special mentioning deserves the authors' idea to periodically offer online further problems and solutions through the publishers CRC web site: https://crcpress.com/9781482239959

This relatively small book of 139 pages, appears to be part of a sequel of additional such textbooks. The Preface of the book mentiones two additional books related to Radiotherapy Physics and to Nuclear Medicine Physics (the latter one has just been published and will be reviewed in our next issue). I assume the latter will include more problems and solutions related to Radiation Measurements and Radiation Protection – wide fields of the profession, requiring good testing of students' knowledge.

The structure of the book makes it easy to navigate. The language is adequate for the purpose. As the book will be useful in many countries, I would suggest the online version to be linked to the Multilingual Dictionary of Medical Physics (www.emitel2.eu) what will help the readers in countries where English is not the first language.

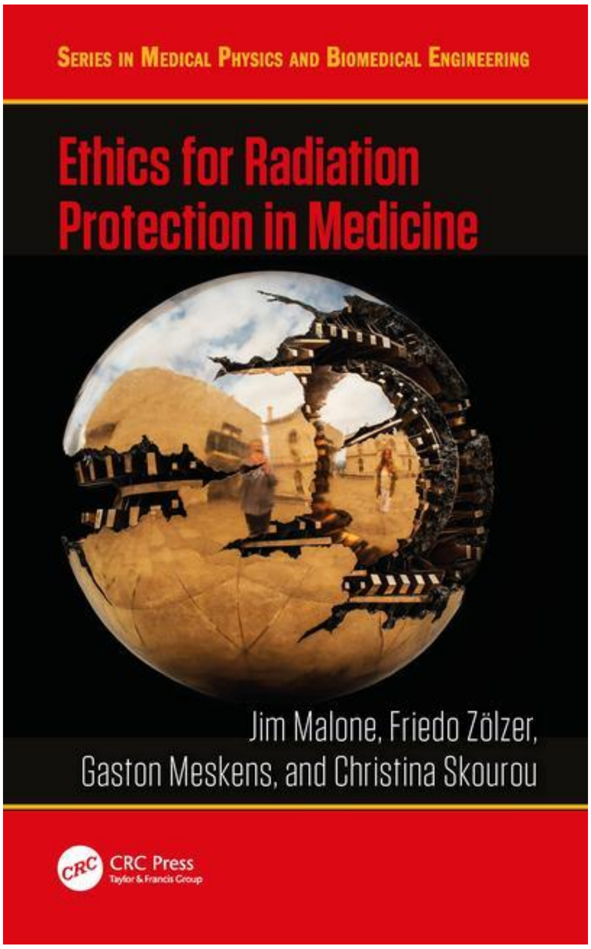
This is a typical book to support the medical physics teaching process (as well as this of related specialties). The book could have significant number of readers from Universities – it will be very useful for lecturers and students in Diagnostic Radiology. One can expect that the sequel of three books, offered by the authors, will support many educational courses around the world.

"ETHICS FOR RADIATION PROTECTION IN MEDICINE" : A BRIEF OVERVIEW

Kodlulovich, S [1,2,3]

[1]National Commission of Nuclear Energy, Brazil, [2]President of FRALC (Federation of Radiation Protection in Latin America and Caribbean), [3] Chair IOMP Awards and Honours Committee

Abstract— **This article is a brief review of the CRC textbook "Ethics for Radiation Protection in Medicine" by Jim Malone, Friedo Zölzer, Gaston Meskens and Christina Skourou, 2018, CRC Press (Series in Medical Physics and Biomedical Engineering), ISBN- 9781138553880**



The theme of the book of Jim Malone, Friedo Zölzer, Gaston Meskens and Christina Skourou is very relevant and appropriated for the current moment of the society. Considering the important changes in the ethical framework and societal background, it is imperative to conduct an analysis of the radiological protection system which ICRP has been operating over the years.

Chapter 1 presents some areas of the society that are affecting these principles. Some aspects such as openness, accountability, transparency and honesty are described as the direction in which external pressures are applied. Other factors which can affect in decision making, overriding medical priorities and individual clinical decisions, are also described. It is well pointed out that the uncertainty to evaluate risk-benefits is still a concern among public and health professionals; however the public expectation is increasing with the constant improvement of the technologies and when something fails it can lead to distrust of the professionals.

Chapter 2 presents one very comprehensive comparison between ICRP core values set (beneficence, prudence, justice, dignity) and the procedural values (accountability, transparency and inclusiveness) with the principles of biomedical ethics (respect of autonomy, beneficence, non-maleficence, justice and prudence) and the 'Pragmatic Value Set' proposed by the authors in this book. Furthermore, a brief historical review of classical ethical theories which were the basis of ICRP principles, such as the utilitarianism, deontological ethics and communitarianism is presented. Another important subject discussed was the need of a cross-cultural approach and cross-cultural ethics and global approached.

Chapter 3 addressed the legal, professional, and ethical aspects of radiation protection that can make the ICRP system, medical ethics, and social expectations compatible. A brief explanation of the ICRP principles and factors such as uncertainty, communication, risk and problems with skeptic doctors are also discussed.

Regarding to regulatory framework for radiation protection, the authors pointed out that in general it relies on ICRP recommendations, but the structure and framework for implementation can differ. As an example, education and training requirements are present in almost all regulations but the dose-risk information of physician is still poor. It was also cited that the importance of radiation protection of the patient was more emphasized only in 2000, particularly in diagnostic imaging. After "The Bohn Call for Action" justification was established as a priority. A brief discussion about the three A's (Awareness, Appropriateness and Audit) and the basic concepts of radiation protection was included in this chapter.

Regarding the pragmatic set values, there is an expectation to guide the evaluation of medical uses of radiation. Especially now, that the alignment of ethical values underlying the practice of medicine and the ICRP's core principles has not been fully explored yet, this pragmatic value set can provide a good interim approach.

Chapters 4 and 5 lead the reader to ethical reflections. Also, applying the pragmatic set and a score system to evaluate different potential medical situations enables a better understanding of these pragmatic set values. The proposal of these values is to supplement the ICRP principles and complement them aiding decision making in social sensitive areas.

In Chapter 6, the set of values is extended to the following core values: Respect for autonomy, Non-maleficence, Beneficence and Justice; correlated values: Dignity, Precaution, Solidarity and Sustainability and Procedural Values: Inclusiveness, Accountability, Empathy and Transparency. Based on this complete set, the previous scenarios are reevaluated and verified if the original pragmatic set with only five values could be sufficient. Certainly, is not a unique solution for every possible ethical dilemma, and additional values maybe could be useful for more complex situations.

Chapter 7 led to a reflection on uncertainty, risk and fairness, including the risk-Inherent technology, from an ethics perspective, justifying risk and the idea of intellectual solidarity and of fair risk governance. When the pragmatic set is analyzed in real perplexing problems, knowledge-related uncertainties and value judgments should be taken into account. In justifying risk, the authors considered:

A) Risk-Inherent Practice Acceptable? (Knowledge-based and assessment);
B) Uncertainty (incomplete and speculative knowledge);
C) Value-Based Assessment Dissent 'moral pluralism' (Governance by deliberation) and Consent 'shared values' (Governance by pacification).

It is also observed the importance of dealing fairly with the complexity of risk governance in medical uses of radiation. It requires joint preparedness of all concerned to adopt a specific responsible attitude.

In addition, is discussed the ethics of care perspective with reflexivity, and intellectual solidarity as ethical virtues which requires connectedness, vulnerability, and a sense of engagement.

The values proposed do not concern health care professionals only but for everyone involved in complex matters.

The pragmatic values set proposed did not intend to be a procedure for decision making, especially because there is no plausive framework that can produce determined solution for all potential cases. However, it seems that it could be a good tool to motivate a dialogue among all who contribute to radiation protection of patients and can be a good approach of ethical values that should be applied in radiation protection.

In 182 pages and 32 very explicative Tables, the authors bring to us a very comprehensive discussion about ethics for radiation protection in medicine. The complex subject matter addressed in this book is certainly of interest to all health professionals as well as all professionals who are directly or indirectly involved in processes or activities that may affect radiological protection in medicine.

"PROTON THERAPY PHYSICS - 2ND EDITION" : A BRIEF OVERVIEW

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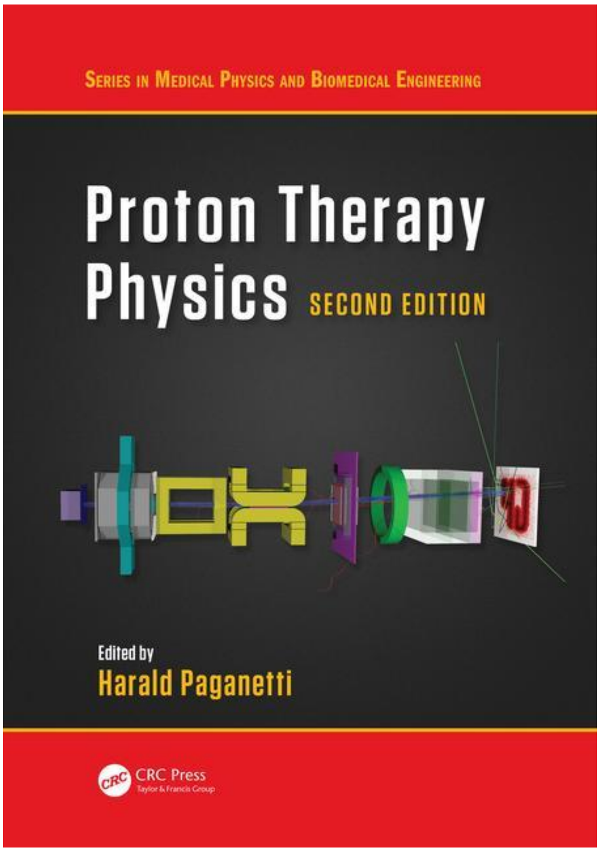
Abstract— **This article is a brief review of the CRC textbook "Proton Therapy Physics – Second Edition" Edited by Harald Paganetti, 2018, CRC Press (Series in Medical Physics and Biomedical Engineering), ISBN-9781138626508**



The first edition of Proton Therapy Physics was published in 2012, at a time when approximately 38 proton and ion beam facilities were operating world-wide (according to the Particle Therapy Co-Operative Group – PTCOG). Today, many of the existing centers have been updated and new ones constructed, with the result that PTCOG estimates there are now 94 centers in operation. Approximately 45 additional centers, or new facilities at existing centers, are under construction with many of them scheduled to begin operation this year or next. PTCOG currently estimates that about 20,000 patients are treated each year with protons. While the numbers of patients treated with protons remains low in comparison to those treated with external beam photons and brachytherapy, this number is increasing steadily.

The treatment capabilities available at proton centers continue to expand as new centers are built and existing centers are updated. The complexity of proton delivery systems similarly is increasing. Several single-room designs have become available with the goal of reducing the cost of the equipment and supporting facility. All modern proton delivery systems now include spot-scanning capabilities, enabling significantly improved conformation of dose distributions to the target volume in comparison to passive-scattered beams.

The rapid changes in technology and availability of proton therapy have warranted a second edition of Proton therapy Physics, and to his credit, the editor delivered a volume with many substantial improvements over the first edition.

The new book retains many of the chapters of the first edition, but all have been updated and expanded. Notably, the 2nd edition has organized the chapters into sections, making it easier to locate a particular topic. The sections of the 2nd edition are as follows:

Section I, Background. The introductory section includes two chapters describing the history and rationale for proton therapy, and the fundamentals of proton interactions in matter. One might expect these chapters to be largely unchanged from the 1st edition, but in fact the focus of both has been revised to better explain the introduction and increased use of spot scanning.

Section II, Beam Delivery. Here, the design of modern cyclotrons and synchrotrons is described in detail, with some time spent describing alternative proton accelerator technologies. It is concluded that the current synchrotrons and isochronous cyclotrons are likely to remain the most common proton delivery systems, and improvements are still being made to both technologies. Subsequent chapters in this section describe the characteristics of clinical proton beams, and the mechanisms for delivering beams to patients. This edition provides separate chapters to explain the technologies behind passive scattering and spot scanning.

Section III, Dosimetry. The first chapter in this section explains shielding design for proton facilities, including the production of secondary radiation. The following chapter describes the development of Monte Carlo codes for a variety of purposes including MC simulations of particle transport through biological materials and the use of MC techniques for design of the beamline and treatment head. Subsequent chapters deal with dosimetry of proton beams. Another change in the 2nd edition has been to separate the discussion of relative dosimetry from that of absolute and reference dosimetry; this is a valuable change as the equipment and techniques are markedly different and depend somewhat on the type of accelerating system used.

Section IV, Operation. This section also has undergone substantial revision from the 1st edition in that three chapters now are provided to discuss acceptance testing and commissioning, quality assurance, and monitor unit calibration.

Section V, Treatment Planning/Delivery. This large section has a chapter to address the characteristics of dose calculation algorithms and two chapters dealing with treatment planning for single-field uniform dose beams and for scanned beams, including intensity-modulated proton therapy. The sections discussing planning of IMPT are especially helpful, and are careful to include a caution regarding the uncertainties inherent in treatment planning, with a clever reference to a famous work of art. Two chapters in this section deal with precision and uncertainties in beam delivery and in the movement of internal organs; and the section concludes with a chapter on optimization.

Section VI, Imaging. The first chapter on proton image guidance discusses the use of x-ray imaging systems (orthogonal images as well as CT systems) and optical imaging of markers and the patient surface. A second chapter in this section discusses in-vivo treatment verification techniques, such as PET imaging and prompt gamma imaging. The first of these techniques capitalizes on the activation of certain elements in biological materials, giving rise to positron emitters that can demonstrate the range of the proton beam in the patient. At the same time, this chapter is realistic about the difficulties encountered when attempting to guide treatment delivery based on images corresponding to the delivered dose.

Section VII, Biological Effects. The final section comprises two chapters from the 1st edition that describe the physics behind biological effects from proton irradiation, and methods for exploiting the benefits of protons. Only small changes are seen in the 2nd edition, leading to the disappointing conclusion that little progress has been made in this area. However, these chapters are an excellent description of what is known today about the biological effects of proton therapy.

It might be apparent from the descriptions above that there is some overlap among different chapters. This is intentional, according to the editor, to allow chapters to stand alone and improve the usability of the text.

All chapters contain numerous citations to reference material, with ample opportunities for the interested reader to pursue these topics in greater detail. In general, the chapters are well-written and easy to read, although there is some inconsistency in the grammar and a few editorial errors exist in several of the chapters. These do not detract from the readability of the book, nor do they diminish its value. In short, the 2nd edition of Proton Therapy Physics (758 Pages, with 282 B/W illustrations) is a comprehensive, well-written compilation of the key issues in the physics of proton therapy.

"HENDEE'S PHYSICS OF MEDICAL IMAGING" 5TH EDITION BY EHSAN SAMEI AND DONALD J PECK

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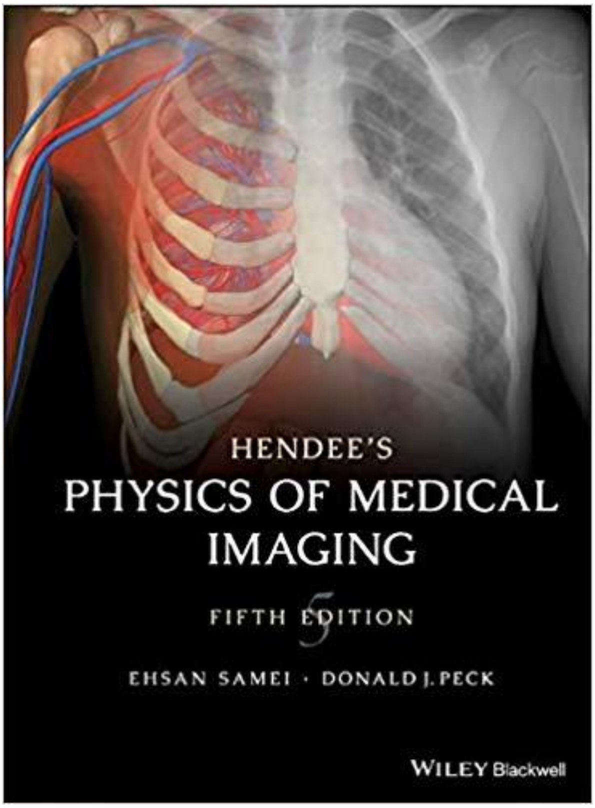
Abstract— **This article is a brief review of the textbook "Hendee's Physics of Medical Imaging" 5th Edition, by Ehsan Samei and Donald J Peck, 2019, Wiley-Blackwell, USA, ISBN-13 9780470552209**



The book "Hendee's Physics of Medical Imaging" – 5th Edition continues the update of the classic textbook of Prof. William Hendee "Physics of Medical Imaging", whose 4th Edition (W Hendee and R Ritenour) currently is one of the most often used textbooks in the profession. The new book (5th Edition) is written by the well-known specialists Ehsan Samei and Donald J Peck. I can only congratulate the authors for naming their book after Prof. Hendee, thus enhancing the great tradition of continuity in our profession.

The new book of Ehsan Samei and Donald J Peck has different look and presentation (compared with the 4th edition), it covers the newest development of medical imaging physics, supported with high quality colour diagrams and very good explanations. This is one of the few textbooks on the subject with plenty of colour figures distributed inside the text. The layout is in two equal columns. Total volume of the book is 468 pages (close to the number of pages of the previous edition – 512). The book has an Introduction and 10 Chapters. Each chapter includes a list with main References. The book assumes some initial background knowledge in physics, what these days is valid also for medical specialists.

The book starts with a brief Introduction to the subject, which takes 7 pages with 5 main parts, supported with 9 figures. It presents the historical foundation and advances of medical imaging physics.

Chapter one "Physics of Radiation and Matter" has the following main parts: Electromagnetic Radiation; Radioactivity; Radiation Interactions with Matter; Production of X-rays; Radiation Detectors. The chapter is 53 pages long with 70 sub-divisions, supported with 67 figures. The explanations are both academic and easy to read without heavy mathematics.

Chapter two "Anatomy, Physiology, and Pathology in Imaging" has the following main parts: Interaction of Radiation with Tissue; Structure and Function. The chapter is 30 pages long with 54 sub-divisions, supported with 27 figures. The chapter is a useful inclusion in such a type of textbook, as it will be very useful for the young medical physics readers, presenting the needs and challenges in imaging various anatomical structures.

Chapter three "Imaging Science" has the following main parts: Basic Statistics; Modeling Radiation Interactions; Image Quality; Image Processing. The chapter is 49 pages long with 77 sub-divisions, supported with 52 figures. The chapter presents very well the physical parameters of an image and thus sets the background for the following description of various image modalities. Again, mathematics is sufficient, well explained, and not heavy.

Chapter four "Radiobiology, Dosimetry, and Protection" has the following main parts: Radiation Quantity and Quality; Radiation Effects in Cells; Radiation Effects in Animal Systems; Determination of Dose in Humans; Protection from Radiation. The chapter is 33 pages long with 64 sub-divisions, supported with 19 figures. This is another background chapter linking general imaging sciences with the specific way images are acquired in medicine, underlying the main principles of Radiation Protection.

Chapter five “Imaging Operation and Infrastructure” has the following main parts: Image Perception; Medical Displays; Imaging Informatics; Clinical Imaging Operation. The chapter is 33 pages long with 45 sub-divisions, supported with 30 figures. This is the final background chapter with excellent descriptions of various medical displays and hospital information systems dealing with digital images.

Chapter six “Projection X-ray Imaging” has the following main parts: Projection X-ray Setup; X-ray Projection Modalities; Key Components of Projection X-ray Systems; Exposure Control. The chapter is 24 pages long with 29 sub-divisions, supported with 32 figures. This is a classical chapter for X-ray radiography and fluoroscopy, which is based on digital detectors, but also includes information on films and Image Intensifiers.

Chapter seven “Volumetric X-ray Imaging” has the following main parts: Tomosynthesis; Computed Tomography; Volumetric X-ray Reconstruction. The chapter is 23 pages long with 44 sub-divisions, supported with 21 figures. This is another classical chapter for X-ray imaging using reconstruction. It is easy to read and is very well explained with minimal mathematics.

Chapter eight “Nuclear Medicine” has the following main parts: Radionuclides; Counting Systems; Principles of Scintillation Camera; Emission Computed Tomography; Single-Photon Emission Computed Tomography (SPECT); Positron Emission Tomography (PET). The chapter is 32 pages long with 60 sub-divisions, supported with 32 figures. This is also a very well explained classical chapter, which will be useful both for medical physicists and related medical specialists.

Chapter nine “Ultrasonography” has the following main parts: Sound Properties; Transducers; Ultrasound Beam; Ultrasound Imaging; Doppler; Artifacts; Therapeutic Use and Bioeffects. The chapter is 31 pages long with 41 sub-divisions, supported with 34 figures. As the other classical chapters, this one includes all parts to make it standalone. The colour figures used in this and the following chapter are a real asset not only for the students, but also for the lecturers in medical physics.

Chapter ten “Magnetic Resonance Imaging” has the following main parts: Fundamentals of Magnetic Resonance; Magnetic Resonance Imaging as a Probe of the Body; Magnetic Resonance Image Contrast; Magnetic Resonance Imaging and Flow; k Space; Additional MRI Contrast Mechanisms; Spectroscopy; Chemical Shift Imaging; MRI Artifacts; Bioeffects and MR Safety. The chapter is 106 pages long with 64 sub-divisions, supported with 113 figures. Understandably, this last chapter is the largest one and, as in the previous ones, provides a very smooth learning curve for the reader.

The book concludes with an extensive Index over 15 pages, which makes it a good reference.

The “Hendee’s Physics of Medical Imaging” – 5th Edition is written with clear and focused academic language. As mentioned above, it will be very useful both for students and lecturers on the subject. The audience of the book will also expand in the field of relevant medical specialists.

This brief review does not intend to compare the 4th and 5th editions of the book, but if one makes a comparison, one will find the same paedagogical values of both. At first sight the new book has different structure and layout, but it carries the same educational components through a slightly different pedagogical paradigm.

I would like to conclude this brief review with a congratulation to both authors for the excellent textbook. Being myself involved in medical physics lecturing and textbooks writing, I know very well how difficult it is to write a good textbook, which to guide the student through his/her way of gradual knowledge built up. These days many Universities undervalue textbook writing, what dissuades some colleagues from such endeavor, what directly affects the preparation of the future generation specialists. This, added to the fact that producing clear explanations of complex processes is a very difficult task, creates a steep path for the authors. It is excellent to see that this has not stopped Dr Samei and Dr Peck in creating a long lasting textbook in Medical Imaging Physics, which will continue the tradition set up by Dr Hendee. I shall not be surprised to see in near future this book translated to other languages.

PhD ABSTRACTS

DEVELOPMENT OF AN OPEN SOURCE TOOL TO AID IN THE EVALUATION OF KNEE CARTILAGE INJURIES

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Federal University of São Paulo - Paulista School of Medicine

Abstract— **Background**: When the cartilage is preserved, the collagen hinders the water mobility, resulting in a short T2 value. However, when this structure is weakened, the flow of water through the cartilage is intense, thus increasing the T2 values. In this way, with Magnetic Resonance Imaging (MRI), T2 maps indirectly present the cartilage content analysis. T2 mapping is commonly used in the evaluation, progression and diagnosis of cartilaginous regions of the knee once it uses a suitable protocol for MRI acquisition and specific software for the post-processing step. Purpose: To develop a tool (open source free software) for the study of T2 relaxometry. **Methods**: Using a 1.5 T MRI, we obtained MRI from seven patients and developed a program in MATLAB to generate T2 maps.

Results: We developed a software program and named it Mapas T2, (Figure 1). The tools and functionalities of the proposed application were based on of Usability principles (International Organization for Standardization (ISO), and the clinical needs of radiologists and academics.

We created a tool that allows the user to contour the anatomical areas in free format, thus obtaining the T2 value of the one or more region of interest (ROI) simultaneously (Figure 2). This tool proves important if one considers that the irregular structures of the knee suggest the need to map the anatomical regions of the cartilage in segmented areas.

We implemented the T2 map generator feature with all sequence images (batch processing mode). This function avoids the need to partition the exam, showing only echoes in an orderly manner in the regions of interest. For example, a protocol with 14 echoes may result in 210 images to cover the whole anatomy of the knee, and with the developed tool it is possible to order the images at every 15 echoes and obtain T2 maps of the entire anatomy.

With the tool, one can visualize the decay curve of the region of interest with the value of the Mean Square Error (MSE). This information allows the user to deliberate on the fitting curve and whether the value of the error is within the degree of reliability adopted in the study.

In the post-processing and T2 mapping step, the script runs automatically and disregards the first echo of the sequence. Then, in a sequence with 10 echoes, only 9 will be used for the calculations. This particular function was implemented in order to minimize intrinsic errors in multi-echo imaging sequence and in T2 estimation since some physical aspects in the first echo are not considered.

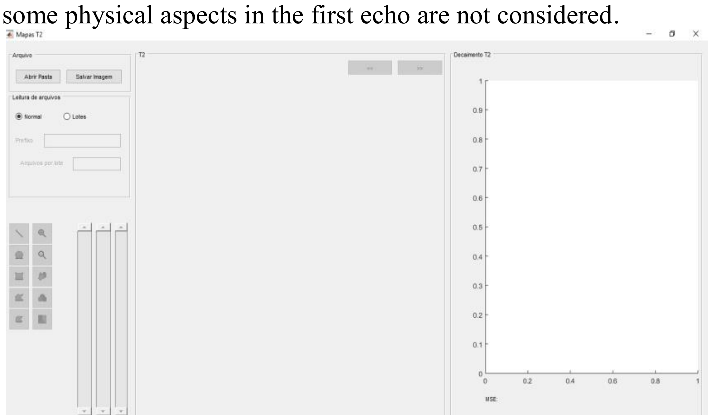

Fig. 1. Interface of the Mapas T2 application. Once the files containing the images are selected, the processed T2 map is displayed in the viewer and, after selection of an ROI, the decay curve is displayed.

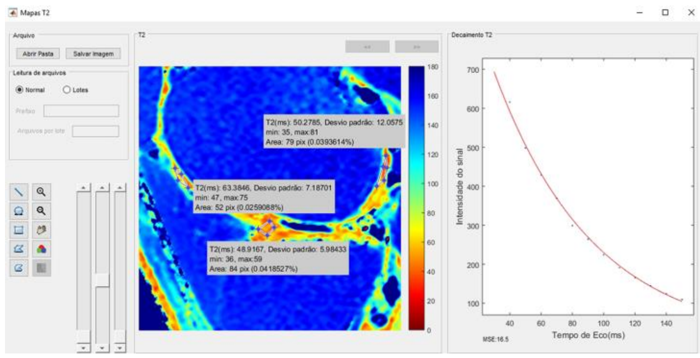

Fig. 2. Simultaneous visualization of three ROIs on a single T2 map

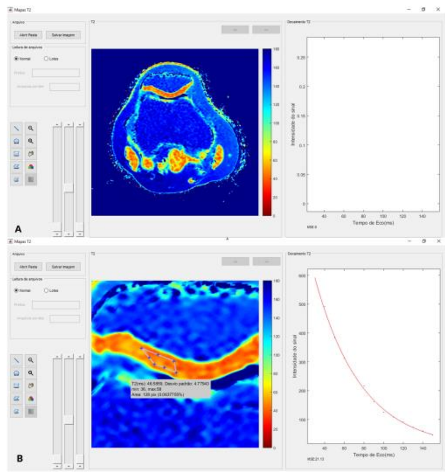

Fig. 3. A) T2 map obtained with 14 echoes. B) The zoom function was used to aid in the visualization and to obtain an ROI in the cartilage.

Immediately, the software provides the T2 value, the decay graph and the MSE value. The user can choose the batch processing mode, so the application will simultaneously provide 20 T2 maps, as shown in Figure 4.

Initially, we performed a pilot test from which we obtained a series containing 280 MRI images in the sagittal plane of the knee of a healthy volunteer (male, 36 years old). In a folder, we separated 14 images of the medial portion and selected the normal processing mode to read the files, resulting in a single T2 map (Figure 3).

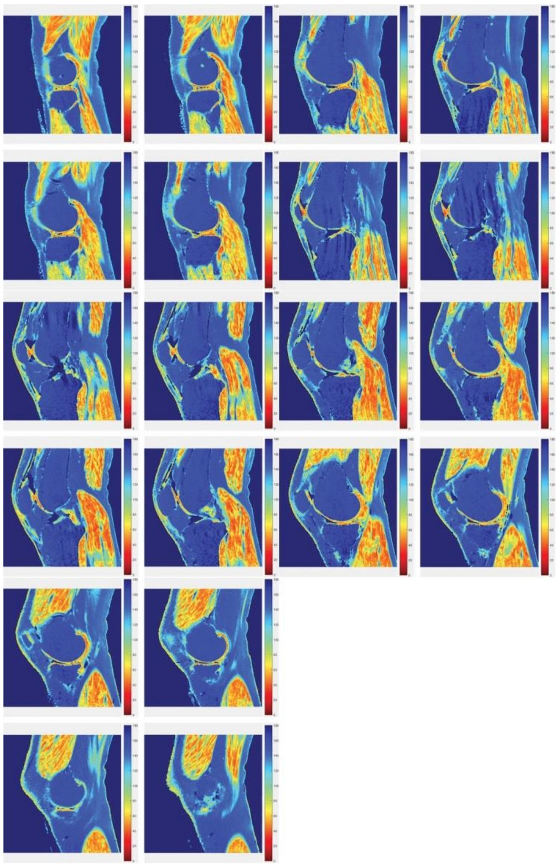

Fig. 4. Simultaneous post-processing procedure of 280 MR images.

We obtained the T2 maps in the clinical routine by MRI of a group of seven patients (N = 7), all of them referred to magnetic resonance examination of the right knee. In other words, there were no calls for patients or volunteers, and the study was approved by the Ethics and Research Committee of UNIFESP (CAAE:16837213.1.0000.5505). In the comparison with the three free programs, no significant difference was found between the values of the T2 maps.

Conclusion: The software developed, now made available to academic and professional environments allows generating T2 maps of cartilaginous structures of the knee in an agile way and with usability features.

The Mapas T2 application is an open source code and it is freely available (http://mapast2.site123.me) under the General Public License (GNU) for non-commercial use and open source development.

Keywords — Cartilage. Relaxometry. T2 maps. MATLAB. Knee. Magnetic Resonance Imaging.

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Title:

Evaluation the Accuracy of Monte Carlo calculation Model Implemented in Monaco Treatment Planning System for Plastic Phantom Dosimetry in radiotherapy

Prospective/Objective: Test the accuracy and a consistent set of criteria for acceptability of photon beam dose calculations in plastic phantoms using Monte Carlo (MC) calculation algorithm model implemented in Monaco treatment planning system. Check the applicability in combination with a test used for evaluating the accuracy of the plastic phantoms dosimetry as a medium in radiation therapy

Materials and methods. Measurements are done by using plastic phantoms PMMA mass density 1.19 g/cm3and RW3 phantom mass density 1.045 g/cm3, irradiated open fields using a different source to surface distance (SSD) with different field size and different depths using Elekta Precise Linear Accelerator MLCi models with two photon energies 6MV and 15MV. The measured absorbed doses in the medium are compared with the calculated ones using MC calculation algorithm in Monaco TPS. Virtual electronic phantoms are simulated reproducing the same measurements setup. In this study we are comparing calculated absorbed dose with measured doses by using PTW 0.3 flex and pinpoint ionization chambers (ICs) with special insert slabs for both chambers. Measure of output factors on central axis at two different depths with RW3 phantom and one depth for PMMA phantom and for different fields size and SSDs are been performed for comparison with calculated data

Results. The accuracy agreement between calculated absorbed doses by Monaco TPS using MC algorithm and measured absorbed doses in RW3 and PMMA plastic phantoms instead of doses in chambers reading taking into account the correction and perturbation factors of corrected doses in plastic phantoms, for both energies and different setups of plastic phantoms; had acceptable accuracy and their confidence limits around 2%.

Conclusions. MC is the most accurate method of calculating dose distribution, has shown significant gains in accuracy of dose calculation in the plastic phantoms, the results of measurements done to check the accuracy of dose calculation in plastic phantoms by used MC algorithms. This results make us confident in using MC calculation plastic phantoms for comparison with pre treatment verification measurements as QA process in radiotherapy for IMRT and VMAT delivery.

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Title:

Small field dosimetry in clinical practice: estimation of micro ionization chamber

Prospective/Objective:
Stereotactic radiation treatments require small field delivery. The dosimetry of such fields is challenging, and a specific formalism was introduced in the last decade. The primary aim of this study was to determine the correction factors of 10 MV small square beam (or kfs) and small modulated beam or for Pinpoint PTW-31016 ionization chamber, using the Gafchromic EBT3 as reference detector. The secondary objective was to apply on stereotactic radiosurgery treatment(SRS).

Materials and methods. Two different sets of measurements were performed for the estimation of kfs and for the Pinpoint PTW-31016 ionization chamber, delivered on RW3 phantom at10 cm depth. The reference field for the correction factors estimation was 5x5cm2.Firstly,for kfs estimation a set of square beams was delivered to the detectors with different field size with 2Gy dose prescription at the isocenter. For correction factors four modulated beam with geometry similar to the SRS plan were produced with the Monaco treatment planning system(TPS)and delivered to the detectors in a sliding window technique. The calculated was then plotted as a function of beam segment area in order to find a fitting curve that can be used to correct ionization chamber measurements in pre-treatment verification of SRS plan. The estimation of, derived from that fitting, was verified with two clinical patient plans by comparing the corrected chamber measurement with the film measurement and with the calculated dose from the Monaco TPS.

Results. kfs increases as the field dimensions decrease: for 3x3cm2, 2.5x2.5cm2and 2x2cm2kfsis close to unity, as expected, while it is 1.027(±2.3%) for the 1.5x1.5cm2and 1.067(±2.9%) for the 1x1cm2. For the 0.5x0.5cm2field, kfs is estimated, from the fitting, to be 1.16(±1%).kpcsr increases as the segment area decreases and for the modulated beams considered the range of variation was between1.003 and 1.089.kfsestimated in this work are in good agreement with published data of kfsat 10MV: the differences are0.1% for 2x2 cm2, 1.5% for the 1x1 cm2 and 1% for the 0.5x0.5 cm2field. The kpcsr fitting curve showed an excellent agreement, with $R2=0.999$,and hence the fitting curve can be used to estimate the kpcsr of modulated beams used in SRS treatment. When we apply the on the two ion chamber values of the clinical plans, we find a good agreements with the film dosimetry: dose difference between chamber and film are

<0.5%.The ion chamber measurement after correction shows a better agreement with the TPS calculation(DVH mean dose to the chamber): dose discrepancy improved from 3.7% to 1.4%.

Conclusion. The good agreement with the published data of kfs allows us to use them to correct the Pinpoint PTW-31016chambermeasurements. Kpcsr estimated from the fitting curve can be used to correct the ion chamber pre-treatment verification of the SRS coplanar beam; further work is required to extend these results for the verification of other kind of SRS treatment, especially when non-coplanar beams are used.

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Title:

PET/CT Acceptance Test and Optimisation

Prospective/Objective: To evaluate the performance characteristic of Philips Ingenuity TF PET/CT system (Philips Healthcare, Cleveland, OH, USA) of both PET and CT parts and to optimize the PET scanner and reconstruction protocols.

Materials and methods. Philips Ingenuity TF is a TOFPET/CT scanner equipped with LYSO type detector which generates images using list-mode reconstruction algorithm, and 64 slices CT with dose reduction tools such as DoseRight and IDose. In this work, the performance of the newly installed Philips PET/CT was evaluated for whole-body scanning procedure using National Electrical Manufacturers Association (NEMA) NU 2-2012 protocol and the recommended phantoms. The set of tests performed were spatial resolution, sensitivity, image quality, scatter fraction (SF) and counting rate performance, and accuracy: corrections for count losses and randoms. The test of the CT was performed by the Philips protocol and then using the CATPHAN the tests were repeated as per the hospital standard protocol for CT acceptance test. The impact on background variability, contrast recovery and relative error in lung by changing the reconstruction settings was analysed on the image acquired on IEC phantom with target to background ratio 4 and 8.76.For the optimisation process of the PET, 120patients'(males and females)data were analysed. The patients were injected with an activity ranging from 90 MBq to 200 MBq. The F18-FDG injection protocol of the hospital is 3 MBq/kg. Whole-body images corrected for attenuation were acquired with the LYSO PET camera60-70minutesafter tracer administration. The true count rates and random rates for each anatomical part (thorax and abdomen) were plotted against the activity injected to the patient. From the graph, the trend of the counts was observed for patients having BMI > 25kg/m2and those having BMI < 25kg/m2. The noise evaluation (Coefficient of Variation (CV) of signal on a ROI on the liver) was performed on the patients studied in this work, by changing the ESD from 60 seconds to 90 seconds per bed.

Results. The average transaxial and axial spatial resolution measured as full width at half maximum (FWHM) of the point spread function at 1 cm (and 10cm) off-axis was 4.68 mm (5.07 mm) and 4.71 mm (4,70 mm) respectively. The average sensitivity for the two radial positions (R = 0 cm and R = 10 cm) was 7944 (8415) cps/MBq. The average scatter fraction was 30.54%. The peak noise equivalent count (NEC) rates was found to be 116.39 kcps at 19.21 kBq/ml (k = 1 in the NEC formula; noiseless random correction) and 93.79 kcps at 15.34 kBq/ml (k = 2; noisy random correction).By varying too much the reconstruction settings from the default setting shows that using the PSF shows a better contrast recovery compared to the default reconstruction settings. But using PSF with iteration number 2 showed an increase in contrast of above 100%.The optimisation process of the PET showed that there is no visible difference between the counts obtained by a patient with high BMI (>25) compared to a patient having a normal BMI (<25). The noise evaluation showed a significant difference in CV when the ESD was increase from 60 seconds per bed to 90 seconds per bed.

Conclusion. The results obtained for the Philips Ingenuity TF PET/CT scanner from the NEMA test are in agreement with the specification provided by the manufacturer. This PET scanner has an overall good performance which is comparable to other PET/CT systems from the same generation of TOF PET scanners. This work shows that the count rates of patients with low BMI (< 25 kg/m2) and high BMI (> 25 kg/m2) are superimposed, contrary to the situation of non-TOF PET scanners. This observation allows eventually to consider an increase in ESD, independently on BMI, but not to increase the administered activity. The PSF image reconstruction increases the contrast recovery and hence improves the image quality. Care should be taken while increasing the number of iterations beyond 1 as the contrast recovery will increase over 100% with an overestimation in the actual uptake of the lesion. Finally, the noise evaluation has shown that it is worth increasing the emission scan duration (ESD) to90 seconds with respect to 60 seconds per bed to decrease significantly the CV on the liver.

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Title:

Treatment planning for gynaecological cancer with 3D, simple IMRT and VMAT

Prospective/Objective: Radiation therapy treatment of gynecological cancer can be delivered with different techniques. In this study we compared the forward planned 4 field box approach with the inverse planned volumetric modulated arc therapy approach. The objective was to become familiar with different treatment planning systems, practicing in a clinical environment. This study could be helpful for my home country in the transition from the simple 4 field box technique that is nowadays used to a more advanced technique that will be introduced next year.

Materials and methods. Ten patients that underwent VMAT treatment for gynecological cancer were chosen; the CT dataset and the structures (target and organs at risk), were exported to a 3D CRT treatment planning system, and planned again with a four field box technique. Dose prescription was 45 Gy in 25 fractions, 15MV photon beams were used, the dose distribution within the PTV was optimized (95% of the prescription dose covering all the PTV, while keeping the hot spots at less than 110%). The Fiorino et al approach was adopted for the small bowel constraints (V30Gy, V40Gy and V45Gy tolerances are defined for IC07, i.e. the whole intestinal cavity minus PTV, with a 7 mm margin). VMAT plans were previously done with a full arc (360°) 10MV photon beam, optimized with inverse planning approach. The relevant data from the Dose Volume Histograms were tabulated for both techniques. The conformity index was calculated for each plan. A comparison between the two techniques was performed, using statistical analysis methods.

Results. The results were analyzed with R software, with non parametric data two tailed paired Wilcoxon signed rank test. The level of confidence was p-value <0.01 .For planning target volume, most of the plan shows a good coverage, homogenous dose distribution, maximum dose around 110% and minimum dose equal or more than 95% . Both techniques are statistically not different. Regarding IC07 there is a statistically significant difference between VMAT and 4 field for all the investigated parameters (V30Gy, V40Gy and V45Gy): VMAT shows a reduction in median values of 61%, 86% and 100% respectively. Regarding conformity index for IC07 there is a statistically significant difference between VMAT and 4 field, with a reduction in median values of 29%. Regarding the bladder mean dose there is a statistically significant difference between VMAT and 4 field, with a reduction in median values of 6%.

Conclusion. The VMAT technique leads to a coverage of the PTV comparable to the one obtained with 4 field technique, while better sparing the intestinal cavity, due to the improved conformality of the high dose region. If it's not possible to have VMAT capability, a optimized 4 field box technique can be a good solution anyway, provided a stricter follow up is conducted, to help facing any clinical consequence due to the higher doses to the small bowel.

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Title:

Statistical process control analysis for patient-specific pre-treatment VMAT QA with PTW Octavius 4D system: setting tolerance limit and action thresholds for different anatomical sites

Prospective/Objective: Pre-treatment patients specific QA are used to validate the dosimetry of VMAT plans and to evaluate dosimetric performance over time of VMAT QA process. The aims of this work are: I)to determine specific Tolerance & Action Limits for VMAT QA of different anatomical sites II)to find a correlation between plan complexity metrics and 3D volumetric gamma passing rates for pre-treatment VMAT QA

Materials and methods. 464 VMAT QA performed in the Florence Radiotherapy Center of the Azienda USL Toscana Centro for patients treated in the period 2013-2018 were evaluated. All patient specific pre-treatment QA verifications were performed by the OCTAVIUS 4D phantom with OCTAVIUS 729 detector. Global and Local 3D volumetric Gamma evaluations with normalization at the 90 % of the maximum dose and different criteria (3%,3mm, 3%,2mm, 2% ,2mm) were performed. Six different anatomical sites were considered: Head and Neck, Lung, Breast, Prostate, Prostatectomy, Abdominal &Pelvic. Firstly, the analysis was based on the whole VMAT QA sample in order to evaluate retrospectively the behaviour of the process over a long time with a large number of pre-treatment QA. Secondly, the analysis was based on a small group of pre-treatment QA (last 20 pre-treatment QA performed for each anatomical sites), in order to monitor the process in a prospective approach and to track the variation of process based on the current status of QA results. In both analyses, the descriptive statistical parameters are calculated for each site of patient and Action &Tolerance limits were established by using the concept of Statistical Process Control, as suggested by AAPM Task Group 218.The Modulation degree, Total MU number and total Leaf Travel were calculated from the DICOM RT files of 120 VMAT treatment plans, 20 for each of the six involved anatomical sites. The relationship between plan complexity and the 3D volumetric global gamma index analysis with 3%, 3mm criteria was investigated. Pearson correlation analysis was performed and considered statistically significant for p-value < 0.001.

Results. Tolerance Limit for complete data set for Prostate, Prostatectomy, Head & neck, Lung, Breast, Abdominal sites were 98.6%, 97%, 91.3%, 91.2%, 91.2%, 88.4% respectively and action limit were 97.8%, 95.5%, 87.6%, 88.5%, 87%, 86%. Tolerance Limit and action limit evaluated on the small data set of QA results were higher than the previous ones for each anatomical site allowing a reduction in the variation of QA results. Average modulation degrees were ranging between 2.4 and 7.5 respectively with the lower modulation observed in prostate cases and higher modulation in Abdominal treatments. The average MU number was ranging between 524 for prostate treatments to 968 for breast plans. The average total leaf travel was minimum for prostate plans and maximum for abdominal plans. A significant negative correlation between each examined complexity parameter and 3D volumetric gamma passing rates was observed showing that for higher value of complexity metrics, lower pass-rates were scored. A Strong positive correlation between each other of the examined parameters (Modulation degree vs Total leaf travel, Total MU vs Modulation degree, Total MU vs Total leaf travel) was found too

Conclusion. Action thresholds for VMAT QA treatments stratified for different anatomical sites were established. These limits could be used to accept or reject patient treatment plans for the specific systems used in this work. The observed correlation between plan complexity metrics and 3D volumetric gamma passing rates showed that planning and QA verification procedures should be considered as a whole process. Some parameters, which have a significant impact on plan dosimetric accuracy, should be controlled during plan optimization, thus reducing the complexity of the plan.

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Title:

Commissioning of Total Body Irradiation for a new installation

Prospective/Objective: The project was aimed at commissioning of the Total Body Irradiation (TBI) technique in a new installation at Maggiore Hospital, Radiotherapy Department.

Materials and methods. Calibration of detectors, Gafchromic EBT3 (GAF), MOSFETs and Ionization chambers (CI), was done under reference conditions for use in TBI conditions. Three reference positions: Source Axis Distance (SAD) 5m (2m from the wall), SAD 4.5 m (2.5 m from wall) and SAD 4m (3 m from wall) were chosen with minimal or no backscatter from the wall. A treatment technique: Lateral-Lateral (LL), gantry angle 900, collimator angle 00 and 6MV energy was chosen with respect to the nature of the bunker. Percentage Depth Doses (PDDs) were evaluated, first with a big water phantom and then with RW3 slab phantom (30x30x30 cm3) at the three positions and then compared. The flatness and symmetry of the profiles were evaluated from the water PDD data. The beam quality was also determined using TPR1020 in TBI conditions. Then in vivo doses were measured with both GAF and CI using RW3 phantom by taking three points on the RW3 phantom: 5 cm from entrance (entrance dose), middle slab (midline dose) and 5 cm from the exit (exit dose). These were compared for GAF and CI. Additionally, previsional calculations for Monitor Units (MU) were made to achieve the nominal prescribed dose of 2Gy at the umbilicus, with 1Gy from either side of the patient. Lastly, the absorption of lead and plexiglass as shielding materials was measured and the corresponding absorption curves plotted.

Results. The beam was characterized in different setups. A length of 140 cm (pediatric) was found to be in the flatness region with a dose variation of 3% while 170 cm (adult) had a dose variation of 10%. TPR1020 was found to be 0.9888 at 2.5 m from the wall. The correction factor (for all influence quantities) changed from 0.994 in isocentric conditions to 0.991 in TBI conditions. GAF, MOSFETs were calibrated and a calibration curve was plotted for GAF while a table of calibration factors was made for the MOSFETs. A dose variation of less than 2% was achieved between Farmer chamber and GAF readings at similar points in the RW3 phantom.

Conclusion. The beam characteristics were important parameters to understand the behavior of the beam in non-reference conditions (TBI conditions). These were within tolerance range as dose variations of up ±10% is allowed in TBI conditions. The doses measured with the CI and GAF were compared with less than 2% difference and this meant they can be used in any TBI setup. Therefore, the bunker was found fit for carrying out the TBI technique and the first patient who was irradiated after the commissioning was a very good experience.

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Title:

Characterization of diamond detector for dosimetry in the reference and non reference conditions in the flattening and flattening filter free beams

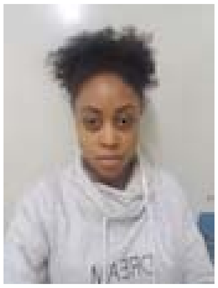
Prospective/Objective. The goals of this work are to characterize new Synthetic Single Crystal Diamond Detector (SCDD) for the dose measurements in the radiation therapy photon beams, in order to use safety it to check the accuracy of TPS modeling for the dose calculation in small field size, penumbra region and dose build up region, to investigate the optimum conditions in which SCDD operate in comparison with other detectors, to find out the possibility of using SCDD for calibration of Delta4, that is the instrument that we use for Delivery Quality Assurance (DQA), that use diodes as detectors.

Materials and methods. The dosimetric properties of a synthetic SCDD were assessed and compared with the FC65-G, A14SL and CC13 ionization chambers measurements of different parameters. The SCDD was operated at zero bias voltage under irradiation with different higher energy photon beams using different dose rates while other detectors were operating at +300V. In all measurements performed, the detectors were connected to the PTW Unidos Electrometer. In this work, True Beam Varian LINAC was used to provide all radiation X rays energies. The Wellhofer IBA Dosimetry Water Phantom (Blue Phantom) was used for acquiring data. Pre irradiation dose of 5Gy were performed before using the detector in order to stabilize the detector as recommended by manufacture. The first task was to perform the constancy check of SCDD and FC65-G using Sr-90 check source. The time between 50s and 400s with the interval of 50s was used, followed by the measurements of SCDD dose response linearity. The field size of 10cm x 10cm, SSD 100 and 10 cm depth were used. The two nominal energies 6MV and 10MV were selected with and without Flattening Filter. Furthermore, the dose rate dependency of SCDD and FC65-G was also determined and compared using 10 x 10 cm2 field size, 10 cm depth, 100cm SSD and 50 MU.

The energy dependency of SCDD and FC65-G in photon beams of nominal energy 6 MV Flattening Filter (FF), 6 MV Flattening Filter Free (FFF), 8 MVFF, 10 MVFF, 10 MVFFF and 18 MVFF beam qualities were measured and compared using the two measured dose in reference condition, with constant dose rate of 400 MU/min and 100 MU were used. The angular dependency of SCDD was assessed in radial and axial directions. In radial direction gantry was rotated from 0° to ± 40° with the detector inserted into the Phantom. In axial direction detector was free in air, inserted in the buildup cap with gantry rotated from 00 to 180°. In both set up the field size of 5 x 5 cm2, 6 MVFF beam quality, 100 MU/min and interval of 10° gantry angles were employed. Beam profiles and Percent Depth Dose for 1x1, 2x2, 10x10 and 30x30 cm2 fields were acquired using SCDD for 6 MVFF and 6 MVFFF beams. Then measurements were compared with the ones measured with A14SL, CC13 and extracted from TPS. The Output Factors (O.F.) for rectangular fields were measured using SCDD and compared with the ones measured with A14SL, CC13 and extracted from TPS. Different rectangular field sizes were obtained by alternate fixing X and Y jaws. Finally, temperature dependency of SCDD was determined in the range between 20° to 30° C, with field size of 5 cm x 5 cm for 6 MVFF beam quality.

Results. The SCDD shows positive linear response with the dose measured with $R2 = 1$. Constancy checks also indicate positive linearity with $R2 = 0.999$ and with ±0.009 (k =1) STD. The response is independent from dose rate with values within ±1%. It was found that the SCDD dose measurements are in agreement with Farmer measurements within ±0.7 % at different beam qualities. The angular dependency of the SCDD was ±0.5% in radial direction and ≤ 0.9% gantry angles in axial direction. PDDs and Profiles for all energies, field sizes and depth acquired by SCDD were in good agreement with those measured with A14SL,CC13 and the ones extracted from TPS.

Conclusion. The results convinces that SCDD investigated is suitable for measurements in reference and non reference condition and small field dosimetry. It was found that TPS can provide correct dose calculation also for 1x1cm2. The diamond detector can be used to calibrate Delta4, as it has negligible angular, energy, dose and dose rate dependency.



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Title:

IMRT dosimetric commissioning of a Monte Carlo based TPS using the AAPM TG 119

Prospective/Objective: IMRT planning demands strict quality assurance and accurate dose determination for delivery of highly conformal dose to the patients. Some procedures from the AAPM Task Group 119 have been given in order to assess the planning and deliver systems. The aim of this survey was to verify whether the Monte Carlo algorithm on Monaco software could meet the plan goals suggested in the protocol and also to verify the accuracy of dose delivery mechanism in a linear accelerator. Thus, the comparison between calculated and measured dose distributions of some specific plans has been done to test the treatment planning system and then it has been assessed as recommended by the TG119 .

Materials and methods. This dosimetric verification has been achieved for photon beams of 6 and 10 MV. First, a measurement of simple open field plans with a water phantom and ionisation chambers placed at 10 cm depth was performed. The report of dose output, percentage depth dose and profiles scans have been made for this part. These acquisitions have allowed the creation of a new kernel to be installed in our TPS; this had to be tested. The planned dose of some of the measured beams at the beginning has been done with this TPS and compared with measured dose in order to verify the accuracy. Secondly, the comparison for complex geometry field, i.e. MLC-shaped plans, was done and the phantom Delta 4 has been used for the acquisition of the five beams for each energy. To finish the Task Group 119 recommendations have been followed to assure the suitable dosimetric commissioning of our TPS. The plans have been done on structure and computed tomography scanned data set downloaded from the AAPM website. IMRT test planning has been performed to achieve conformed dose and dose distribution similar to the one described in the AAPM TG119 report. All the beams of this work have been optimized and calculated with Monte Carlo based Elekta Monaco treatment planning software and the delivery system was Elekta Synergy S linear accelerator. The data analysis has been realized with the Beam Data Analysis Software for the first part and then the Delta 4 software has been used for the both others

Results. The open field planning had a dose calculation accuracy lower than 2% with 2% and 2 mm acceptance criteria. Complex fields planning had all pass rates higher than 99.6% for 3% and 3 mm criteria and 95.8% for 2% and 2 mm criteria. Concerning the five tests from TG119, the planned dose distributions have respected dose prescription recommended by the group mostly; the others were within mean ± SD results of AAPM TG119 facilities. The comparison between calculated and measured dose of these tests for 3% and 3mm and 2% and 2mm gamma criteria has given respectively a mean passing rate of 99.4% and 97.5% and a confidence limit of 2.5% and 7.6%. The results were in good agreement with the Task Group recommendation

Conclusion. The good results obtained between planned and measured dose distribution and their comparison with reference recommendations have allowed to assure the accuracy and validate the commissioning of the new treatment planning system and our delivery system.

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Title:

Commissioning of Varian Eclipse version 15.5 TPS for photons 6 MV and 6 MV FFF from Varian TrueBeam STx

Prospective/Objective: This work dealt with the measurements of basic dosimetric aspects of commissioning for conventional 6 MV (WFF, With Flattening Filter) and 6 MV Flattening Filter Free (FFF) photon beam from a LINAC Varian True Beam STx in the Eclipse 15.5 TPS (algorithm of dose: AAA).

Materials and methods. Measurements of basic beam data (PDD curves for a range of fields, beam profiles (OARs) at different depths, relative Output factors for various rectangular field sizes ranging from 2 × 2 cm2 to 40 × 40 cm2, Multi Leaves Collimator dosimetric parameters) for the modelling are done with Blue-Phantom2 water phantom (IBA dosimetry). The following detectors were employed: Semiflex 3D (PTW) (for measurements of PDD curves, relative output factors for small fields and absolute dosimetry), Microdiamond (PTW) (for measurements of beam profiles at different depths), CC13 chamber (IBA dosimetry) (for measurements of beam profiles of large fields and output factors larger than 4x4 cm2), IBA Farmer-like chambers FC-65p Wellhofer IC 69, FC-65G Wellhofer IC 70 (for reference dosimetry and MLC dosimetric parametrization). Since FFF beams are characterized by a value of dose per pulse greater than conventional beams, ion collection efficiency within the scanned volume was investigated to establish if it affects the shape of beam profiles. For the absolute dosimetry for 6 MV and 6 MV FFF beams, Code of Practice TRS398 and the recent Cop TRS 483 were adopted respectively basing on Famer-like chambers. Furthermore, for clinical reference dosimetry, 3D Semiflex chamber was used too. For driving the TPS commissioning and its analysis, different guidelines were studied. In particular, we paid attention to the recommendations by AAPM (MPPG 5a). To test the match measurements /calculated values, we applied an open-source software tool (MPPG #5 Profile Comparison Tool created in MATLAB environment as part of a multi-institution research collaboration) to compare scanning water tank measurements to 3D DICOM-RT Dose distributions. Implementation of tolerance values and evaluation criteria were discussed.

Results. 6MV-FFF has a softer spectrum compared the conventional beam, so their PDD curves are steeper. Relative Output factors for FFF beams show reduced field-size dependence, as a consequence of minor head scatter. The results of the validation tests of the model meet the tolerances for the basic beam data. Besides, the use of PCT for analyzing the basic tests allowed us to detect characteristics of the model not explicitly evaluated in beam Configuration of Eclipse.

Conclusion. Basic Beam data showed good agreement with the calculated. PCT revealed a valid, simple, quite flexible framework for commissioning and validation of TPS dose calculation algorithms. Remaining steps of the current study are the analysis of the TPS performance in different conditions compared to implementation and end to end tests for IMRT and VMAT planning.

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Title:

Applications of radiomic features to radiobiological models and radiomics: new strategies for selecting the optimal radiotherapy treatment plan

Prospective/Objective: The aim of this work is to select the most automated planning techniques to achieve a high probability of local tumor control (TCP) at a low risk of normal tissue complications (NTCP).

Materials and methods. 10 patients with prostate cancer, treated with a prescribed dose of 62Gy in 20 fractions were selected. Radiotherapy plans were made for every patient using 5 techniques (Box, Wedge, Field in Field (FiF), IMRT and VMAT) ranging from the less convenient, in terms of dose distribution, to the most modern and conformal (VMAT). The TPS chosen was Eclipse. The dose distribution obtained can be visualized as colour maps so radiomic features were extracted from them using 3D Slicer software. From the records of ten patients, the dose-volume histogram was used. Using radiobiological models the probabilities for tumor control (TCP) and normal tissue complications probability (NTCP) were calculated for each dose distribution to be used as gold standard for selecting the optimal plans and assessing a planning score between rival plans.

Results and conclusion. The features were correlated with the TCP and NTCP which are chosen as radiobiological variables using the package R as statistical tool. A Principal Component Analysis (PCA) is introduced for the analysis of the distribution of treatment plans. It identifies linearly independent combinations of parameters that summarize the statistical correlations present in the data. Radiomics has been used to identify more appropriate indicator able judging the more appropriate technique for the prostate cancer patients able to increase the TCP while sparing the organs at risk (bladder and rectum).

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Title:

Comparison of different simultaneous integrated boost (SIB) approaches in whole brain irradiation of metastatic disease with hippocampal sparing

Prospective/Objective: We want to investigate the main magnitudes involved in the treatment dose of HS-WBRT-SIB through the analysis of the main characteristics defined in ICRU report 83, so that we can evaluate the overdosage of WB considering the intermediate doses received by the patients. organs when the dose prescribed for WB and the metastatic lesion are between 30 and 40 Gy respectively.

Materials and methods. Ten cases of patients with cerebral metastases were treated with HS-WBRT at Azienda Ospedaliera Universita Integrata -Verona, Italy. These had been planned with the ECLIPSE software version13.6.23and treated with the Linear Accelerator DHS for VMAT and 2100 for IMRT of VARIAN, both with HDMLC Millennium120 collimation system and for Tomotherapy was used Tomotherapy planning station 5.1.12, when re-planning, CTs have been taken from already treated passages with fusion of magnetic resonance images and the process has been reedited from the contour of the structures, and the planning of the treatment. each pass was re-planned for the three techniques and with the data obtained from the planning system in the RT-Plan, the dose homogeneity index, the PTV coverage index, the behavior of the doses near to the minimum and near to the maximum were analyzed. as described by ICRU 83.In addition to the statistical analysis we will help the XLSTAT tool which allows us to perform the Freidman test to the data of interest

Results. PTV WB -IPPO -META is a volume that is totally covered when we analyze isodose of 98 and 95%, for the three techniques. For D98% we find: for IMRT 28.91Gy, for VMAT (28.83Gy) and for TOMO (29.09Gy). In relation to the dose close to the maximum, the results obtained were: for IMRT (34.22Gy), for VMAT (32.87Gy), and for TOMO (31.97Gy).The indices of conformity found through the analysis of the data are: in the 95% isodose: IMRT (1.23), VMAT (1.22), TOMO (1.26).in the isodose 98%: IMRT (0.94), VMAT (1.05), TOMO (1.12).As for the risk organs, all comply with the internal restrictions of the hospital.

Conclusion. In the evaluation of the three treatment techniques (IMRT, VMAT and TOMO) through of the analysis of dose-volume histograms (DVH) We found that the coverage of the defined white PTV and defined risk organs are respected in the different plans. Regarding the dosimetric result no significant variance was found between the three techniques analyzed with respect to the modal dose, if between doses near to the minimum D98% and near to the maximum D2%, where the significant differences are between volume and IMRT. The percentage of underdosing of the PTV WB for the dose near to the minimum D98% is: 3.64% for IMRT, 3.9% for VMAT, 3.04% for tomotherapy, As for doses near to maximum D2%were obtained overdosage percentages of: 14.05 % for IMRT, 9.56% for VMAT and 6.57% for Tomotherapy. According to the analysis performed with the statistical software we conclude that the best results for the treatment of HS-WBRT-SIB are obtained with the treatment of tomotherapy but if this is not available VMAT is a possible option.

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Title:

Assessment of the spatial, temporal and dosimetric accuracy of a linear accelerator dedicated to stereotactic body radiation therapy (SBRT)"

Prospective/Objective: The scope of this work was to commission Varian TrueBeam STx linear accelerator equipped with BrainLab ExacTrac in-room X-Ray based monitoring system, Vision RT AlignRT optical solution for IGRT, Varian RPM system for motion management and to assess the spatial, temporal and dosimetric accuracy for SBRT implementation.

Materials and methods. Varian TrueBeam STx linear accelerator equipped with BrainLab ExacTrac in-room X-Ray based monitoring system, Vision RT AlignRT optical solution for IGRT, Varian RPM system for motion management was commissioned. Measurements required by vendor to model the beams in the treatment planning system were performed: percentage depth doses, profiles both transversal and longitudinal, output factors, MLC transmission factors and dosimetric leaf gap. Measurements for EPID dosimetry were carried out. Commissioned energies were 4 MV, 6 MV, 8 MV, 10 MV of photons with flattening filters. 6 MV FFF and 10 MV FFF photon beams were commissioned as well. Dosimetric characteristics of beams with flattening filters were compared with flattening filter free beams. For electron beams energies of 6, 9, 12, 16, 20, 22 MeV were commissioned. The data was processed and input in the Eclipse treatment planning system. Measurements of small fields were performed with a MicroDiamond detector, and they were compared to measurements with a 0.125 cc ionization chamber. Several tests were performed in order to assess the spatial, temporal and dosimetric accuracy. The results were compared with recommended tolerances for SBRT treatment.

Results. Commissioning of Varian TrueBeam STx Linear Accelerator was successfully carried out. Softening of beam spectra and loss of beam hardening effect yield reduction in PDD at 10 cm for 6 MVFFF and 10 MVFFF beam from their corresponding 6 MV and 10 MV FF beam were 4.6% and 3.6% observed respectively. Flatness and symmetry of scanned profiles of 4, 6, 8, 10 MV flattened beams were not exceeding 2% and 1% respectively. Evaluated data, such as PDD, TPR etc., was fully compliant with the published literature. After the data was inserted into the TPS, a model beam was calculated for 6 MV and then compared with measured data. The biggest difference was observed in PDD curves, more precisely in the build-up region the difference was up to 5%. This data helps to understand the limitation of TPS used for dose calculation, and avoid errors. With AlignRT real time monitoring on test object was performed with moving couch 1 cm and 5 degree in each axis of motion. Tracking was confirmed to be within <0.5 mm and 0.5 degree of accuracy. More precisely: vertically 0.1 mm, longitudinally 0.2 mm, laterally 0.1 mm and 0.1° rotationally. Accuracy validation test showed RMS of 0.113 mm, 0.385 mm, 0.170mm, 0.075° for vertical, longitudinal, lateral and rotational errors respectively.

Conclusion. The results obtained during this work are within the tolerances for SRS/SBRT techniques, hence the system assessed in this work is adequately suitable for SBRT treatment.

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Title:

Comparison of advanced techniques for radiation treatment of prostate, breast and Oropharynx malignancies

Prospective/Objective: To compare the dosimetric performance of advanced radiotherapy techniques used for radiotherapy treatment of prostate ,breast and Oropharynx malignancies; evaluate variation of TPSs parameters, optimization functions, calculation grid resolution, and assess of the impact of the number of segments, beam configurations and planning solution allowed by different LINAC and TPSs.

Materials and methods.: A total of 83 plans were optimized for 25 patients (eight prostate, eight breast and nine oropharynx cases). For prostate and breast cases 3DCRT, IMRT and VMAT plans were generated. IMRT plans of prostate cases were prepared in three versions, investigating impact of the number of segments and calculation grid resolution during the optimization process. Cases were studied using dose grid of 2 mm and 4 mm varying the optimization segments between 40-70 segments in order to optimize time of delivering. While VMAT plans of breast cases were optimized using single and dual arc mode, respectively to evaluate an optimize coverage of the PTV and sparing of the OARs. For Oropharynx cases, IMRT and VMAT plan where assumed as a standard techniques and none 3DCRT was investigated for these cases. The plan and analysis is performed for two different TPS (Pinnacle v.9.8 and Raystation v.8a) assuming delivering of the plan with two LINACs Elekta (Synergy and VERSA HD).To minimize time, and automatize extrapolation of dosimetric data an in-house code was developed using Octave to optimize DVH data and dosimetrical analysis, to calculate and compare index and metric calculation. A complex statistical analysis was performed using ANOVA and Tukey's HSD statistical tests and provide automatic generation of the box plots graph.

Results. Results showed no significant difference between different versions of IMRT and VMAT plans. Concerning prostate cases all techniques satisfied limits of PTV coverage as suggested by ICRU 83. VMAT and IMRT showed significantly less values for the range V40-V70 of rectum and V75 of bladder comparing with 3DCRT ($p<0.01$). VMAT achieved higher dose sparing in interval V40-V60 of rectum comparing with IMRT ($p<0.03$). Concerning breast cases, VMAT achieved significantly higher values for D98, D95, D5 and D2 of PTV comparing with IMRT and 3DCRT ($p<0.005$). 3DCRT had the highest homogeneity ($p<0.0005$) and the least V20 of contralateral lung and D2, V20 and V30 of heart of left breast cases ($p<0.017$). While VMAT achieved significantly lower Dmean of heart of left breast cases and higher

Dmax of contralateral breast ($p<0.01$) comparing with 3DCRT and IMRT. Concerning Oropharynx cases no significant difference between techniques was found in terms of PTV metrics. VMAT achieved significantly less values for V40 of ipsilateral parotid and less values for Dmean of ipsilateral parotid and Dmax of spine comparing with IMRT (with $p<0.04$, $p<0.01$ respectively). Both the techniques had succeed (in average) the dose constrain of ipsilateral parotids due to the relative position within PTV.

Conclusion. For prostate cases VMAT was superior to IMRT in terms of PTV and OARs metrics. This is extendable to breast cases with performance of IMRT similar to that of 3DCRT. While for cases of Oropharynx VMAT and IMRT showed equivalent performance, but the delivery time is significantly decreased using VMAT, as reported in literature and this can contribute to optimize patients access to the clinical service. The developed code shown to be usable, fast and applicable to similar studies. These results can be useful for management evaluation in investments and clinical assessment of patients cohort and also in randomized controlled trials.

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Title:

A Comparative Analysis for quality assurance result of IMRT and VMAT Cancer Treatment Plans using three dosimetric tools

Prospective/Objective: Patient-specific quality assurance (QA) for intensity-modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) is extremely important in ensuring quality care for cancer patients in radiation therapy. The main objectives of this study is to analyze the sensitivity of different types of detectors by comparing their gamma index passing rates and investigate the sensitivity of various gamma criteria in intensity modulated radiation therapy (IMRT) and Volumetric modulated arc therapy (VMAT) quality assurance (QA) for the detection of systematic positioning and dose errors using an electronic portal imaging device (EPID), cylindrical (ArcCHECK) diode arrays.

Materials and methods. Various methods, including the use of an ion chamber, two-dimensional (2D) array detectors, and an electronic portal imaging device (EPID), have been employed during patient-specific QA in pre-treatment verification to detect possible errors between the dose calculated by the treatment planning system (TPS) and the measured dose. Due to the increasing complexity of modulated treatment plans and delivery, point dose measurements using an ion chamber alone may not be sufficient to verify dosimetric accuracy because a modulated plan can generate a steep dose slope near the organs at risk. A common tool for evaluating the agreement between the calculated dose and the measured dose is the quantitative comparison of the planar dose distribution using the gamma index.

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Title:

Comparison of beam characteristics in reference and non reference conditions and treatment plans for flattening filter and flattening filter free photon beams

Prospective/Objective: The objective of this thesis is to evaluate dosimetric difference between flattening filter free and flattened photon beams of Varian True Beam TM linear accelerator and to investigate the difference in treatment plan quality of different treatment techniques for selected brain cancer with flattening filter beam and flattening filter free beam.

Materials and methods. Non reference condition dosimetry were performed with IBA water phantom dosimeter system (RFA-Blue Phantom) with Omni-Pro Accept-7 software. AAPM TG-51 and IAEA TRS-398 protocol were used for dosimetry in reference condition for both flattening and flattening filter free photon beams. Comparison was made between the two protocols for the two beams. The procedure for Dosimetric Leaf Gap and MLC transmission factor measurements were carried out according to Varian specified guidelines. The chamber used for beam data collection and measurements were CC13, A14SL, A1SL, PTW30012 and FC56-G.

For treatment plan comparison fourteen patients with brain cancer were studied. A total of twenty eight treatment plans were generated using flattening filter beams and flattening filter free beams among which 10SRS, 6SRT, 6VMAT and 6IMRT plans. Standard clinical constrains were provided by the physician for planning target volume (PTV) and OARs. These were applied to generate the treatment plans. All plans were optimized and calculated using AAA algorithm of Eclipse treatment planning system. All treatment parameters such as iso-center position and beam set up were set to be identical for the flattened and the FFF beam plans. The homogeneity index (HI), gradient index (GI), target coverage (TC) and conformity number (CN) extracted from Dose-volume curves were used to compare the plan quality. The monitor unit number and beam on time were used to evaluate the delivery efficiency of treatment plans.

Result. Compared with FF beams, Dmax was shallower for FFF beams for all field sizes; the ionization curve shows smaller gradient for FFF beams in build up region. The FFF beams depth-dose curve shows a faster dose falloff compared with FF beams. As compared to FF beams, the output factor for FFF beams shows less variation with field sizes. FFF beams had lower MLC transmission and Dosimetric leaf separation than the FF beams.

In all four techniques the FFF beams provides the same TC as the FF beams. However, the use of 6MV FFF beams offers a clear benefit in delivery time when compared to 6MV FF beams, especially for SRS treatment techniques. It was obtained that compared to 6MV FF beam 6MV FFF spared 54.4%, 12.9%, 24.3% and 32.16 % of Beam On Time (BOT) in SRS, VMAT, SRT and IMRT techniques respectively. With regard to MU no significance difference were observed for VMAT and SRS techniques, but clear difference in MU were obtained in SRT and IMRT techniques: 6MV FFF uses higher MU amount than 6MV FF to achieve the same TC. The highest difference was obtained in IMRT in which 6MV FFF uses MU 1.5 times those of 6MV FF. From DVH analysis of OARs, FFF plans obtained better normal tissue sparing effect than FF plans in all four techniques.

Conclusion As expected, removal of flattening filter alters various commissioning associated parameter such as beam quality, MLC Leaves Transmission factor and Dosimetric leaf separation. It was observed that IAEA-TRS398 and AAP-TG51 protocols give comparable results for both flattened and flattening filter free photon beams for dosimetry in reference condition. Negligible difference in beam quality conversion factor was observed using the two protocols for both FFF and FF beams. Similarly negligible difference in ion recombination of available chambers was obtained using the two protocols. However, relatively higher recombination correction factor was observed for FFF beams as compared to FF beams with the same nominal energies for both protocols. The FFF has the benefit of faster treatment delivery with smaller dose to normal tissues. Those features will help to increase patient safety, increase patient comfort and reduce chance of developing secondary cancers after radiotherapy. In this study, we observed that, compared to 6MV FF beams, 6MV FFF beams obtained clear time sparing effect in IMRT and SRS techniques. However, in IMRT relatively higher MUs were used by 6MV FFF as compared to 6MV FF to obtain the same TC. Anyway, in compromise with its highest time sparing effect and insignificant difference in MUs between FFF and FF beams, for SRS techniques (in which high dose per session, from 7 up to 21 Gy, with different number of sessions) we can conclude that 6MV FFF beams is a good choice for brain treatment with SRS techniques.

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Clinical Supervisor:
Dr. Marta Paiusco

Title:

Evaluation of shielding for a facility where Volumetric Modulated Arc Therapy (VMAT) technique is to be used

Prospective/Objective: The purpose of this work is to assess the feasibility of reducing the bunker thickness when VMAT is to be used. The formalism of NCRP report 151 and treatment planning are applied so that we can estimate important parameters affecting shielding calculation such as use factor, modulation factor and field dimension. Measurements in the bunker for treatment plans delivered in 3D CRT, IMRT and VMAT were performed for the study.

Materials and methods. First and foremost, evaluation of the bunker shielding was performed using NCRP 151 formalism. In the second part, calculations of the use factor (U) were carried out for 30 radiation treatment planning (10 patients, each in 3D CRT, IMRT and VMAT techniques, therefore 30 plans delivered). Through Eclipse treatment planning system, the beam data was obtained from extracted RT images, exported to excel spreadsheets and data analysis performed in Matlab. Diagrams in rose plot of beam fields direction for each patient and each radiation treatment technique, graphs related to the workload in Monitor Units (MU) and in cGy were generated. Thirdly, the radiation treatments plans are delivered with TrueBeam LINAC. In this study, we compared VMAT treatments to IMRT treatments to estimating important parameters affecting shielding calculation such as the use factor, the modulation factor and field dimensions. Subsequently, we placed in the bunker the ambient dosimeters (TLDs) in different positions according to the shielding calculation on existing treatment room and established the correlation between modulation factor, treatment techniques and radiation shielding.

Results. Evaluation of the radiation shielding workload of the TrueBeam LINAC, using NCRP151 formalism is performed. The thicknesses calculated are then compared to existing ones. On the other side of the radiation treatment planning, the results were based on the workload for 30 radiation treatment plans in each treatment technique such 3D CRT, IMRT and VMAT used. After extracting data from DICOM-RT (RT plans) on the treatment plans including gantry direction (U) to deliver, the MATLAB tools was used and the resulting rose plot shows that the weekly workload in MU is less in VMAT than in IMRT. In VMAT, the workload in cGy is obtained by multiplying the effective fluence with the dose deposition matrix at each arc sector during the continuous gantry rotation. The modulation factor (MF) for each treatment technique was computed (1.8 for VMAT and 2.13 for IMRT). The dose in primary barrier is higher for IMRT than VMAT and the correlation established was approximatively equal to unity in respect to the secondary barriers and higher dose for IMRT for primary and secondary shielding.

Conclusion. VMAT technique has the advantage to reduce significantly the number of MU, the treatment time, VMAT treatment plans generally use less MU compared to IMRT and which result in decreased whole body scatter dose, allow for more patient throughput and require short times. The shielding can be therefore reduced if the radiotherapy facility is dedicated to VMAT since there is a very strong correlation between treatment techniques.

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ICTP & UniTS's Medical Physics Graduates (IUMPG)

INFORMATION FOR AUTHORS

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MEDICAL PHYSICS INTERNATIONAL Journal

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I. INTRODUCTION

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Author	12	Regular	After: 10
Authors' info	9	Regular	After: 20
Abstract	9	Bold	
Keywords	9	Bold	
Chapters			
Heading - 1st letter	12	Regular	Before: 20
Heading - other letters	8	Regular	After: 10
Subchapter heading	10	Italic	Before: 15, After:7,
Body text	10	Regular	First line left: 4mm
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Tables			
Caption, 1st letter	10	Regular	Before: 15
Caption – other letters	8	Regular	After: 5
Legend	8	Regular	
Column titles	8	Regular	
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MEDICAL PHYSICS INTERNATIONAL Journal

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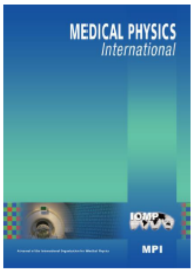

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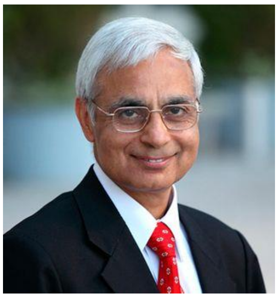

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ICMP2019 Presidential Message

Dear Readers,

We are delighted to bring to you the Book of Abstracts of the International Conference on Medical Physics (ICMP) held on 8-11 September 2019 at the Hotel InterContinental, Santiago, Chile. The conference was jointly organized by the International Organization for Medical Physics (IOMP), the Latin American Medical Physics Association (ALFIM) and the Chilean Medical Physics Society (SOFIMECH).

ICMP2019 is the 24th ICMP. The Latin American region had the pleasure of hosting 18th ICMP in 2011 in Porto Alegre, Brazil as also the World Congress on Medical Physics and Biomedical Engineering (WC1994) in 1994.

The conferences provide impetus to the development of medical physics and radiation safety in the region. Medical physics in Latin America has been developing steadily and there is a need to keep up with changing scenario that are happening all over the world in terms of newer technology being adopted some of them may help to strengthen the profession whereas others may pose threat. The abstract book shall give a window to the world as to where countries in the region stand in terms of academic pursuits and professional and scientific activities.

Santiago is not a typical Convention city and holding this event in Chile meant a huge challenge and a great responsibility for SOFIMECH. We are delighted that SOFIMECH took this challenge in the interest of professional development of colleagues in Latin American region to bring the latest knowledge in medical physics to a large number of professionals who otherwise would not have access to listening to so many experts directly and having the chance to interact informally.

The Scientific and Program Planning Committees headed by Geoffrey Ibbott and Maria-Ester Brandan have worked hard to create an excellent Scientific Program for ICMP 2019.

Happy reading and collectively we can make our profession strong and useful to the humankind.

Madan Rehani	Rodolfo Alfonso	Jose Luis Rodriguez
IOMP President	ALFIM President	SOFIMECH President

ICMP2019 Scientific Committee / Program Planning Committee Message

On behalf of the ICMP2019 Scientific Committee and Program Planning Committee, we are pleased to offer this program of invited and proffered talks and electronic posters. We are confident that you will agree that the program includes a wide variety of contemporary topics, presents numerous scientific accomplishments, and represents a range of regional and cultural perspectives.

We thank the members of the Scientific and Program Planning Committees who worked diligently to evaluate the nearly 400 abstracts that were submitted for the conference, and to sort the accepted abstracts into a coherent and meaningful program. We believe their efforts have resulted in a highly-organized program of exceptional quality, with easily-navigable tracks and sessions that will appeal to all attendees.

We were fortunate to be able to work closely with the members of the Conference Organizing Committee, who created a program structure that fit with past ICMPs and who undertook to contact many of the invited speakers. This program, like those in the past, is designed to entice international attendees, and at the same time, offer sessions designed specifically for local participants.

In particular, you will notice that every morning, there is at least one session in Spanish, with a mix of international and local speakers, and topics of special interest to Latin American physicists. In most afternoons, there will be four parallel tracks of proffered oral presentations, grouped without overlap so that most attendees should find talks of interest and relevance to their specialties. E-poster sessions are organized to minimize conflicts with the oral sessions, to allow participants to visit posters without having to miss oral presentations on related topics.

We are sure that you will enjoy this program and look forward to meeting many of you during the week.

María-Ester Brandan
Geoffrey S. Ibbott

ICMP 2019 / ALFIM 2019

PLENARY TALKS AND INVITED PAPERS

IOMP School, joint session with IAEA-PAHO-ISR: The role of medical physicists in justification in medical imaging

O. Holmberg (IAEA), A. Bouëtté (Luxembourg), D. Remedios (UK), P. Jiménez (PAHO), P. Soffia (ISR).

Over the past 20 years much successful work has been devoted to developing and consolidating approaches to optimization of radiation protection in diagnostic imaging. Less effort has been committed to justification of medical exposure, although authoritative sources suggest that a significant fraction (20-40 % in some areas) of radiological examinations may be inappropriate. While the main responsibilities rest with the radiological medical practitioner and the referring medical practitioner, other professional groups such as the medical physicists may have radiation protection competence and a key professional role that makes them vital for strengthening the implementation of the principle of justification of medical exposure in diagnostic imaging in their country. The workshop will aim to discuss the main facts and concepts regarding justification in imaging; practical measures that can be taken to strengthen the implementation of justification; and examples of implementation where medical physicists have played a key role.

The role of medical physicists in justification in medical imaging

Pablo Jimenez

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Applying the justification principle in medical imaging requires a special approach. It is generally accepted that the use of radiation in medicine produces more benefits than harm. However, it is necessary a generic justification of a given radiological procedure by the health authorities in conjunction with appropriate professional bodies. This generic justification must be appropriate to the local epidemiological situation, be based on the best available evidence, and consider aspects of cost effectiveness. It should be reviewed from time to time taking into account new knowledge and new technical developments as they evolve. Finally, the justification of a radiological procedure to a given individual should be carried out by the radiological medical practitioner, in consultation with the referring medical practitioner. This individual justification should consider objectives of the exposure, the clinical circumstances and the characteristics of the individual involved. Medical physicists have an advisory role in the justification mainly for the new procedures, and on the risk assessment of the procedures.

The role and relevance of virtual imaging trials in imaging research and practice

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The complexity of medical imaging technologies has continued to accelerate, outpacing our ability to optimize their design and clinical use. Given this rapid technological evolution with their multitudes of features and abilities, determining the optimal design and use of imaging technologies has proven to be a significant challenge across many and diverse objectives of scientific inquiry and clinical application. The evaluation of new imaging technologies and applications would ideally be achieved through clinical imaging trials. However, such trials are often not feasible or even definitive due to ethical limitations, expense, time-requirements, difficulty in accruing enough subjects, or the fundamental lack of ground truth. Meanwhile, assessment of imaging technologies currently relies on simplistic models and subjective perception of image aesthetics, the results from which cannot readily predict clinical utility, leaving the effectiveness of many imaging techniques tenuous at best.
Virtual imaging trials (VITs) offer a powerful solution to the above challenge, allowing scientists to conduct realistic and accurate "human" trials of emerging imaging concepts and technologies via simulation. With virtual trials, experiments are conducted quickly and cost effectively on a computer, giving researchers the ability to answer fundamental questions that can only be practically answered using the precise controls and known ground truth afforded in the virtual domain. In this presentation, we discuss the components and needs of VITs in terms of realistic modeling of a) the patient, b) the imaging system, and c) the image interpreter. We further discuss the needed realism of the simulations and offer demonstrations of select applications in CT imaging.

Precision Imaging Through Medical Physics

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Precision imaging involves targeting, delivery, and confidence that each imaging examination is precisely performed to provide maximum value to each patient. This requires proper quantification of quality, safely, and consistency of each exam, tracking them across the imaging practice, and taking proactive adjustments to the imaging processes to achieve *a priori* operational goals for each. These tasks are most in line with the expertise of medical physicists. Based on the foundations of medical physics, in this presentation, we offer a description of quantification approaches in image quality (eg, task-based performance, detectability, estimability), in safety (eg, effective dose, organ dose), and consistency. This follows with the methods to integrate quantifications into an informatics infrastructure to enable monitoring of the attributes, as well as strategies for establishing operational goals and conformance for each of the three goals. Demonstrations are offered for select applications in CT imaging and beyond.

Quantitative CT: The role and limitations of radiomics

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CT-based quantification is the extraction of quantitative measures from patient images. The measures, often terms radiomics, are in turn are related to patient outcomes. A strong relation enables predictive models. Ideally, the measures are rooted in the biology of the disease and thus their predictive power. However, a lack of direct correlation between the biology and the imagery has led to much ambiguity in the field of quantitative imaging. This presentation aims to clarify some of these ambiguities. For CT-based quantification to be most effective, radiomics quantification should meet four requirements: relevance, objectivity, robustness, and implementability. Relevance refers to measures of biological or clinical phenomena. Relevance can be assessed by studying how the quantification metrics correlate with clinical patient outcomes. Objectivity refers to the accuracy of quantifications in terms of ground truth. Robustness refers to the precision of the quantification. Objectivity and robustness can be assessed using phantoms and biological models to test how different feature extraction workflows lead to different biases and variabilities in the feature measurements. Finally, implementability speaks to the practicality of the use of the measures in a clinical environment and workflow. That includes provisions for automation and interfaces that are intuitive and efficient. CT-based quantification has the potential to improve consistency and quality of patient care if it is implemented using the principles of relevance, objectivity, robustness, and ability to be implemented.

Quantitative Ultrasound Imaging: How to do it

Ivan Miguel Rosado-Mendez

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This talk will review the physical principles and technical aspects of three Quantitative Ultrasound techniques aimed at reducing the well-known operator and system dependence of ultrasound imaging: Backscatter Ultrasound Spectroscopy (BUS), Speckle Statistics Analysis (SSA), and Shear Wave Viscoelasticity Analysis (SWVA). These techniques allow the extraction of quantitative imaging biomarkers (QIBs) that are surrogates of physical and structural properties of tissue from echo signals produced by clinical scanners. BUS allows quantification of the ultrasonic attenuation and backscatter coefficients. In particular, the backscatter coefficient can be used to extract information on structural properties of tissue below the resolution limit of the ultrasound system. SSA informs on the level of microstructural organization by fitting models to the histogram of ultrasonic echo-signal amplitudes. Lastly, SWVA provides elastic and viscous properties of tissue by analyzing the propagation of shear waves created with conventional ultrasound transducers. Special emphasis will be paid to the importance of assumptions about the structural and physical properties of tissue behind these techniques in the context of clinical applications.

Quantitative Ultrasound Imaging: Strengths, limitations and current applications

Ivan M. Rosado-Mendez[1,2], Hassan Rivaz[3], James A. Zagzebski[2], Chrysanthy Ikonomidou[4], Helen Feltovich[5], and Timothy Hall[2]

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Radiomics (the mining of large amounts of quantitative data from medical images to be used in clinical decision support) plays an important role in the development of personalized medicine. At the heart of Radiomics are Quantitative Imaging Biomarkers (QIBs), image features that can be obtained from medical images and that are surrogates of the morphological and physiological state of tissue. The wide-spread availability, safety and low cost of ultrasound imaging provide a great opportunity to expand the use of Radiomics, particularly in healthcare systems with limited resources. For this idea to succeed, the well-known system- and operator-dependence of ultrasound need to be reduced. This talk will cover applications in gynecology, obstetrics and perinatal care of Quantitative Ultrasound (QUS) imaging techniques that are being developed to provide QIBs with reduced system- and operator-dependence. Special emphasis will be put on the strengths and limitations of various QUS techniques, as well as on current challenges that need to be addressed to extend their translation to the clinic.

Improving patient radiation protection or evaluating risks in medical imaging: what matters most?

Cari Borrás, D.Sc.

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This presentation will define and discuss quantities and units used for radiation protection in the medical field and those acceptable for patient dosimetry, including risk assessment. Although effective dose is often used as a patient dose metric, the term was never meant to express risk, since it applies to a reference person -the w_R and w_T factors used in its computation were derived averaging age and gender from large populations. Risk can only be inferred by assessing organ doses. Current methods and uncertainties of organ dose determinations, such as exposing film, TLD or OSL dosimeters on the patient's skin; making ion-chamber measurements in/on patient-simulating phantoms; performing Monte Carlo computations modeling patient and radiation transport; and accessing electronic data calculated by the imaging system during a patient procedure, such as the Radiation Dose Structured Report (RDSR) and the Patient-RSDR DICOM standards, will be reviewed. On the other hand, if the goal is not to assess risk, but to reduce it, dose-related machine parameters such as incident or entrance air-kerma and kerma-area product for radiography/fluoroscopy and $CTDI_{vol}$ and DLP for CT, can be measured easily and compared against previously-established diagnostic reference levels (DRLs). Typical DRLs for adults and children will be presented.

Real-time dosimetry in Interventionism

John Willians

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While interventional therapies using fluoroscopy offer significant and well-documented benefits to patients, the exposure to radiation in the work environment can create major health risks. These risks exist for the whole care team: physicians and staff, which can include radiation-related illnesses and orthopedic issues. It is extremely important to understand and now "see" when radiation is emitted and know how to minimize or avoid exposure during a procedure.

Image Quality Improvement in Breast Tomosynthesis and Breast CT

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The main limitation of mammography, screen-film and digital, is its two-dimensional nature, resulting in tissue superimposition. This effect limits the sensitivity and specificity of mammography, especially in dense breasts. To overcome this issue, over the last two decades, and thanks to the introduction of flat panel digital detectors, two new imaging modalities have been introduced: digital breast tomosynthesis and dedicated breast CT. The former has already achieved widespread implementation, and has already taken over the diagnostic workload from mammography, and the screening workload in some countries. Breast CT, a more recent development, although now clinical commercial technology, is in a more exploratory phase, with its clinical impact still being evaluated. This session will review the physical and technological principles of both of these modalities, and the impact on image quality of the several parameters that affect them: acquisition technique and dose, hardware characteristics, reconstruction algorithms, and image post-processing. The current and future clinical impact of these modalities will also be discussed.

Personal dosimetry results on interventional radiology. Sapra Landauer Historical data from 2013 to 2017

Yvone M Mascarenhas, Ph.D.

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The use of X-rays in the operating rooms, hemodynamic and interventional procedures is of great benefit for patient recovery time lap, minimizing infection risks and allowing for better use of health service installations. There has been a significant increase in these procedures in the last ten years. This increase in the number of intervention procedures has led to an increase in the number of facilities for these procedures as well as the number of exposed persons. In this study we performed an analysis of the doses received by professionals in this area monitored by Sapra Landauer in the last 5 years. This study indicates the growth in the last five years in the radiation dose accumulated annually and a clear manifestation of inappropriate use of radiation monitors by these health professionals. Urgent actions in this area of X-ray application in interventional medicine in order to implant a radiological protection culture at this moment is crucial.

CT technology – and dose – in the 21st century

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Since its introduction in 1971, x-ray computed tomography (CT) has experienced many major advances in technology. The 20th century saw the introduction of spiral CT and multi-detector-row CT, making possible numerous new clinical applications, including imaging of the thorax in a single breath-hold and CT angiography. Since the dawn of the 21st century, cardiac CT has become a routine exam, and images of the entire heart can be acquired in just one heartbeat, lowering the effective dose from cardiac CT from ~15 mSv to less than 1 mSv. Dose optimization efforts, including tube current modulation, automated tube potential selection, and iterative reconstruction have reduced dose levels by almost a factor of 4 since the 1980s. Dual-energy CT is now in widespread clinical use, enabling the assessment of material composition and concentration, as well as a range of new clinical applications, and isotropic spatial resolution of 150 microns has also been demonstrated. All of these advances have increased the medical benefit and decreased the potential radiation risk associated with CT. However, care must be taken to ensure that doses are not lowered too much, to the point where the clinical value is compromised.

Imagenología Mamaria con Rayos X

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El cáncer de mama es el cáncer mas común en la mujer en el mundo. La introducción de cribado mamográfico ha tenido un importante impacto en la reducción de la mortalidad por cáncer de mama, pero este sigue resultando mundialmente en medio millón de muertes al año. En las ultimas dos décadas, sin embargo, el mundo clínico de la imagenologia mamaria con rayos x ha cambiado radicalmente. Hemos pasado de las mamografías con placas con tubos de molibdeno a la mamografía y tomosíntesis digital con tubos de tungsteno y nuevos filtros, y con la tomografía computada de mama asomando por el horizonte. En esta presentación haremos un raconto de la nueva tecnología, hoy y a futuro, presente en la imagenologia del cáncer de mama con rayos x, y su posible impacto en la física medica y en la radiología. Discutiremos sobre las bases físicas, los avances tecnológicos, los algoritmos de reconstrucción, procesamiento y análisis de imágenes, la percepción de imágenes por los radiólogos, y las consideraciones dosimétricas de las distintas modalidades.

Theoretical and practical workshop on Dosimetry of Small Static Fields in External Beam Radiotherapy - IAEA TRS 483

M. Saiful Huq

AAPM President-Elect and Chair of TG-100

Jan Seuntjens,

Unit Director Medical Physics *Unit, McGill University;*

Technological advances in the different radiotherapy modalities currently used have generated a considerable increase in the use of small photon fields. Different radiotherapy techniques, including Stereotactic Radiosurgery (SRS), Fractionated Stereotactic Radiotherapy (SRT), Stereotactic Body Radiotherapy (SBRT) and Intensity Modulated Radiotherapy (IMRT), are based on the conformations and calculations that integrate small field dosimetry. .

In addition to dedicated equipment for these types of treatment, like Tomotherapy, Ciberknife and Gammaknife, the use of non-dedicated conventional linear accelerators has highlighted the need to use a code of practice for dosimetry of small fields, thereby enabling increased accuracy in dose delivery to the patient.

Historically, in conventional radiotherapy dosimetry, agreements have been reached in the use of Codes of Practice such as IAEA TRS 398 (IAEA, Vienna, 2000), where reference dosimetry is based on a field size of 10cm x 10cm, but the difficulty in defining this geometry in some of the most specialized equipment has required to include different proposals in the development of this dosimetry.

The aim of this course is delivering theoretical and practical classes, to disseminate the clinical application of the new IAEA / AAPM CoP 438 Code of Practice for the calibration of small photon beams and train medical physicists in their implementation.

Emerging Techniques and New Protocols in Brachytherapy

Sergio Lozares Cordero, PhD.

Miguel Servet Hospital, Zaragoza, Spain

Santiago Pellejero, PhD.

Complejo Hospitalario de Navarra, Spain

Victor González Pérez, PhD.

Instituto Valenciano De Oncologia

In the workshop on Emerging Techniques and New Protocols in Brachytherapy, an overview will be given of the advances and new protocols in brachytherapy in which professionals from the Spanish Society of Medical Physics (SEFM) are involved. The different sessions will deal with following aspects of brachytherapy:

- New calculation algorithms in BT.
- Trends in prostate BT: focal therapies and alternative treatment techniques from the perspective of the medical physicist.
- Skin brachytherapy and dosimetry controversies.
- Electronic brachytherapy. Indications and results in gynecological and breast cancer.
- Accelerated partial breast irradiation in breast BT and very accelerated fractionations.
- Advances in gynecological BT.
- Presentation of the cervical gynaecological brachytherapy protocol of the SEFM and current state of EMBRACE project.
- Transfer of European and American treatment guidelines and protocols to the reality in Latin America.

Treatment planning of SRS and SBRT treatments

Daniel Venencia, Ph.D.

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A practical course on treatment planning techniques os SRS and SBRT treatments. Introduction to Physical aspects of SRS and SBRT treatments. SRS of multiple metastasis, Acoustic Neurinoma, Pituitary tumors. Patient specific QA on SBRT treatment. Practical sessions implemented on 10 treatment planning workstations with ELEMENTS Spine, Multiple Mts and Cranial SRS from BRAINLAB. Exercises on Image fusion, distortion correction, automatic organ segmentation, treatment volume delineation, PTV generation, treatment planning, and treatment plan evaluation.

Recent advances in image guidance for radiation therapy

Geoffrey S. Ibbott, Ph.D.

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The introduction of image guidance in radiation therapy has revolutionized the delivery of cancer treatment. Modern imaging systems can supplement and often replace the historical practice of relying on external landmarks and laser alignment systems. Rather than assuming a constant relationship between skin markings and internal anatomy, image-guided radiation therapy (IGRT) uses x-ray-based techniques such as computed tomography (CT), cone-beam CT, MV on-board imaging (OBI), kV OBI, as well as optical surface imaging, MRI, and PET. IGRT and its variants allow the patient to be positioned based on the internal anatomy. These advances in technology have enabled more accurate delivery of radiation doses to anatomically complex tumor volumes, while simultaneously sparing surrounding healthy tissues. While x-ray imaging modalities provide excellent bony anatomy image quality, magnetic resonance imaging (MRI) surpasses them in soft tissue image contrast for better visualization and tracking of soft tissue tumors with no additional radiation dose to the patient. However, the introduction of MRI into a radiotherapy facility carries with it a number of complications including the influence of the magnetic field on the dose deposition, as well as the affects it can have on dosimetry systems. Similarly, a novel PET-guided treatment system allows treatment guidance based on biology and physiology, but requires a small additional radiation dose. The development and introduction of these new IGRT techniques will be reviewed and the benefits and disadvantages of each will be described.

Advanced Imaging in Radiotherapy

J. Daniel Bourland, PhD

AAPM

Medical imaging contributes greatly and is invaluable for the radiotherapy processes of treatment planning and simulation, validation of treatment delivery, and assessment of treatment response. Such images contribute anatomical, biological and temporal information on the spatial extent and biological functionality of tumor and normal tissues, providing “a picture of the patient.” In particular, molecular and biological imaging have great potential and progress for showing the distribution of disease, it’s severity or grade, and local environmental conditions that may affect the outcome of treatment. Modalities with molecular or biological imaging capabilities include optical, ultrasound, radiologic, radionuclide and magnetic resonance techniques. These techniques typically require or may provide anatomical or structural information, as well. This presentation will review molecular imaging terminology, advanced and biological imaging modalities and techniques, including their physical and biological bases and relevance across spatial scale, and the applications of these images in radiotherapy planning and assessment of treatment response. Additionally, roles and challenges for the medical physicist in the use of advanced oncology images will be discussed.

Learning Objectives:

1. Understand the physical and biological bases of biological and molecular imaging.
2. Review imaging modalities used for biological and molecular imaging.
3. Review the spatial domains of anatomical and biological imaging.
4. Understand the current status and future directions of biological and molecular imaging in radiotherapy planning and assessment of treatment response.

Artificial/Augmented Intelligence Applications in Radiotherapy

Jatinder R Palta, PhD

AAPM

Despite many studies over the last three decades that have attempted to explicitly quantify the decision-making process for radiotherapy treatment planning and delivery, judgments of an individual radiation treatment's degree of quality are still largely subjective and can show inter- and intra-practitioner variability even if the clinical treatment goals are the same. Several factors conspire to confound the full quantification of radiation treatment quality, including uncertainties in dose response of cancerous and normal tissue, the rapid pace of new technology adoption, and the human component of treatment planning. However, the advent of artificial/augmented intelligence (AI) technologies in many fields such as computer vision, natural language processing, audio processing, and automobile auto piloting have opened the doors for its applications in radiotherapy. In radiotherapy, AI is likely to improve the treat outcome and reduce toxicity by providing more precise cancer detection, diagnosis, more personalized and precision treatment strategy, more accurate target delineation and organ segmentation, better, faster, and more precise treatment planning and delivery, and more convenient, frequent, and accurate patient follow up. AI may greatly improve patient safety by automatically detecting and preventing medical errors. This review discusses the potential impact of AI on four important aspects of radiation oncology; organ segmentation and target delineation, treatment planning, adaptive therapy, and response assessment.

Learning Objectives:

Understand the challenges associated with advanced radiotherapy planning and delivery techniques;

Understand the current status and future direction of AI research for radiotherapy planning, delivery and outcome assessment.

End-to-End Testing for Stereotactic Radiosurgery

F. Bregains

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The End-to-End test for Stereotactic Radiosurgery (SRS) consists of simulating a treatment technique from its beginning to the end. This simulation checks the process of the treatment while analyzing the accuracy of the delivery. In this presentation the StereoPHAN ™ Phantom will be discussed as a tool designed to perform End-to-End quality control of radiosurgery systems. Using a series of inserts, the StereoPHAN allows quality assurance of image fusion algorithms of CT and MRI modalities, as well as the possibility to use different tools for dose measurement, such as diode array, ionization chamber or radiochromic film. The experience of CEMENER Foundation using this tool on a TrueBeam® linac, with both cones and high definition multi-leaf collimators will be presented. All aspects of treatment are considered, including immobilization, simulation, planning and treatment delivery. In addition, a new detector array, SRS MapCHECK, will be introduced showing high resolution, accuracy and allowing real-time results to be shown quickly.

Patient-specific QA in stereotactic treatments

Tomas Spretz

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Eduardo Sabino

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SRS and SBRT is a technique that uses high doses of treatment in small volumes, demanding extreme accuracy and high dose gradients. For this reason, a Quality Assurance procedures are highly recommended for this type of technique. During this session we will discuss aspects of ICRU 91, TG 101 and TG-218 protocols presenting an analysis of uncertainty during each stage of treatment, guidelines according to the implemented techniques and the current tools to perform quality assurance. We will present experiences with multiple solutions for Patient Specific QA in SRS, such as Gafchromic EBT3 film, Portal Dosimetry, SRS MapCHECK and point measurements with detectors, comparing the performance of each in different clinical cases. Additionally, an integrated and automated platform, SunCHECK ™, will be presented to improve the routine quality assurance of patient and machine quality management. Also, we will discuss the workflow for Patient Specific Quality Assurance from Secondary Dose Calculation algorithms, using ArcCHECK or EPID (phantom-less), to in-vivo transit dosimetry of each fraction of treatment.

Pilot testing of the CoP TRS-483: Results of an IAEA CRP

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The IAEA has organized a Coordinated Research Project (CRP E2.40.21) in order to test the practical implementation of the small field Code of Practice TRS-483, by clinical medical physicists from Member States (MS) and identify potential challenges. Through this CRP, the participating MSs developed and implemented a state of the art research in the field of small field dosimetry. The preliminary results on application of the TRS-483 recommendations with different treatment machines, detectors and phantom media from the participating MSs are presented and discussed.

Automated planning and Artificial Intelligence

Laurence E. Court, PhD

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Carlos E. Cardenas, PhD

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The field of artificial intelligence has been a driving force in automation across a breadth of disciplines including health care. In radiation oncology, we have seen very rapid and promising work focused on automated segmentation, treatment planning, quality assurance, and numerous other areas. To continue fostering these advances, it is critical to understand the basic principles behind these artificial intelligence techniques. This will lead to successful implementation and clinical deployment of these novel tools. In this session, we will introduce basic artificial intelligence concepts, demonstrate current topics of artificial intelligence research for radiotherapy treatment planning, and introduce the Radiation Planning Assistant which is being developed to bring high quality radiotherapy planning to clinics with limited resources.

Updates on nonstandard beam dosimetry

Jan Seuntjens, Ph.D.

Professor & Director, Medical Physics Unit, Gerald Bronfman Department of Oncology, McGill University

Modern external photon beam radiation therapy for several sites is often delivered by using high radiation doses in few fractions using robotic machines that deliver these treatments using small fields or composites of small fields. The calibration of these machines often cannot be done using conventional dosimetry protocols, since standard reference conditions typically cannot be realized. Recently, IAEA-AAPM Report TRS-483 was published and provides guidelines to calibrate these nonstandard reference fields and also provides guidance on the measurement of output factors in small fields. The goal of this presentation is to provide a review of the TRS-483 protocol with emphasis on new elements that have come up since its publication in terms of data, detectors and application limitations. In the presentation we will discuss (1) limitations of machine-specific clinical reference dosimetry; (2) update on detectors for output factors in small and composite fields and (3) updates on standards for nonstandard beams.

Independent Patient QA verification of Advanced Treatment Techniques

Jan Würfel, PhD.

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In this presentation, we will introduce the concepts of calculation-based and measurement-based patient QA and then go deeper into patient QA employing array dosemeters within a phantom. This will cover the algorithms of the PTW OCTAVIUS 4D and DVH 4D system, gamma pass rates and their parameters, the differences between global and local percent values and how much all this depends on the specific array in use. At the end of the session, the presented features will be demonstrated in a software demo using PTW DIAMOND and PTW VeriSoft.

Detector Physics for Modern Linac Modalities

Jan Würfel, PhD.

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The lecture will begin with a quick introduction of the most important small field dosimetry aspects and then move on to the basic physical properties of dosimetry detectors. The different types of detectors on the market will be thoroughly discussed and some examples will be given where the detector properties enter into every-day and small field measurements. The small field part finishes with some information on TRS483 correction factors. Then, the focus will move on to an introduction to FFF linac physics and dose rate dependence with a focus on the practical application of the presented information. The electrometer is an important part of the dosimetry signal chain. The lecture will finish with a roundup of electrometers and their properties.

SHORT COURSE ON "MONTE CARLO BASED VERIFICATION OF COMPLEX TREATMENT PLANS: THE PRIMO PLATFORM".

Miguel Rodriguez, PhD

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A two hours course on the PRIMO system will be lectured. The course will focus on the use of the PRIMO system for radiotherapy treatment verification. PRIMO is a software solution for the Monte Carlo simulation of beams of linear accelerators and the estimation of the absorbed dose. PRIMO simulates the radiation transport through the whole linac head and multi-layered phantoms or patient CT using the general-purpose Monte Carlo code PENELOPE 2011 or a parallel version of the fast-Monte Carlo code DPM. The system supports a wide range of Varian linacs. The linac geometries are part of the package; therefore, the user is not required to enter any geometrical information. PRIMO can produce PSFs at the downstream end of the upper parts of the linac and can import external PSFs, provided they are compliant with the IAEA specification. To reduce simulation time, the code incorporates a number of specifically developed variance-reduction techniques. Additionally, the simulation can be distributed among the cores in a computer. The system can import CT volumes, structures and treatment plans in DICOM format and is able to estimate the dose distribution for dynamic treatment plans. PRIMO operates in interactive mode as well as in macro-mode; the later uses a command interpreter to automatically execute configuration, simulation and data processing operations and enables the incorporation of PRIMO as calculation tool in a treatment verification platform. The system is freely distributed in the site http://www.primoproject.net.
The topics addressed in the lecture will be the following:
- The Monte Carlo method for radiation transport. Generalities.
- Introduction to the Monte Carlo codes PENELOPE and DPM.
- PRIMO architecture
- PRIMO operations
- Radiotherapy plan and treatment verification with PRIMO.

What Physics says about Co-60 source for HDR brachytherapy

Daniel Rodríguez Latorre, Ph.D.

Medical Physicist, Hospital Universitario Central de Asturias, Oviedo, Spain

The lecture is on past and present of Co-60 brachytherapy sources; Ir-192 vs Co-60: half time, energy, absorption coefficients, TG-43 parameters, integral dose, shielding.

Co-60 HDR brachytherapy source in the clinic

Daniel Rodríguez Latorre, Ph.D.

Medical Physicist, Hospital Universitario Central de Asturias, Oviedo, Spain

The lecture is on quality assurance issues with Co-60 HDR brachytherapy sources, source changes, traceability; applicators: is there differences in applicators between Co-60 and Ir-192?; TG-43 accuracy for Co-60 dose calculation in different body sites.

Out-of-field doses and secondary cancer risks estimations in modern Radiotherapy

Beatriz Sánchez-Nieto, PhD.

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In recent years, radiotherapy (RT) has undergone considerable development that has had a positive impact on the survival rate after a cancer diagnosis. This has increased interest in the possible risk of induction of second primary cancers with a late onset of at least five years. The induction of a second cancer is associated with the inevitable exposure to radiation of organs or tissues outside the treatment field.

The difficulties in the calculation of peripheral doses have hindered reasonable estimations of second cancer risks (LNT models and parameters –e.g. in BEIR VII- were available more than a decade ago). Regardless of the type of radiotherapy being used, out-of-field doses delivered by photons (commertial treatment planning systems can only provide accurate photon dosimetrical information within the 5% isodose), electrons, protons, or neutrons pose unique challenges to medical physicists (AAPM TG 158). This talk focuses on the challenges associated to nontarget radiation dosimetry by photon and neutron and provides solutions on on how to best determine the out-of-field doses associated with individual photon RT plans. Then, a methodology to estimate the risk of second cancers based on the the best source of dosimetrical information available for individual plans will be presented and discussed in the light of the findings of epidemiological studies.

The potential impact of convergent X-rays beams: High performance radiotherapy by CONVERAY & integral theranostics by OSIRIS

Rodolfo Figueroa Saavedra, PhD

Universidad de La Frontera (UFRO), Temuco, Chile

The state of progress, characteristics and impact of two technologies under development at UFRO are shown. These innovations will be known as CONVERAY (Convergent Ray) and OSIRIS (Integral System of Orthovoltage Source Induced Radiation).
CONVERAY is an experimental convergent beam device adaptable to a LINAC, with dual output of electrons or photons and will allow the future CBRT (convergent beam radiotherapy) technique. CBRT therapy is characterized by presenting a peak of relative high intensity dose, similar to that shown by a hadrontherapy device. However in this case, it is with photons or electrons that can focus on the area of the tumor. This technique will improve effectiveness in the irradiated area, reduce side effects and treat hard-to-reach tumors. To achieve its current state, the development of CONVERAY has carried out several projects. The global project takes about nine years and a device is expected to be started in the clinical phase within two years.
On the other hand, OSIRIS is a device in the development stage of prototype for the detection of tumors, functional images and simultaneous radiation therapy in a single device at orthovoltage energy level. This device will operate on the basis of a large confocal array (~103 cc) and secondary radiation induced in metal nanoparticles (Au, Gd) used as biomarkers. Secondary radiation is composed of: photoelectrons, Auger electrons and high energy characteristics X-ray, XRF from K edge in heavy metal. These nanoparticles will be previously injected into the patient and are stick to the tumor as a bio-targeting agent, allowing its detection and guided radiation therapy in real time and also improves contrast and dose. The studies we have done show that confocal geometry allows the application of convergent beams in the orthovoltage energy range (CONVERAY Low). The focuses the radiation on the bio marked point and appropriate arrangement of solid state CdTe detectors or scintillators or both, make it possible to detect deep neoplastic tissue and simultanealy generated electrons in the focal spot zone impart dose. Making a 3D scan of the focal spot of the radiation in on the tumor zone it is possible to obtain a functional image of the bio marked volume. An increase in the intensity of the tube current can make a second accurate sweep through the effectively marked area. It will also be possible to include a second converging beam of higher power and slightly offset (ms) of the first and guided by it. A highly accurate treatment scan will not require immobilization of the patient.
In summary, these technologies based on a convergent beam will allow to make CBRT in conventional tele-therapy equipment with CONVERAY technology and also more the future, more precise and economical effective theranostics processes (OSIRIS) could be carried.

Advances in Nuclear Medicine Physics

Sergio L. Mosconi

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Quantitative harmonization in PET: current status and new developments: Measurements derived from PET scans are usually non comparable accross different scanner models and/or reconstruction settings. In this talk, the major aspects affecting quantification of PET images will be discussed as well as current harmonization approaches.

Protocol optimization in PET: Acquisition factors affecting image quality will be discussed . Current and state-of-the-art strategies for injected dose and acquisition time adaptation will be introduced.

Quantification in SPECT/CT: The main requirements for converting a conventional SPECT/CT system into a quantitative device will be discussed, with emphasis on attenuation and scatter correction and absolute system calibration.

Methodological Aspects for in vivo activity quantification and dose assessments during the RT.

Leonel Torres, PhD.

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Formalisms for absorbed dose estimations at cellular, organ and voxel levels will be presented and discussed. It will include the procedures for in vivo activity quantification and patient specific methods for dose calculations. Dosimetry formalisms such as the MIRD methodologies, Monte Carlo techniques, local deposition approaches, etc. will be presented enhancing their main features and their requirements for practical use; their strengths and limitations will be also highlighted. The available methods for in vivo activity quantification will be discussed considering correction of the main physical factors affecting the quantification accuracy such as attenuation, scatter, partial volume effect, background, etc. Finally, well-known and new tools for activity quantification will be analyzed.

Clinical Dosimetry in the therapy of malignant and benign diseases.

Marco A. Coca, MSc.

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Specific procedures for Internal dose estimations will be shown emphasizing on the dosimetry calculations of current clinical procedures for cancer treatment using radionuclide therapies. It will include dose estimations methods during the therapy of HCC with labeled spheres SIRTEX, NET with 177lu-peptides, thyroid diseases treatments, etc.

Image-based radiobiological dosimetry.

Carlos Calderon, MSc.

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The radiobiology aspects and mechanisms of actions involved on the cancer therapy-using beta and alpha emitters will be presented. The contribution of radiobiological parameters to the response and radiotoxicity prediction after the radionuclide therapy of malignant diseases will be evaluated using a comprehensive approach. Basis for personalized biological treatment planning in radiopharmaceutical therapy, as well as, the combination with external beam radiotherapy or different radionuclides based on iso-effective relationships will be discussed.

The Challenges Professional in the Radiation Protection of the Patients

Carlos E. de Almeida Ph.D. FAAPM. FIOMP

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The continuous increase of the use of ionizing radiation sources for diagnosis and treatment has been substantial in last decades. There is no doubt that and effective benefit to the patient is a reality, but in some cases the family doctor may request a disproportionate number of exams or the exam is repeated due to lack of appropriate QA. As result, the radiation dose that some patients are submitted may turn out not having a positive net benefit. The whole process we all know is very complex, as it enroll several factors such as, the clinical indication, human errors, management, education, QA programs, regulations and the technology available.

In addition, even more important is to promote the user understand of the source of the data (UNSCEAR) that allow the periodical update of the recommendations made the international bodies i.e. ICRP and IAEA. Unfortunately, the documents in most cases are just translated without a thorough discussion among the local scientific community, the regulatory agencies and the final users.

Those challenges must be faced, discussed and be part of the educational curriculum of each professional working in the area and the professional societies as well as the regulatory agencies must play a considerable role to promote that. This paper expects to address those issues mainly for our reflection.

Workshop on optimization of safety in modern radiotherapy

Antonio Torres, PhD.

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Radiotherapy practices move towards the application of increasingly sophisticated techniques, from the hardware and software point of view, such as IMRT itself, which would mean the reduction of human errors and the doses applied to patients during treatments. However, when it seems that in some stages human participation decreases, just to mention two examples: the quality controls are increased, as well as the maintenance actions of the equipment. Thus, the necessary monitoring of possible human errors becomes more important, which is associated with the development and application of the study of risks in these practices. The workshop provides for the active involvement of participants through discussion of their own cases with a focus on risk modeling. The workshop includes three work sessions during which training and exchange will be achieved through a focus on problems for teaching-learning.

Radiation Protection of Patients in the Latin American and the Caribbean Region

Pablo Jimenez

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The continuous introduction of technologies that use ionizing radiation in the health sector is producing substantial benefits for public health. Latin American and the Caribbean Region is benefiting to some extent from these advances. Demand for radiological services is increasing in the Region due to the surge in illness, new clinical applications, and broader societal trends. This is stimulated by the increase in population and specifically aging population, lifestyle changes, and increase in healthcare programs and reforms towards Universal Health. However, these procedures may be dangerous to patients. At the facilities level, quality assurance programs designed to obtain accurate diagnoses or efficient therapies, and to ensue radiation protection of patients are more necessary than ever. The existence of well-trained professionals is essential for achieving the main clinical objective. At the governmental level, there are still challenges to establish appropriate and sustainable national regulatory infrastructures. In many countries their technical capacity and resources are still too limited to satisfactorily carry out the functions established in the BSS, while in others there are non-existent. PAHO has been advising governments and providing technical cooperation for many years in this field.

Radiation Protection Symposium: Analysis and Evaluation of Radiology Facilities in preparation for IAEA Audits

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Radiology environments must meet a series of requirements that guarantee the safety of occupational workers and the public. For this, knowledge of the type of radiation, the equipment to be installed, as well as its characteristics (maximum value of kV and mA), the estimation of the number of studies and the description of the continuous areas to the environment in question is essential ; with which the physicists in charge of fulfilling the function of radiological safety officer of a health center, must handle not only the technical documents related to the calculation of the protection and the radiometric survey, but also must analyze the workflow of the workers, patients and the public, in order to ensure that estimates, shielding and verification measures go hand in hand, optimizing the resources of the institution and ensuring the safety of all.

Radiation effects in the uterus, the embryo/fetus and children

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The course will review stochastic and deterministic radiation effects on the uterus prior and after conception. The effects of in utero radiation should not be confused with the heritable effects that can be manifested by irradiating germ cells (ovules or sperm cells) before conception, which are always stochastic. Irradiation of somatic cells of the embryo/fetus can cause: embryonic death, which can happen in the period of pre-implantation at doses above 100 mGy; malformations, which can occur during organogenesis with a threshold dose of 300 mGy, and severe mental retardation (decrease of 30 IQ), which can appear 8-15 weeks after conception with a threshold of 500 mGy. It is important to note that the spontaneous incidence of these effects is, respectively, 1 in 17, 1 in 200 and 1 in 1,000 unirradiated embryos or fetuses. Epidemiological data from large in utero exposed cohorts in Hiroshima and Nagasaki, Chernobyl and the Southern Urals (Mayak Plant and Techa River) will be presented. Epidemiological studies on radiation effects on children, highlighting their different tissue radiosensitivities, will also be examined. The impact of these findings on therapeutic and diagnostic radiology procedures will be explored.

Education & Training in Medical Physics. From academic training to recognition

Pablo Jimenez

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Medical physicists have been working in the health sector for many decades, however both proper training and recognition are still major challenges worldwide. The International Basic Safety Standards (BSS) require that medical physicists have education and training in the concepts and techniques of applying physics in medicine, and that are competent to practice independently in one or more of the subfields (specialties) of medical physics. Additionally, medical physicists should be recognized as health professionals. Only national health authorities are able to include medical physicists in the cadre of health professionals. Therefore, additional efforts from the professional societies and from intergovernmental organizations such as PAHO and WHO should continue in order to achieve the deserved recognition.

IAEA guidelines for postgraduate medical physics academic education

Giorgia Loreti

Training Officer (Medical Physics), International Atomic Energy Agency (IAEA), Vienna

The IAEA guidelines, published in 2013 and endorsed by the International Organization for Medical Physics (IOMP), provide recommendations for the establishment of a postgraduate academic education programme in medical physics. Concurrently, they highlight the importance of a postgraduate-level degree in medical physics to underpin the subsequent clinical training providing the competencies needed to work in a clinical setting. The postgraduate-level academic education and related knowledge also play a key role in contributing to the recognition of medical physicists, placing them at the same level as other medical professionals with whom they collaborate in their daily clinical work. Despite its inclusion among the healthcare professions by the International Labour Organization, the medical physics profession has yet to be recognized worldwide. The IAEA is committed to addressing this lack of recognition, as it often undermines the impact of the contribution of clinical medical physics professionals to safe, quality and effective patient care.

Practical Experience with Training in Low-to-Middle Income Countries

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New generations of medical physicists, particularly in low- and middle-income countries, face the challenge of decreasing access to resources for research and training. However, the increasing availability of virtual communication and learning tools offers new opportunities to bring students, scientists and clinical medical physicists closer to new advances in the application of physics to diagnostics and therapy. This talk will present some ongoing efforts aimed at using free virtual communication resources to improve access to Medical Physics training in Latin America, with special focus on the International Academic Virtual Exchange (IAVE) Network. IAVE is a collective of students, academic and clinical medical physicists with the mission of promoting a culture of collaborative research and mentorship among students from different international institutions using virtual platforms. A summary of the achievements and challenges of the first two years of activities will be presented.

A hands-on introduction to deep learning for medical physics.

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Background: The application of machine learning to medical physics has created tremendous excitements with research that encompass: quality assurance1-3, outcome prediction4, 5, segmentation and image registration 6 or dosimetric prediction 7. Within machine learning algorithms, deep learning techniques in particular seem to motivate big part of the hype due to successes in other industries. The popularity of deep learning algorithms started in 2012 when Krizhevsky et al won the 2012 ImageNet Large-Scale Visual Recognition Challenge (ILSVRC) by more than 11 percent compare to the next competitor using a Convolutional Neural Network (CNN)8. Convolutional Neural Networks were not new but access to a big annotated dataset (1.2 million images), new regularization techniques called dropout, techniques to generate more training examples by transforming the existing ones (data augmentation) and computational power made this achievement possible. Soon, other applications followed with similar results (e.g. machine translation). Medical Physics has not been oblivious to this excitement and many applications of deep learning algorithms can be found in the literature.
Session description: Deep learning is the state-of-the-art machine learning technique in object recognition, image segmentation, speech recognition, and machine translation. Deep learning is also the best tool for medical image analysis. PyTorch is an open source deep learning library developed by Facebook AI. This course is a hands-on introduction to deep learning and its application to medical physics. You will learn model building for image analysis using PyTorch. Additionally, you will learn direct application of these models to medical physics which goes from predicting patient specific quality assurance metrics to predicting 3D dose distributions. The future of Deep Learning in Medical Physics will be discussed at length.
Outline:
1) Introduction to deep learning with PyTorch. (1 hr)
2) Applications of deep learning to medical physics. (45 mins)
3) Hands-on image analysis pipeline with PyTorch. (1hr 15 mins)
Prerequisites: The examples will run in Python, so knowing the basics of Python syntax is recommended. Bring a computer with Anaconda (Python 3) and PyTorch installed.

X-Ray Based Breast Imaging

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Breast cancer is the most common type of cancer in women worldwide. The introduction of mammographic screening has had a substantial impact on breast cancer mortality, but breast cancer continues to cause half a million deaths a year. In the last two decades, there have been important changes in the realm of x-ray based breast imaging. We have moved from screen-film mammography with molybdenum-anode x-ray tubes to digital mammography and breast tomosynthesis with tungsten targets and new filters, and with dedicated breast computed tomography being recently introduced and its impact in the clinic approaching. The current and future technology involved in x-ray based breast cancer imaging, and their possible impact on medical physics and radiology will be reviewed. The physical and technological basis for these advances, and their dosimetric aspects will be discussed.

Results of IAEA survey on clinical training in the LAC Region - part of the regional workshop on new approaches for clinical medical physics.

Giorgia Loreti

Training Officer (Medical Physics), International Atomic Energy Agency (IAEA), Vienna

According to IAEA guidelines Roles and Responsibilities, and Education and Training Requirements for Clinically Qualified Medical Physicists, published in 2013 and endorsed by International Organization for Medical Physics (IOMP) and the American Association of Physicists in Medicine (AAPM), structured clinical training is essential to achieving the competencies required to work independently in a clinical setting as a medical physicist. In early 2019, a survey was circulated by the IAEA in the Latin America and Caribbean region with the aim of collecting information on the ongoing clinical training in the three medical physics sub-specialties. The good response rate to the survey, together with the information received, helped provide an overview of clinical training in the region. Audience interaction and discussion will be encouraged, with the aim of sharing information on this important topic.

The Professional Master Degree on Medical Physics in Brazil, a Novel Experience

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A Medical Physics Master's degree program in progress is a joint effort of the Cancer Foundation and the State University of Rio de Janeiro as part of the National Education Program in Radiotherapy. The purpose of this program is to train, qualify and update professionals, linked to public, philanthropic or private health therapy centers that treat patients from the Brazilian Health Care System (SUS). This program aims to train 20 medical physicists to work in Radiotherapy during the period 24 months ending in June 2018. It is intended to help to minimize the present gap of qualified medical physicists in Brazil enhanced by installation of 80 new Linac's within the next 2 years. The total workload of the Master of 5410 hours divided in 610 hours of theory and lab work plus 4800 hours of clinical experience plus clinical research project. Each student was awarded a fellowship, and received a laptop with a treatment planning system installed, internet access to the bibliography, lectures and the clinical cases. This innovative paperless Project allows an effective interaction among the students, professors and the coordination team. All lectures, exams, lab reports and home works are loaded into the managing platform developed in-house, called Tandle (Teach and Learning) to be made available to other training programs in the Latin America region. For the clinical training the students are distributed in 15 different carefully selected institutions under the supervision o of Board Certified Medical Physicist.

This project was financed by the Ministry of Health –PRONON

Clinical Training in Medical Physics as per IAEA Guidelines and Relevant Activities

Giorgia Loreti

Training Officer (Medical Physics), International Atomic Energy Agency (IAEA), Vienna

In pursuit of supporting safe, quality and effective diagnosis and treatment of patients, the IAEA is committed to help Member States enhance their healthcare services through the contribution of competent and well-trained health professionals. Consequently, the IAEA developed specific documents to provide guidance on structured and supervised clinical training to medical physicists, with the aim of equipping them with the competencies needed to work in a clinical setting. The best practices contained in IAEA guidelines will be presented, exploring pathways toward their sustainable implementation in the region, for example considering harmonization through regional or sub-regional approaches. The IAEA encourages regional ownership and strategic planning to enhance sustainable approaches to clinical medical physics competency building, as done for example in the Asia and Pacific and Africa regions. The workshop aims at encouraging the exchange of opinions among participants, with a view toward addressing the specific regional challenges of the medical physics profession.

Current Issues regarding Artificial Intelligence in Cancer Care. Implications for Medical Physicists and Biomedical Engineers.

Eva Bezak[1,2], Loredana Marcu[1,3] and Chris Boyd[1,4]

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The development of Artificial Intelligence (AI) in health has been a long road with many significant obstacles that at the same time present opportunities for Biomedical Engineers and Medical Physicists to assume leadership roles in development and implementation of AI and data mining in health. IOMP, IFMBE and IUPESM must take initiative in addressing the current challenges in AI and big data science, including:

A) Big data collection. Large data set acquisition is needed across all areas (clinical, treatment, imaging, biological/genetic, etc.), requiring multi-institutional and multinational collaboration.

B) Registries. Development of national and international registries is a must for big data collection.

C) Data Privacy while performing Data Sharing (potential obstructions to data sharing owing to patient privacy protection).

D) Data Input and Standardization of Reporting. There is need to standardize data reporting.

E) Image variability. Differences in quality and interpretation of images.

F) What knowledge/data should be recorded and used. The volume and variability of data mean that it is hard to translate them into knowledge and leverage that knowledge to guide clinical decisions.

G) Algorithms. A diagnosis can only be expected to have as much accuracy as the information on which it is based.

H) How can we use these models in a strategically optimal manner to adapt a patient’s treatment protocol?

I) Implementation, validation, and quality assurance.

J) Rapidly growing volumes of data to be stored and processed (IT infrastructure and data storage).

K) Ethical consideration – e.g. the bearing of responsibility in case of misdiagnosis done by an AI system.

L) Many others.

The IMPCB certification process

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This lecture will be given in Spanish (slides in English). The International Medical Physics Certification Board, IMPCB, was formed on year 2010 with the purpose to support the practice of medical physics through an individual certification program in accordance with IOMP (International Organization for Medical Physics) guidelines. Among IMPCB objectives are to establish requirements and procedures for the accreditation of medical physics certification programs, to establish the examination procedures for the certification of medical physicists, and to provide guidance to medical physics organizations for the establishment of national medical physics certification boards and to conduct board examinations for physicists in countries which have not yet established certification boards. This lecture will present an overview of IMPCB and the model for its Medical Physics Certification Process.

IOMP School, joint session with IAEA-PAHO-ISR: The role of medical physicists in justification in medical imaging.

Ola Holmberg

IAEA

Over the last decades, there has been much progress in the area of optimization, but progress in the area of justification has been progressing more slowly. Authoritative sources suggest that a substantial fraction of radiological examinations may be inappropriate, from 20% to 50% in some areas. Key practical issues to the effective implementation of justification are first, the means of ensuring that those referred for radiological examinations really need them, second, auditing of the effectiveness of referrals and related processes and third, effectively communicating radiation risks to the relevant persons involved.

The International Atomic Energy Agency, in cooperation with the World Health Organization, has over a number of years been systematically addressing the strengthening of justification of medical exposure in diagnostic imaging. Outcomes of this work has been *e.g.* the AAA Campaign which advocates actions to take in relation to Awareness, Appropriateness and Audit; the highlighting of the justification issue within the Bonn Call for Action; and the series of technical meetings and scientific articles on clinical imaging guidelines, guiding health professionals, mainly radiologists and referring physicians, as well as regulators. These approaches will be discussed, together with what the role of a medical physicist can be in this context.

From academic training to recognition

Renato Padovani,

ICTP, Italy

Recognition of clinical medical physicist profession is a constant issue in all countries and, in particular, in countries where medical physics programmes are not present or where medical physics is not a developed profession. International and national MP societies have and are working to develop strategies to give to the clinical medical physicists the necessary knowledge and competences, the certification of the individual competences and the formal recognition.

Which are the keys for a successful strategy? Primarily a solid and high-level academic education. Due to the increasing complexity of medical practices, a Master in medical physics is a prerequisite. Organisations, like IOMP, IAEA, EFOMP, AAPM, are requesting this level of education and are providing recommendations and syllabi. Then a supervised structured clinical training of at least 2-4 years is also requested.

Medical physics organisation should work to establish this type of education and training programmes. This level of education and training, similar to that of medical specialist, will give a different reputation to the MP inside the health service. Another not trivial aspect, with this level of E&T the contract and the salary can be expected to be similar to the medical specialist.

Regional or international accreditation of the E&T programme (e.g. by IOMP and IMPCB) can help national societies to harmonise programmes and this is another step to reach recognition.

Due to the rapid changes of clinical practices and technologies, a continuous professional development programme (CPD) is another mandatory step. If CPD is not required by national rules, MP societies should develop and maintain a CPD programme.

All these steps, assuring the delivery of a high quality health service, will facilitate the recognition of the profession and, finally, the recognition of our MP colleagues as high level and necessary professionals in the health services.

New approaches for Clinical Training of Medical Physicists in Latin America and the Caribbean

Renato Padovani

ICTP, Italy

At the Master after master of medical physics, jointly organised by ICTP and the Trieste University and supported by IAEA, we had up-to-now 21 students from Latin America and Caribbean. For the development of medical physics In the region, our graduates can be seen as new resources for their international experience and the year spent in an advanced medical physics department in Italy. Many of them have reached a good level of competences, mainly in radiation therapy, to act as teachers and trainers of medical physicists.

Concerning the small countries in the region, a critical mass for the development of MP can be reached, in my opinion, only through collaborations and integration of programmes for nearby countries. ALFIM should support these actions with a strategic plan that provides expertise, harmonisation and accreditation of programmes, CPD resources, and government contacts. IAEA supporting programmes should integrate and support such a strategic plan.

In an education and training programme, the clinical training part is probably the most difficult task to achieve. Accredited training centres with a number of senior medical physicists and up-to-date technologies should be identified over the network of countries. However, the network of training centres should be supervised, audited and coordinated at the regional level, e.g. throughout ALFIM or an ad-hoc institution. Do not forget that the training can take advantage of distance learning platforms and mentors, but only a extended period of supervised clinical training in a training centre can provide the necessary skills and competences that can be acquired solving the daily problems and with the inter-professional interactions.

First Tomotherapy System in Argentina: experience of its clinical commissioning and the impact of placing it far from large cities.

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The arrival of Tomotherapy System at Argentina occurred in a small town in the interior of the country. How is it done to take advantage of the potential of this technology in a small city far from big urban centers? The challenge was not easy; however, the hiring of experienced personnel and acquisition of high-quality QA devices allowed the institution to perform the 2-3 first months operation successful and safe. Commissioning new kind of advanced technology equipment is a complex issue, not only for the users (MP, MD, RTTs, including administrative staff), but also for the authorities because it requires to incorporate new concepts as well as updating traditional knowledge.

ICMP 2019 / ALFIM 2019

ORAL PRESENTATIONS

O-1

MEASUREMENT OF DOSE TO THE LENS OF THE EYE DURING FLUOROSCOPIC IMAGE GUIDANCE OF INTRA-ARTERIAL CHEMOTHERAPY

Leonardo Vieira Travassos[1], **Rafael Figueiredo Pohlmann Simões[1]**, Cláudia Lúcia De Pinho Maurício[2], Alfredo Viamonte Marin[1], Kelma Macedo Pohlmann Simões[3]

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[2]Instituto de Radioproteção e Dosimetria
[3]Instituto Brasileiro de Oftalmologia

Diagnostic and Interventional Radiology – General

Objective: This work aims to estimate, under simulation conditions, the absorbed doses of radiation received by the patient lens during treatments of retinoblastoma by intra-arterial chemotherapy (TRIC) using optically stimulated luminescent (OSL) detectors placed on the ocular region surface (ORS) of an anthropomorphic phantom of head and neck.

Methods: The absorbed doses were measured with a set of four OSL detectors placed on both left and right ORS of the phantom. All irradiations were done using the same Philips Allura Xper FD20 angiograph, following the same protocols used in the TRIC. Three consecutive irradiations were performed for five different fluoroscopy times (5, 10, 15, 20 and 25 min) and two source positions, right (+90°) and left (-90°), totaling six irradiations for each interval of time. The detectors were calibrated in an ISO W 80 x-ray beam from the Brazilian National Metrology Laboratory in order to ensure the traceability.

Results: The absorbed doses in the ORS increase linearly to the irradiation time. According to literature data, the threshold recommended to ensure that there are no late effects on the lens, such as cataracts, is ideally up to 100 mGy and, certainly, less than 500 mGy. The ORS adjacent to the source accumulates a dose around five times greater than in the opposite ORS. The irradiation time threshold on the eye adjacent to the source that would guarantee doses absorbed in the ORS up to 100 mGy would be 35 min and 162 min for opposite eye for the set and beam characteristics considered at this work.

Conclusion: The adoption of time control and the possibility of calculating the time alternation of the position of the source present themselves as determinants for the optimization of the irradiation doses and, consequently, increasing the chance of preserving the patient visual acuity.

O-2

NEW SUGGESTION OF WINDOW AND ENERGY LEVEL FOR PROTOCOLS USED FOR ACQUIRING IMAGES OF PATIENTS ADMINISTERED BY RA-223

Rafael Figueiredo Pohlmann Simões[1], Lídia Vasconcellos De Sá[2], Carlos José Da Silva[2], Ronaldo Lins Da Silva[2]

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[2]Instituto de Radioproteção e Dosimetria

Nuclear Medicine

The Radium-223 has being used for a nuclear medicine therapeutic technique in patients affected by prostate cancer metastasis. The dosage are currently only defined by the patient's weight as the directions of the drug laboratory. This study has the aim of collaborate to the trend of individualizing the therapeutic protocol for each patient according to the lesions extensions and clinic conditions. Gamma Camera's images of patients administrated by Radium-223 can be determinant for theses intentions. This radionuclide has a very small gamma emission probability, less than 2%, and this is a theranostics ability's obstacle. The literature recommends to acquire images with an 20% window centralized in 82 keV at the x-ray region in spectrum, however this region has an emission of characteristic x-ray from the lead collimator together and its results in a relevant level of noise that turn the internal dosimetry very hard. Therefore, the goal of this study is to propose a new window and energy center avoiding the lead collimator's characteristic x-ray emission using the results of an spectroscopic GeHP (High-Purity Germanium), ORTEC® GWL well-type model 120-15 that means 120 cc active volume GWL detector with 15.5 mm diameter well tube and 70 mm diameter endcap. This detector has a greater energy resolution that can split and identify the components of the only one peak visualized at the NaI crystal of the major of gamma cameras equipments. The results of this analysis suggest a window of 24% centralized at 89 keV in order to be open from 78 keV to 100 keV. It shown that the traditionally used window eliminates an important region of x-rays emmited by the Radium-223 and collect almost 50% of noise from lead collimator's characteristic x-ray, so this results can collaborate to the redefinition of the acquire image protocol for this radionuclide.

O-3

CAD SYSTEM FOR MICROCALCIFICATIONS AND MASSES IN DIGITAL MAMMOGRAPHY

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Diagnostic and Interventional Radiology – General

Breast cancer is the most common malignant injury among women and the second cause of death after lung cancer. It represents 16% of all female cancers. The X-ray mammography is the diagnostic test of choice for early detection. It manifests basically by some characteristic lesions such as masses, microcalcifications and abnormal ducts. However, the breast is composed of soft tissues and the anomalies do not differ much from healthy areas in attenuation of X-rays, which is why it is essential to have high contrast and resolution images, low noise and no artifacts; otherwise, radiologists have trouble diagnosing accurately for lack of visibility and false positives or negatives can be obtained. In this context, computer-aided detection (CAD) systems are a diagnostic aid tool for physicians.

In this work a CAD system is proposed, which improves the quality of the digital mammographic image; segments the gland and remark the presence of micro-calcifications and / or masses on the improved images. The system is based on the implementation of segmentation methods using Laplacian, opening of binary areas, determination of binary related components, global thresholding based on the image entropy, morphological filtering, iterative methods for the improvement of image contrast and segmentation by active contours. The system was tested with the database (DB) annotated MIAS, in oblique lateral views, of glandular, glandular-dense and predominantly adipose breasts, which included lesions or were normal. The system was evaluated with respect to the DB annotation, for a sample of 115 images. A sensitivity of 93.2% was obtained, a specificity of 85.3%, an accuracy of 90.4% and an precision of 92%.

O-12

DOSIMETRIC CONSIDERATIONS IN TRANSLATIONAL RESEARCH WITH PRECLINICAL IRRADIATION DEVICES (SMALL ANIMALS AND CELLS IRRADIATORS)

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Dosimetry – Reference quality

Introduction
Although there is clear evidence that drug-radiotherapy combinations improve overall survival, one of the problems related to new drugs development has been irreproducibility of preclinical data. Among the variables involved are the dosimetric aspects of the irradiations. Uncertainty for absolute and relative dose measurements in medium energy X-rays small animals and cell irradiators is still at relatively high level. Very small fields collimators and purposely build microbeams like patterns, add to the level of complexity. Dosimetric complications can undermine translation of data and information between in vitro and in vivo models into clinical practice.

Methods and Materials
The current state of dosimetry in radiobiological studies is presented. Studies referring to the consequences of the lack of dosimetric harmonization among centres performing preclinical studies are summarized. The challenges of dosimetry in medium energy X-Rays beams and in conditions different from the ones referred by the known dosimetry protocols are explained.
A project leaded by the National Physical Laboratory in collaboration with Xstrahl, the University of Hull and supported by Innovate UK Research and Innovation Group had investigated different detectors that could be used for absolute and relative measurements of dose (EBT3 films, inorganic scintillators, pixelated detectors). The effect of different back and lateral scatter conditions were also investigated. A SARRP device at UCL Cancer Institute had been commissioned and a mouse phantom and alanine measurements of targeted deliveries were compared with treatment planning calculated doses.

Results and conclusions
Dosimetry in preclinical irradiations is currently non standardized. Procedures and methodologies that are identified with the true geometry of the irradiations are required. Zoomorphic like phantoms are more suitable for dose verification of treatment planning systems. Pixelated detectors could be a way forward for characterization of very small fields and microbeams. Biological research will benefit from more accurate and traceably dosimetry.

O-14

EVALUATION OF AAPM REPORTS 204 AND 220: ESTIMATION OF EFFECTIVE DIAMETER, WATER-EQUIVALENT DIAMETER, AND ELLIPTICITY RATIOS FOR ADULT AND PEDIATRIC CHEST AND ABDOMEN CT LOCALIZER

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Diagnostic Radiology –Dosimetry

PURPOSE
AAPM Reports 220 reported that water-equivalent diameter (WED) is a sound descriptor of patient size because it depends on the patient's attention to calculate the size-specific dose estimate (SSDE) from a CT examination. It also mentions that calculating WED from CT localizer radiographs will make it possible to calculate SSDE prior to CT scanning. However, a calibration method that relates pixel values to represent water-equivalent attenuation has been proposed but not tested on phantom data.

METHOD
To perform the calibration we acquired CT axial and CT localizer scans of CTDIvol phantoms of 1.0, 10, 16, 32 cm diameters. We extracted localized pixel values (LPV) from all lines in the CT localizer within the CT axial scan range. We plotted the water-equivalent area per lateral diameter as a function of LPV to get a linear calibration line-of-best fit, to calculate the WED. We scanned CT axial and CT localizer CIRS abdomen and chest phantoms for adult and pediatric scans obtained from a clinical CT system. We extracted LPV from the lines in the CT localizer and used the calibration curve to calculate WED. We plot the WED extracted from the "gold standard" CT axial scan as a function of the WED calculated from the CT localizer. We use the AAPM 204 formula to calculate NDC.

RESULTS
The localizer-based WED calculated had an excellent correlation (R^2=0.98) with the gold standard approach. The minimum and maximum of difference between localizer-based and gold standard was 6.6 and 14%, respectively. The correlations were excellent for abdomen only (R^2=0.99) and chest (R^2=0.98) scans with a minimum/maximum difference of 6.8/8.8% and 6.6/14% difference, respectively. The localizer based NDC had an excellent correlation (R^2=0.98) with a maximum of 10% difference.

CONCLUSION
The calibration and model-based magnification method gives an accurate estimate of NDC to achieve accurate SSDE.

O-15

SYSTEMIC RESPONSE TO RADIO- AND CHEMORADIOTHERAPY BY MEANS OF 1H-NMR BASED METABOLOMICS AND BATCH MODELLING

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Radiation Oncology – Dosimetry

Introduction
Anticancer treatment results in temporary/permanent toxicity considered as changes in normal tissues and/or involved regions. The net effect is mirrored in morphological, functional and molecular disturbances, thus in a systemic response. We aimed to investigate the real-time (during-treatment) changes in serum metabolome in order to identify metabolic signatures of acute radiation sequelae (ARS) in head and neck cancer (HNC) patients, as well as to find the biomarkers that could help prevent of ARS escalation.

Methods and Materials
170 HNC patients were enrolled into the study. Patients were treated radically with radiotherapy and chemo-radiotherapy. Chemotherapy was realized as induction and/or concurrent treatment. Blood samples were collected weekly, starting from the day before the treatment and stopping within the week after the treatment completion. Patients were clinically monitored until the resolution of all ARS symptoms. Serum samples were analyzed using 1H-NMR spectroscopy followed by multivariate projection techniques and batch analysis.

Results and Conclusions
Biomarkers related to the outlying cases (e.g. due to ARS escalation) as well as those related to the general response to treatment were successfully identified. Intensified ARS resulting in dysphagia, weight loss and cachexia was accompanied by significant increase of ketone bodies (KB) concentration in serum. In 45% of patients the during-treatment percentage weight loss was above 10%. The measurement of KB concentration predicted significant weight loss earlier than standard clinical nutrition markers (albumin, prealbumin, BMI). The general response to treatment was mostly reflected in altered concentrations of inflammatory and energy involved metabolites.
Metabolic monitoring of anticancer therapy may give insight into individual treatment toleration as well as contributes to a better understanding of metabolic and cellular background of ARS. Presented results show possibility of clinical application of 1H-NMR based metabolomics in detection of high risk patients.

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O-20

IAEA-ATIA SOFTWARE FOR IMAGE QUALITY EVALUATION IN PLANAR RADIOGRAPHY

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Diagnostic and Interventional Radiology – General

Objective: To generate a software tool that will allow performing quality control of radiographic and mammographic imaging systems using a remote and automated method.

Methodology: A working group was established by the IAEA to provide Member States with a framework that can facilitate frequent constancy testing without the need of on-site supervision by the medical physicist. Two simple and cost-effective radiographic and mammographic phantoms are proposed. An Automated Tool for Image Analysis (ATIA) was developed in order to facilitate the analysis of images from both phantoms. ATIA tracks the AEC performance by following the kilovoltage, current, mean pixel value (MPV), dose level, and dose to the detector. It automatically calculates the following IQ metrics: signal to noise ratio (SNR), signal difference to noise ratio (SDNR), modulation transfer function (MTF), normalized noise power spectrum (NNPS) and detectability index (d´). It can also extract and report relevant tags from the DICOM header. Additionally, ATIA can generate a variance map of the image phantom and check for uniformity and image artefacts.

Results: Prototypes of both phantoms have been constructed and tested satisfactorily in different clinical scenarios. Images generated for both CR and DR in radiology and mammography have been analyzed with ATIA software both locally and remotely. Information about IQ metrics on weekly images over a period of more than a year in some facilities have generated good data to assess the image quality over time of those devices.

Conclusions: ATIA is a free software tool from the IAEA that works with images of two easily constructed and inexpensive phantoms. This framework will facilitate the evaluation of image quality in planar images on a frequent basis that will complement regular QC by a medical physicist and can do the analysis in a remote fashion.

O-21

DEVELOPMENT AND CONSTRUCTION OF AN IMAGE QUALITY PHANTOM FOR DENTAL CT SCANNERS CBCT.

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Diagnostic and Interventional Radiology – General

Objetive:
The aim of this paper is to present the development and construction of a phantom that allows the evaluation of image quality metrics in dental Cone Beam Computed Tomography (CBCT). This equipment is increasing in use and no formal image evaluation is always possible due to lack of phantoms in our countries.
Method:
The Mora-Rizo phantom consists of two bases of 16 cm in diameter and 5 cm in thickness (to provide support and rigidity, adequate dispersion to simulate the head of a patient, alignment and positioning) and 5 interchangeable PMMA modules to evaluate: MTF, CNR, uniformity, noise/artifacts and CT numbers of dental inserts. MTF evaluation was done through a copper wire of 0.22 mm in diameter and CNR through a PVC test object. The innovative part is the introduction of dental materials (such as gutta percha, lithium disilicate, porcelain, fiberglass, resin) in different discs sizes . These materials used for prostheses and shims in dental clinics will be used to assign gray and CT values for specific clinical protocols.
Results:
A first prototype was constructed and evaluated in 3 different CBCT equipment using a clinical protocol of 80 kVp and 5 mA. For each equipment MTF, CNR, uniformity and noise/artifacts were evaluated and validated with the QUART phantom of the SEDENTEXCT project (exposed under the same clinical conditions). Dental inserts allowed the assignment of CT numbers for each of the dental materials.
Conclusions:
The Mora-Rizo phantom is a low cost, versatile and easy to use device that has allowed the evaluation of different image quality metrics, obtaining similar results as when the QUART phantom is used. The added advantage of characterizing dental inserts with their CT numbers is important for clinicians when evaluating the patient image and identification of foreign objects in the anatomy of the patient.

O-26

SAFETY EVALUATION FOR AN ORTHOVOLTAGE RADIATION THERAPY SYSTEM, WOMED T-200

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Radiation Protection

Orthovoltage equipment uses low-energy photons to treat tumors that are located on or near the skin. These treatments are very effective in treating this type of injuries, their quality is linked to multidisciplinary factors that need to be taken into account whenever a safety assessment is made. Objectives: To carry out the evaluation of the safety of the treatment process in a superficial radiotherapy team and to identify the causes and consequences that can cause accidental exposures, for patients, worker or public, from the installation of the equipment, to the completion of the treatment. Methodology: The Risk Matrices method was used, using the SECURE-MR-FMEA 3.0 code that allows a combined analysis of the frequency of occurrence of the initiating event, the probability of human errors or failure of barriers and the severity of the consequences , facilitating the identification of the risk associated with the procedures. The method establishes priorities for risk management and identifies the main causes that could cause accidental exposures, allows to prevent the occurrence of accidents using risk criteria that take into account the probability and magnitude of potential exposures. Results: We evaluated 79 initiating events of them 6 with RA for 8%, 41 RM for 52% and 32 RB for 40%. Conclusion: We identified the main causes that can cause accidental exposures, the vulnerable points, related to the treatment that is provided, we worked on them, and it was possible to decrease all the initiators with high risk. The work showed that human errors are the main cause that can trigger an accidental risk sequence.

O-36

RADIATION EXPOSURE TO ANAESTHETISTS ASSISTING EMBOLIZATION INTERVENTIONAL PROCEDURES

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Radiology – Radiation Protection

Introduction
Anaesthetists are frequently involved in exams requiring X-rays during interventional radiology procedures. As well as the main operator, anaesthetists may also be subject to significant radiation exposure. Some studies have found that anaesthetists assisting interventional procedures may receive high radiation doses in a single procedure that may be three times greater than doses received by the main operator. The aim of this study was to assess the exposure received by anaesthetists assisting embolization procedures in a reference hospital in Recife, Brazil.

Methods and Materials
This study was conducted in the largest public hospital in the city of Recife, Brazil. Occupational dosimetry was performed to one anaesthetist who participated in ten prostatic artery embolization (PAE) and seven hepatic chemoembolization (HC) interventional procedures. The exposure received by the anaesthetist, was quantify with thermoluminiscent dosemeters at the following physician's positions: on the eyes, at the neck level (over the collar), at the chest level (under the apron), at the wrists and on the feet. The effective dose was estimated using a conservative double dosimetry algorithm.

Results
The results show that the mean doses per procedure to the eyes, the wrists and the feet of the monitored anaesthetist in PAE and HC procedures were: 143.0 μSv, 112.8 μSv, 389.6 μSv, 127,5 μSv, 58.3 μSv, 283.4 μSv, respectively. The highest doses in PAE procedures result by the use of oblique projections that require the anaesthetist then to stand closer to the patient in complex procedures.

Conclusions
This study found that anaesthetists assisting embolization procedures can be subject to high radiation doses when they assist in complex procedures that require then to stand closer to the patient. In these instances the effective dose and the eye´s doses of anaesthetists may be five to eight times greater than doses received by the interventionalist.

O-47

ENERGY DEPENDENCE OF AN INDIVIDUAL DOSIMETER: EXPERIMENTAL AND PENELOPE-MONTE CARLO ASSESSMENT

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Radiation Protection

Introduction
Thermoluminescent dosimetry is widely used for individual monitoring. In Brazil, CaSO4:Dy is the most used phosphor for that purpose. The energy dependence coefficients obtained for these dosimeters are used to determine the operational quantities in individual monitoring. The goal of this work was to assess the energy dependence curves of the multi-filter thermoluminescent dosimeter used at Brazillian laboratory CIDRA.

Methods
Experimental data was obtained in selected energies and Monte Carlo simulation with PENELOPE was used to interpolate experimental data. CIDRA's dosimeter employs three CaSO4:Dy detectors in an acrylic badge. The three CaSO4:Dy pellets are filtered by plastic, copper and copper+lead, respectively. The dosimeters were irradiated with beams ranging from 15 to 250 keV, as described in ISO 4037-1. Monte Carlo simulations with PENELOPE were performed in the same geometry and irradiation conditions. The energy dependence curves were used to determine Hp(10) in a blind test for 63 dosimeters irradiated in beams ranging from 15 keV up to Cs-137. Trumpet curves were used to evaluate the Hp(10) assessments.

Results
Experimental and simulated curves show similar behavior, presenting high energy dependence of the CaSO4:Dy for energies lower than 250 keV, as shown in the literature. The largest energy dependence was found for the pellet positioned between the copper+lead filters (0.01 relative response to 15 keV relative to Cs-137). The maximum differences between experimental and simulated data was observed also for the copper+lead filter in the energy range of 30 to 70 keV (up to 4.5%). All the Hp(10) values determined for the 63 dosimeters were inside the trumpet acceptance limits.

Conclusions
The comparisons of obtained experimental and simulated results show that simulation has become an essential tool, making it possible to interpolate and extrapolate energy dependence coefficients used in individual monitoring dose determinations.

O-50

EVALUATION OF THE IRRADIATION OF AN ANTHROPOMORPHIC LIVER PHANTOM WITH PHOTON BEAMS

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Radiation Oncology – Quality Assurance

Purpose:
Evaluate the pass rate for irradiations of an anthropomorphic liver phantom with multiple targets and motion using photon beams.

Methods:
The phantom has one insert that represents the liver and includes two non-coplanar targets PTV1 and PTV2. The insert is made of polystyrene and the targets are made of solid water. PTV1 is an ovoid 2 cm in diameter and 2.5 cm long. PTV2 is a 3 cm diameter sphere. There is one TLD and 2 planes of radiochromic film in each PTV. The phantom includes a motion table to simulate 1 cm respiratory motion mostly in the superior-inferior direction. Institutions were instructed to design and deliver a plan that delivers 6 Gy to ≥95% of each PTV. Algorithm for dose calculations include Superposition Convolution type of calculations as well as Monte Carlo based dose calculations. Motion management include gating, breath hold, tracking and ITV.

Results:
More than 200 irradiations were evaluated. The mean TLD/TPS value was 0.99 (±0.03). While the TLD values were statistically different by TPS algorithm (ANOVA, $p<0.05$), the pass rates were not different by algorithm. The mean percent of pixels passing the 7%/4mm gamma analysis were 91% (±9%). The pass rate was 72.8%. The pass rate was statistically worse for phantom irradiations using an ITV technique compared to other motion-management techniques (Chi-square, $p=0.05$).

Conclusions:
The pass rate for the liver phantom, while low, continues to improve. The ITV technique of motion management performs worse than other motion-mitigation techniques. All centers could potentially improve their pass rate with implementation of tracking, gating, or breath-hold techniques.

O-56

COMPARISON OF ELECTRONIC BRACHYTHERAPY WITH MAMMOSITE SYSTEM IN BREAST TREATMENTS FOR SKIN, LUNG AND HEART DOSE

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Radiation Oncology – Brachytherapy

Purpose
We have treated 350 patients at our center from May 2015 to December 2018 for breast cancer with Axxent (Xoft Inc.) intraoperative radiotherapy (IORT), in this work we compare the doses in the skin, lung and heart of the 350 patients treated with the 50 kVp source with the doses they would have received using the Mammosite system using an Ir192 source.

Material and Methods
To the 350 patients treated in our center after removing the tumor, the appropriate balloon size is chosen to cover the tumor area with a dose of 20 Gy on the balloon surface.

Results
The differences in maximum skin dose for both types of treatment are 8.1 ± 1.2 Gy for the case of Mammosite and 5.7 ± 1.5 Gy for patients treated with electronic brachytherapy source. This explains the very few cases of acute dermatitis at 6 months (8 cases of grade 2 and 2 cases of grade 3) with no recurrence to date.We also show the mean and maximum doses (expressed as percentage of prescribed dose) for the left lung (Axxent 1% and 20.4% vs Mammosite 3.9% and 29.9%) and heart (Axxent 0.8% and 4.1% vs Mammosite 3.3% and 10.4%) in cases of left breast tumor for the volumes of 30 and 35 cm3, which are the most common in our hospital (70% of cases):

Conclusion
It is concluded that the IORT treatments performed with the Axxent equipment with electronic source are a good alternative to those performed with Ir192 and our 350 patients treated to date to the good results presented by other centers are joined.In addition to the low skin toxicity, there is no recurrence in patients treated so far, which makes us very optimistic about the results.

O-57

SINGLE CELL DOSIMETRY FOR IODINE RADIOISOTOPES USING GEANT4-DNA

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Radiation Oncology – Dosimetry

In this study low energy extension of Geant4-toolkit, Geant4-DNA,was used to compute the cellular S-value, mean energy deposited and radial energy profile in different sub-cellular regions when radiation sources are distributed within different cellular compartments. The electron emission spectra for 123I, 125I and 131I was also simulated using radioactivedecay module of Geant4. To study the effect of using different emission spectra on S-value, the comparison was made between the S-values obtained using the emission spectra from ICRP 2008 Nuclear decay data for 125I and decay of 125I simulated using Geant4. The radial energy profiles displayed that the energy deposited by 125I along the radius was twice of that deposited by 123I and approximately four times of 131I. Mean energy deposited per decay was found in good agreement with the literature, with approximate variation of 10%. The S-values obtained using ICRP decay spectra was found deviating by~30% on an average with respect to the one obtained using Geant4 radioactive decay module. On comparison of S-values against the literature for S(C←C), S(N←N), S(C←CS) on average variation of 10% was observed, moderate variations were obtained in case of S(N←Cy) upto -28% and the highest deviations up to 69% were noted for S(N←CS). It was also found that the electron emission spectra plays very important role in computation of the mathematical quantities

O-60

COMPARISON OF EXCRETORY FUNCTION BY INTRAVENOUS PYELOGRAM (IVP/IVU) & DIETHYLENETRIAMINEPENTACETATE (DTPA RENOGRAM) OF OBSTRUCTIVE UROPATHY

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Nuclear Medicine

The aim of the study is to about excretory function and different kidney status, to study about effective dose of IVU and DTPA Renogram, to study about time measurement of diagnostic modalities and find out the comparison between IVU and DTPA renogram for evaluation renal function of Obstructive Uropathy. According to IAEA guideline, study has performed prospectively conducted at radioisotope center in INMAS, Dhaka and Gonoshasthaya Kendra, Savar, Dhaka. X-ray contrast medium or dye (Lopidam-370) has injected to a patient via a needle or cannula into the patient arm vein. Tc-99m DTPA has injected to the patient according to patient conditions, age and weight. The demonstration of kidney function by IVU are-Normal functioning kidney LK is 33% and RK is 50%. Nonfunctioning kidney LK is 23% and RK is 12%.Mild HDN kidney LK is 8% and RK is 10%. Moderate HDN kidney is 16% and RK is 15%.Marked HDN LK 3% and RK is 4%,Gross HDN kidney LK is 9% and 7%.Horseshoe kidney is LK is 2% and RK is 2%PUJO LK is 6%. The demonstration of kidney function by DTPA are-Normal functioning kidney LK is 43% and 71%. Nonfunctioning kidney LK is 12% and 5%.Mild HDN kidney LK is 16% and 5%.Moderate HDN kidney LK is 6% and RK is 3%.Marked HDN LK is 8% and RK is 8%.Gross HDN kidney LK is 14% and RK is 7%. Horseshoe kidney LK is 1% and RK is 1%.The IVU is valuable examination of urinary tract anatomical images. DTPA Tc-99m scan superior to IVU because it can be easily performed, less preparation needed, and less radiation hazard to the patient and others, more accurate divided relative function and even determines blood flow of obstructive kidney.

Key Words: Intravenous Urogram, DTPA renogram, Obstructive Uropathy, Excretory functions, gamma camera, X-ray.

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AUTOMATED WINSTON-LUTZ TEST USING XML SCRIPT AND DEVELOPER MODE IN TRUEBEAM STX

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Radiation Oncology – Quality Assurance

Purpose: The use of Winston-Lutz (WL) test for isocenter verification, prior to a radiosurgery procedure, is recommended in TG101. The objective of this work was to develop an automatic WL test procedure using XML script with the developer mode of a TrueBeam STx.

Methods: The WL test consist in the setup of a WL phantom (Brainlab) with the mechanical isocenter of the TrueBeam STx (Varian). After verification, 12 EPID images (aS1200), with different combinations of gantry (0, 90,180, 270 deg), collimator (90, 270 deg) and couch (0, 45, 90, 270, 315 deg) angles are obtained. EPID images are analyzed by RIT software v6.7 (Radiological Imaging Technology) to obtain the deviation between radiation and mechanical isocenter. An XML script was created in the development environment Microsoft Visual Studio Community (2017). The script contains automatization sequences with specific control points including acquisition of all images. The XML file is executed in the Developer Mode version 2.0. Comparison between manual and automatic WL were done for 5 procedures based on execution time, WL displacement and 3D maximum displacement are compared.

Results: The XML routine run satisfactorily without any bug. The average execution time for manual and automatic WL test was 12.7±0.2 min and 4.28±0.02 min respectively. The WL displacement for manual and automatic was 0.58±0.04 mm and 0.50±0.10 mm respectively and the WL 3D maximum displacement for manual and automatic was 0.61±0.06 mm and 0.75±0.05 mm respectively.

Conclusion: The automatization of WL test using XML script is feasible and reduces the execution time and the displacement obtained are the same to the obtained manually. XML script and Developer Mode improves test WL time efficiency. Adaptations of the current XML are being extended to automate others quality controls in our institution.

O-62

AUTOMATIC GENERATION OF PLANNING PROSTATE SBRT STRUCTURES WITH SCRIPTING

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Radiation Oncology –Treatment Planning

Purpose: Prostate SBRT planning require the generation of multiple planning structures based on the treatment volumes defined by the physician. This procedure is done by the dosimetrist, is time consuming and could have user's errors. The objective of this work was to create an automatization process to generate planning structures using Eclipse's scripts.

Methods: Varian's Eclipse scripting application programming interface (API) v15.1 together with integrated development environment Microsoft Visual Studio Community (2017) (write and compile a plugin-script in C # executable) in Eclipse was used. A graphic interface was done using windows presentation foundation (WPF) and forms (WF). Manipulation and operations of structures was done using the "Structure Class" contained in the Eclipse’s “Model.API.dll” library. All structures were transformed to high resolution and named following TG263 recommendation. The script can be executed in External Beam Planning workspace of Eclipse and automatically detect CTVs and OARs. Comparison between manual and automatic structures were done measuring the volumes for 15 patients.

Results: The Script run well for all test patients. The average script execution time was 39±2 seconds. Planning time was reduced by 20±3 min. The maximum difference between volumes generated automatically and manually was 1.9cc (0.5% of volume) for large structures (bladder) and 0.02cc (0.3%) for smaller structures (urethra).

Conclusion: Through the implementation of the Script it was possible to standardize criteria among users when creating the planning structures, it was possible to reduce the human random errors and the planning time was reduced. No significant difference was found between structures generated with the script and manually. Implementation and adaptations of the current script are being extended to different treatment sites in our institution.

O-63

DENOISING FRAMEWORK USING THE BLOCK MATCHING AND 3-D COLLABORATIVE FILTER FOR DOSE REDUCTION IN MOLECULAR BREAST IMAGING

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Nuclear Medicine

Purpose: The objective of this study was to determine if application of a block matching and 3-D collaborative filtering (BM3D) denoising algorithm to molecular breast imaging (MBI) studies would allow for a reduction in the total number of counts that needed to be acquired in an image to retain lesion conspicuity.

Methods: The initial input dataset contained 20 MBI patient studies with positive findings, acquired in dynamic mode that allowed summation to simulate full-dose or half-dose images. The BM3D filter setting for the half-dose images was optimized by two methods. In the 1st method, the filter setting was adjusted so that the relative noise in the filtered image (matched half-dose image) matched that of the original full-dose image. In the 2nd method, the filter setting was adjusted to provide user-preferred image quality. After validating both filter settings, a second dataset of 50 MBI patient studies with positive findings, was used in 2-alternative forced-choice (2AFC) studies where 2 readers were presented with the full-dose image and either the half-dose image, or one of the 2 filtered images (matched half-dose, or preferred half-dose image). In each 2AFC study, readers selected the image that best showed the documented lesion and assign a lesion conspicuity score.

Results: As expected, the full-dose image was selected 96% of the time over the half-dose. The full-dose and matched half-dose images were each selected 50% of the time. The preferred half-dose images were selected over the full-dose images 76% of the time. Inter-observer agreement ranged from 85%-90%. There were no reports of any induced artifacts from the BM3D algorithm.

Conclusion: The BM3D algorithm can be used to post-process MBI images that were acquired at half-dose to provide equivalent or better lesion conspicuity to images that were acquired at full dose.

O-65

PREDICTION OF RESPONSE AFTER CHEMORADIATION FOR ESOPHAGEAL CANCER USING A COMBINATION OF DOSIMETRY AND CT RADIOMICS

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Radiation Oncology – Dosimetry

Purpose: To investigate the treatment response prediction feasibility and accuracy of an integrated model combining computed tomography (CT) radiomic features and dosimetric parameters for patients with esophageal cancer (EC) who underwent concurrent chemoradiation (CRT) using machine learning. Methods: The radiomics features and dosimetric parameters of 94 EC patients were extracted and modeled using Support Vector Classification (SVM) and Extreme Gradient Boosting algorithm (XGBoost). The 94-sample dataset was randomly divided into a 70-sample training subset and a 24-sample independent test set while keeping the class proportions intact via stratification. A receiver operating characteristic (ROC) curve was used to assess the performance of models using radiomics features alone and using combined radiomics features and dosimetric parameters. Results: A total of 42 radiomics features and 18 dosimetric parameters plus the patients' characteristic parameters were extracted for these 94 cases (58 responders and 36 non-responders). XGBoost plus principal component analysis (PCA) achieved an accuracy and area under the curve of 0.708 and 0.541, respectively, for models with radiomics features combined with dosimetric parameters, and 0.689 and 0.479, respectively, for radiomics features alone. Image features of GlobalMean X.333.1, Coarseness, Skewness, and GlobalStd contributed most to the model. The dosimetric parameters of gross tumor volume (GTV) homogeneity index (HI), Cord Dmax, Prescription dose, Heart-Dmean and Heart-V50 also had a strong contribution to the model. Conclusions: The model with radiomics features combined with dosimetric parameters is promising and outperforms that with radiomics features alone in predicting the treatment response of patients with EC who underwent CRT.

O-66

QUANTITATIVE EVALUATION OF MATERIAL DECOMPOSITION METHODS IN CHEST DIGITAL TOMOSYNTHESIS

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Diagnostic and Interventional Radiology – General

Dual-energy chest digital tomosynthesis (DECDT) is a promising new medical technique that could improve capability of differentiating among materials compared to CDT. However, the development of DECDT is challenging due to noise amplification during material decomposition. In this study, we investigated the feasibility of four material decomposition methods for CDT system and quantitatively evaluated how different material decomposition methods affect the image quality. We used a prototype CDT system consists of a CsI(Tl) scintillator flat panel digital detector (Pixium RF 4343, Thales, France) and X-ray tube (TE-E7869X, Toshiba, Japan). To acquire the dual energy images, the image intensifier of CDT system was used with tube voltages of 80 and 120 kVp in LUNGMAN (Kyoto Kagaku, Japan) phantom. Reconstructed images were acquired by using simultaneous algebraic reconstruction technique (SART). To evaluate the image quality of decomposed images for CDT system, we applied four methods such as standard log subtraction (SLS), simple smoothing of the high-energy image (SSH), anti-correlated noise reduction (ACNR), and general linear noise reduction algorithm (GLNR). Quantitative evaluations of reconstructed images were performed by both contrast-to-noise ratio (CNR) and artifacts spread function (ASF). We found proper values of decomposition parameters improving reconstructed images. The resulting images showed that CNRs were highest in GLNR method for decomposed bone and soft-tissue images. Particularly, the CNR with GLNR method for bone image was 2.1 times higher than that for the single energy technique. We calculated the ASF curves to compare the quality of vertical resolution with four material decompositions. This results show that GLRN provides better ASF. This study demonstrated that DECDT could improve the diagnostic accuracy by providing images of specific tissues. We highlight the potential of GLNR method with proper decomposition parameters to improve the image quality.

O-73

3D GYNY HYBRIDE HDR BRACHYTHERAPY FOR CERVIX

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Radiation Oncology – Brachytherapy

INTRODUCTION
Brachytherapy (BT) plays a major role in the therapeutic management of patients with cervix cancer from stage I to IV. The rapid dose fall-off allows a very high dose to the central pelvis, while relatively sparing bladder, rectum, sigmoid and small bowel
Hybrid adaptive and MRI guided brachytherapy is used when intracavitary alone could not cover the volume. (large Stage IIB/IIIB with minor parametrial response)
We will present the results of 8 cases where we use this technique
METHODS AND MATERIALS
A dedicated applicator is used for this technique, it s Utrecht from Elekta the application is done at the theatre then CT scan and MRI with applicator in place after contouring of targets and OAR by physicians, and reconstruction of applicators by physicist, then optimisation and evaluation according to GEC ESTRO Recommendations, our patients are treated
RESULTS AND CONCLUSIONS
Hybrid adaptive and MRI guided brachytherapy significantly improves the coverage of large target volumes, while retaining sufficient organs at risk, in addition it allows a synchronous parametrial complement which results in a considerable gain on the spreading total of radiotherapy. It constitutes the best all-in-one technical solution available to date for the implementation of interstitial brachytherapy in centers that do not have sufficient expertise to apply a free-hand gynecological brachytherapy

O-76

ESTIMATION OF WATER EQUIVALENT DIAMETER FROM DOSIMETRIC MEASUREMENTS IN COMPUTED TOMOGRAPHY

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Diagnostic Radiology –Dosimetry

The average dose delivered in a study of Computed Tomography (CT) can be found by using Size Specific Dose Estimators (SSDE). The effective diameter has been replaced by the water equivalent diameter dw to take into account the attenuation properties of patients for the estimation of the SSDE. The use of the dw facilitates to obtain an exact value of absorbed dose. In order to guarantee the equivalence of dw with those on phantoms and its high precision, the x ray spectra were estimated at the entrance of dosimetric phantoms of Polymethyl Methacrylate (PMMA). These spectra were attenuated for each dw and fitted to guarantee relative differences lower than 2% between the air kerma measured at the center of the phantom and those simulated from spectra. The function spektrEquiv_mmAl_CompoundsNIST from the software SPEKTR 3.0 was modified to calculate the dw. The dw corresponding to each combination of diameters of PMMA phantoms (dpmma) with scanning factors was calculated. For the dpmma of 16 and 32 cm, the values of dw were equal to 16.9 ± 0.6 cm and 35.8 ± 1.6 cm respectively. The estimation of spectra fitted from dosimetric measurements in phantoms, allows to estimate the water-equivalent diameter and include it in predictive models of kerma indexes for CT and image quality. Once known the association between the dw and the effective diameter for each anatomical region, the drawbacks of the estimation of the dw based on previous irradiations of the patient can be overcome. With respect to the attributes of the patient, it is recommended to develop investigations that contribute to make reference records of magnitudes of water-equivalent dimensions of pediatric and adult patients for the different anatomical regions of interest in imaging.

O-80

DEVELOPMENT OF KV X-RAY IMAGING DOSE CALCULATION SYSTEM FOR IMAGE GUIDED RADIATION THERAPY

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Diagnostic Radiology –Dosimetry

Purpose: Knowledge of the imaging doses delivered to patients and accurate dosimetry of the radiation to organs from various imaging procedures is becoming increasingly important for clinicians. The purposes of this study were to develop kV X-ray imaging dose calculation system for image guided radiation therapy and to evaluate the impact of kV X-ray imaging doses on treatment doses.

Methods: The Vero4DRT was equipped with gantry-mounted orthogonal kV X-ray imaging subsystems, consisting of two sets of X-ray tubes and flat-panel detectors. The EGSnrc/BEAMnrc and EGSnrc/DOSXYZnrc packages were used to simulate kV X-ray imaging dose distributions of Vero4DRT. Then, the kV X-ray imaging dose distributions such as 4D-CBCT, 3D-CBCT, correlation modeling and monitoring doses were calculated for 9 lung cancer patients based on the planning CT images with dose calculation grid size of 2.5×2.5×2.5 mm3. Finally, the imaging dose distributions derived via 4D-CBCT, 3D-CBCT, correlation modeling and monitoring, of planning target volume (PTV), the skin and the bone, were evaluated by examining dose-volume histograms (DVHs).

Results: Based on 4D-CBCT and 3D-CBCT, the doses covering 2-cc volumes (D2cc) were maximally 6.0, 10.5 and 58.1 cGy for the PTV, the skin and the bone. Then, the maximum D2cc of correlation modeling and monitoring imaging were 6.0, 9.3 and 48.4 cGy for the PTV, the skin and the bone.

Conclusions: We have developed kV X-ray imaging dose calculation system for image guided radiation therapy using Vero4DRT and evaluated the impact of kV X-ray imaging dose on treatment dose.

O-83

COMPARISON OF THE STANDARDS OF AIR KERMA AND ABSORBED DOSE TO WATER IN CO-60 RADIATION FOR THE NATIONAL RESEARCH COUNCIL CANADA AND THE DEPARTAMENTO DE METROLOGÍA DE RADIACIONES IONIZANTES, COMISIÓN CHILENA DE ENERGÍA NUCLEAR.

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Dosimetry – Reference quality

Purpose: An indirect comparison has been carried out of the standards for air kerma and absorbed dose to water for 60Co radiation of the National Research Council (NRC), Canada and of the Laboratorio de Metrologia de Radiaciones Ionizantes (LMRI), Chile. The DMRI is currently traceable to the National Physical Laboratory, UK.
Methods: A single reference-class Farmer-type ionization chamber (IBA FC-65 G) was used as the transfer instrument and additional measurements were carried out at both laboratories to confirm the correct operation of the transfer chamber throughout the comparison exercise and to evaluate influence quantities such as atmospheric pressure, equilibration, polarity effect, beam uniformity and experimental set-up.
Results: There was no observed difference in the performance and operation of the transfer chamber at the two laboratories (NRC altitude = 70 m, DMRI altitude = 600 m). The polarity correction was determined to be 0.9996, consistent with published values and showing no significant difference at the 0.01% level between measurements at the two laboratories. For the absorbed dose determination at DMRI, both a vertical and horizontal beam geometry was tested with two different water phantoms and agreement was at the ± 0.2% level. Measurements also confirmed that using a solid PMMA phantom introduced no significant additional error.
The comparison results, based on the calibration coefficients, evaluated as a ratio of the DMRI and the NRC standards, were 0.9972 for absorbed dose to water, with a combined standard uncertainty of 8.9 × 10-3, and 0.9945 for air kerma, with a combined standard uncertainty of 8.6 × 10-3.
Conclusion: The comparison results are consistent with the NRC/NPL ratios for these quantities published in the BIPM key comparison database at the 0.3% level, indicating no significant error in the dissemination of air kerma and absorbed dose to water calibrations by the DMRI.

O-85

PRESAGE® DOSIMETER AS ANTHROPOMORPHIC PHANTOM.

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Radiation Oncology – Dosimetry

Abstract:
Introduction: Radiation oncology has been rapidly improved by the application of new equipment and techniques. With the advent of new complex and precise radiotherapy techniques such as intensity modulated radiotherapy, stereotactic radiosurgery, and volumetric modulated arc therapy, the demand for an accurate and feasible three-dimensional (3-D) dosimetry system has increased. Methods and Materials: In this study anthropomorphic PRESAGE® was used for evaluation of radiation dose delivery. The most important features of 3-D PRESAGE® dosimeter, apart from being precise, accurate and reproducible, include also its low cost, feasibility, and availability. Many studies have been performed on the PRESAGE® dosimeters that show acceptable agreement between measured and reference doses. It also demonstrated that the PRESAGE®/optical CT system has excellent precision, accuracy, reproducibility, and robustness for 3D dosimetry. Results: Previous work has focused on the basic dosimetric characteristics of PRESAGE® and investigation of the feasibility of the PRESAGE®/optical CT system for 3D dosimetry. The latter investigations involved delivering simple dose distributions or IMRT distributions to dosimeters fabricated in regular cylindrical shapes. The present study evaluates the feasibility of a breast shaped anthropomorphic PRESAGE® dosimeter, and builds on this earlier work by applying the PRESAGE®/optical CT system for the verification of IMRT, 3D and HDR brachytherapy dose delivery. Conclusion: This work demonstrates the feasibility of fashioning PRESAGE® into an anthropomorphic shape for verification of radiation doses, and it provides groundwork for future investigations into more complex anthropomorphic phantoms.

Keywords: PRESAGE®, 3D dosimetry, Optical CT, Anthropomorphic, radiation dose

O-89

DETERMINATION OF THE MEAN ENERGY REQUIRED TO FORM AN ION-PAIR (W-VALUE) IN GASES OF RELEVANCE IN REFERENCE DOSIMETRY FOR PROTONTHERAPY

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Dosimetry – Reference quality

International protocols for reference dosimetry in radiotherapy, as TRS-398, provide a methodology to determine the absorbed dose in water using ionization chambers filled with air. The percentage of gas ionization can be determined using an electrometer that collects the electrons generated. The dosimeter lecture is proportional to the absorbed dose in liquid water, but conversion factors like W-values (mean energy required to form an ion-electron pair after the complete dissipation of the projectile initial energy) are required. For swift protons used in protontherapy, W-values are not accessible precisely by experiments; therefore, they must be obtained using theoretical models able to simulate all the physical processes involved in the ion-matter interaction. As experimental data are scarce and theoretical calculations are very complex, international dosimetry protocols for protons and heavy ions take constant values corresponding to the trend observed by electron impact. Uncertainties in W-values for hadrontherapy dominates the global uncertainties of the absorbed dose.

In a recent work (Tessaro et.al, NIMB 2018), we calculated W-values by electron and proton impact on vapour and liquid water. We used two different methods considering all the processes involved in the energy deposition by the primary and secondary particles. These are: the Monte Carlo code MDM, which allow us to represent the stochastic nature of the ion-matter interactions, and the Fowler Equation, based in the Continuous Slowing Down Approximation. The results obtained for vapour water are in very good agreement with experimental data and with simulations results reported in the literature from other authors. Here, we present an extension of these models in air gases by proton impact. We present results in the middle and high-energy range, reaching energies higher than 100 MeV where no experimental values exit. Results are in good agreement with experimental data and with recommended values at intermediate impact energies.

O-101

3D PRINTED TUMOR-SHAPE SCINTILLATOR MEASUREMENT SYSTEM

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Radiation Oncology – Dosimetry

We developed a tumor-shaped scintillator detector system using a customized 3-D printable scintillating plastic resin to measure the whole absorbed energy in the tumor and assess the accuracy of modern radiotherapy treatment plans. A scintillating plastic material was developed to be used in a commercial 3-D printer and three patient specific scintillator models were printed along the shape of the tumor. The scintillator was fixed by a probe head adapter which is connectable to optical fiber probe, and they were inserted into a spherical solid water phantom. A photomultiplier tube was used to measure scintillation lights. The effect of Čerenkov light was excluded by subtracting the light output of a dummy adapter. The conversion factors from net current to absorbed dose rates were obtained by comparing results of Monte Carlo simulations using Geant4 10.03 to measured values in GK PFX. A treatment plan for the tumor shaped scintillator in the phantom was created using CT images of the system. The total absorbed energy to the tumor-shaped scintillator was obtained by integrating over the irradiated time and compared with the treatment plan values. The conversion factor was 4.18±0.05, 2.88±0.04, and 4.09±0.05 (Gy/min·uA) for each of the three models, and the adjusted R-square was 0.9990, 0.9989 and 0.9991, respectively. The total dose measured on the tumor-shaped scintillator according to the treatment plan was 7.493 ± 0.034 Gy, which is 1.3% different from treatment planning system. The accuracy of the light output conversion factor showed good linearity so that the feasibility of the system was proved, but more sophisticated manufacturing and verification are necessary to be used in actual patient specific quality assurance.

O-102

KNOWLEDGE-BASED PROSTATE RADIOTHERAPY PLANNING: AN INNOVATIVE MODEL FOR HYPOFRACTIONATION WITH SIMULTANEOUS INTEGRATED BOOST

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Radiation Oncology –Treatment Planning

Purpose: To create a knowledge-based model for prostate cancer radiotherapy with unique ability to handle two distinct target doses in a hypofractionated regimen.

Material and Methods: An initial RapidPlan model was trained using 48 patients treated with 60 Gy to prostate (PTV60) and 44 Gy to pelvic nodes (PTV44) in 20 fractions. All clinical plans used volumetric modulated arc therapy (VMAT) and met institutional dose constraints. To improve the model's goodness-of-fit, an intermediate model was generated using the dose-volume histograms of best-spared organs at risk (OARs) of the initial model. Using the intermediate model and manual tweaking, all 48 cases were re-planned. The final model was trained using these re-plans and validated on 50 additional patients. The validated final model was used to determine any planning advantage obtained by using three arcs instead of two on 16 VMAT cases. It was also tested on 25 additional cases to determine its efficacy for single PTV (60 Gy to prostate) treatment planning.

Results: For the model validation study, PTV V95% of 99.9% was obtained by both clinical and knowledge-based planning. D1% was lower for model plans: by 1.2±0.1 Gy (PTV60), and by 2.4±0.4 Gy (PTV44). OAR sparing was superior for knowledge-based planning: ΔDmean = 3.7±0.4 Gy (bladder), and 3.2±0.4 Gy (rectum); ΔD2% = 1.2±0.3 Gy (bowel bag), and 4.8±0.4 Gy (femoral heads). All stated improvements have $p<0.001$. Total knowledge-based planning time (typically under 30 minutes) was shorter than manual planning (typically 2.5 hours). The benefits of using three arcs instead of two on OAR sparing and PTV coverage were statistically significant, but of magnitudes less than 1 Gy. The model failed to produce reliable DVH predictions for single PTV plans.

Conclusions: Our knowledge-based planning model delivers efficient, consistent plans with excellent PTV coverage and improved OAR sparing compared to clinical plans.

O-108

ANALYSIS OF RAMAN SPECTROSCOPY IN NAILS FOR DIABETES IDENTIFICATION: PRELIMINARY RESULTS

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Biomedical Engineering

The relationship of the nails with the general state of health and nutritional deficiencies is reflected in the changes in the intercellular links and epithelial cells of the keratinization, which is affected due to the alterations of biochemical processes that cause diseases, like Diabetes. In Mexico, according to the World Health Organization WHO one of the main diseases that is increasing is Diabetes Mellitus 2 (DM2) of 422 million by 2030. Diabetes is a metabolic disease due to the alteration of carbohydrates and the variation in blood sugar levels, this change is related to a protein glycation process that generates hardening of collagen causing different neurological disorders, hyperglycemia and is considered a risk factor for the development of osteoporosis. Some authors, such as Gupta D. et al, correlate depression in diabetes, presenting lower levels of free tryptophan in relation to other neutral amino acids and the inhibition of the enzyme 5-hydroxylase 2 of tryptophan (5HT) that decreases serotonin. Therefore, tryptophan circulates in plasma through proteins along with other essential amino acids, present in patients with diabetes. In this pilot test, 24 nail samples from people with the Raman DRX spectroscopy technique were analyzed, of which 12 are from healthy patients and 12 from patients diagnosed with DM2. To obtain samples, a cut was made in the distal area or free edge of the nail. The results provided information where a significant tryptophan increase of (α = 0.15%) in the mineral ratio of each patient's fingernail was detected, as well as the identification of the main amino acids. The relation as such of tryptophan with diabetic patients so a larger sample will be made, and statistically analyze the difference in intensities between peaks of each mineral identified.

O-111

PHYSICAL DOSIMETRY OF THE TREATMENT OF HYPERTHYROIDISM WITH I-131 COMPARED TO THE COMET'S ASSAY.

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Nuclear Medicine

In hyperthyroidism, the MN doctor prescribes the activity of I131 using the Marinelli ‘404’ equation, in this sense, patient-specific dosimetry has not been implemented in the region. This work shows the possibility of performing post-treatment dosimetry in 50 patients, accompanied by cytogenetic evaluation with the comet assay (EC), the results are consistent with the compartmental model of internal dosimetry. An image dosimetry conjugated with a SPECT and a Pinhole collimator was implemented, using the MIRD methodology. Fifty patients were sampled, obtaining the conjugated images of the thyroid in five samples spaced during 6, 12, 24, 48, 96 hours and different peripheral blood samples were obtained from the fifty patients in 3 days. Once the images were obtained, the relative count number of the images was determined by the free program ImagenJ 1.51K, these values were represented as a fraction of incorporation as a function of time, to which a least-squares approximation was applied, the area under the curve was determined, which represents the activity of I131 accumulated during the residence time, with which the absorbed dose was determined. The cytogenetic damage values were determined with the EC. Some patients do not follow the retention curve considered ideal, it could be observed that in several of them the thyroid did not normally capture I131, so the images were distorted with respect to the normal thyroid. In general, the doses are greater than the doses estimated as euthyroid doses, which for women of childbearing age means complications to procreate. The physical dosimetry shows a great coherence with the values of residence time in blood determined with the EC and, according to the experience acquired, the feasibility of applying a specific dosimetry for the patient has been demonstrated.

O-112

IRRADIATION PROTOCOL FOR THE CENTRAL NERVOUS SYSTEM WITH THE CRANIAL-NEURAXIS TECHNIQUE IN TOMOTHERAPY

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Radiation Oncology – Dosimetry

TomoTherapy equipment, unlike conventional linear accelerators, allow the treatment of volumes with lengths greater than 100 cm in the same treatment plan to be carried out. An example of these types of volumes occurs when radiation needs to be applied to the Central Nervous System due to the presence of some type of cancer. This work shows the protocol that was developed and applied to 3 patients at the State Cancerology Center in Durango, Mexico using TomoTherapy HDA equipment and the cranial-neuraxis irradiation technique. The development of the Simulation Process, Treatment Plan, Specific Patient Quality Control, and Delivered Dose Verification is presented. Gamma results greater than 97% are obtained for the Specific Patient Quality Controls taking into consideration a 3% dose and a 3 mm distance to agreement with more than 4,000 points measured (using ArcCHECK). The results for the Delivered Dose Verification have less than 1% difference between what was planned and what was delivered to the patient on a daily basis. Based on the procedures shown for carrying out the Quality Control, Specific Patient and Delivered Dose Verification, the ease and good performance of the TomoTherapy equipment to perform treatments at volumes with lengths longer than 40 cm in one treatment plan is demonstrated; this avoids the complications implicit in conventional accelerators for this type of treatment.

O-114

DOSE HOMOGENEITY ON INTRABEAM®-SYSTEM SURFACE APPLICATOR BEAM OVERLAPPING AND NON-OVERLAPPING REGION USING 3D PRINTED BOLUS

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Radiation Oncology –Treatment Planning

Purpose:The Carl Zeiss INTRABEAM® system is a mobile miniature x-rays device which delivers treatment by a number of methods; including intraoperative, interstitial, intra-cavity, and surface treatments. The main purpose of the study is to develop Dose homogeneity on INTRABEAM®-System surface applicator beam overlapping and non-overlapping region using 3D printed bolus.
Material and Methods:The different thickness and filament densities ABS (Acrylonitrile Butadiene Styrene) concave, convex and main body parts of bolus was made for Carl Zeiss INTRABEAM® system surface applicator of diameter 4cm with the help of German RepRap 3D printer. GafChromic eBT films were irradiated with 50 kv x-ray of carl Zeiss INTRABEAM® system with surface applicator in presence of bolus. Then films were scanned with an EPSON® Expression 10000 XL/Pro flat bed scanner and dose profile were plotted with ImageJ Software.
Result:The dose profiles were plotted for the different combination of concave and convex boluses (printed from 3D printer) with thickness 5mm, 6mm, 7mm, 8mm, 9mm and 10mm. From the plotted profiles, the maximum flat profile was seen in the boluses with each thickness 10mm and combination of concave filament density 45% and convex filament density 100%.
Conclusion: The dose homogeneity can be achieved for the INTRABEAM® system Surface applicator beam overlapping and non-overlapping region by using homemade bolus with different combination and filament density of concave and convex parts of bolus.

Keywords: INTRABEAM® system (Electronic Brachytherapy), surface applicator, 3D printer.

O-116

DIRECT MR IMAGE TO SYNTHETIC CT CONVERSION METHOD – OVERVIEW OF THE SIX-YEAR EXPERIENCE ON THE CLINICALLY USED PROSTATE PROTOCOL WITH RESEARCH ON ABDOMEN, THORAX AND H&N

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Radiation Oncology – Treatment Delivery

Introduction: Establishing the whole RT workflow based on MR images can reduce coregistration uncertainties, eliminate unnecessary dose to healthy tissue, increase patient comfort, and optimize clinical resources. Purpose of this work is to overview the in-house sCT method for prostate cancer patients with reflecting possible usage in abdomen, thorax and head.
Materials/Methods: The dual model technique for sCT creation is based on a single MRI sequence and consists of two consecutive steps: automatic contouring of bone volumes, following direct MR intensity to HU value conversion.
Results: Mean absolute HU uncertainties in sCTs were 34 HU in head and 42 HU in pelvis. Mean CTV dose differences against CT images with VMAT and IMPT in brain and prostate were below 0.3 %. Technique was tested also for prostate patients with metallic hip implants, providing absolute dose calculation accuracy of 0.2±0.1% for mean PTV dose. The sCT method was tested on four different MRI platforms - with large intensity variation between scanners – with PTV mean dose difference of -0.6 ± 0.4%. Pediatric patients imaged with T2w images were investigated for targets in abdomen, vertebrae and lungs. Mean dose difference on abdomen target ITV V95% for VMAT and PBS scanning were 0.5 % and 0.0 % against CT images, respectively. Lung and vertebrae PTV mean dose comparison resulted 0.1 ± 1.4 % and 0.2±0.1 %, respectively. The MR-only protocol has been used for nearly 500 prostate patients in our clinic. Approximately in 8% of cases, CT image has been applied due to either poor gold seed visualization, artifacts caused by metallic implants, or motion artifact.
Conclusion: Dual model method can provide flexible and practical sCT creation based on widely available MRI sequences, and has performed properly during our six-year utilization. Workflow can be performed on an open source software platform if necessary.

O-124

MONTE CARLO MODELING AND VALIDATION OF AN ORTHOVOLTAGE RADIATION THERAPY UNIT FOR TREATMENT PLANNING OF SUPERFICIAL LESIONS

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Radiation Oncology –Treatment Planning

Introduction
Monte Carlo (MC) modeling of an orthovoltage radiation therapy unit was performed, and simulated orthovoltage X-ray beam data was validated with measurements. This MC model of the unit will be used with a CT image based orthovoltage radiation treatment planning system (ORTPS) for volumetric dose calculations.

Methods and Materials
The EGSnrc MC code system (NRCC, Ottawa) was used to simulate the Xstrahl 200 orthovoltage unit (Xstrahl, Surrey, UK) with various beam energies and applicators (20 cm and 50 cm FSD). The MC-calculated dose distributions were validated against dose profiles and PDDs measured with a CC13 ion chamber (IBA Dosimetry) in water. The phase space files generated at the bottom of the applicators will be used in the ORTPS for the MC dose calculation within the patient.
The ORTPS, currently under development, is being built on the existing open-source software for 3D image analysis and visualisation, 3D Slicer, and will be based on the treatment planning module in the SlicerRT extension. In order to do MC dose calculations, the software will be integrated with EGSnrc.

Results
The MC-calculated and measured dose profiles and PDDs agree better than 2% for both types of applicators, except for 4% in the heel effect regions for the 50 cm FSD applicators. The MC-calculated dose in a water phantom with voxels of size 0.20×0.20×0.25 cm3 has an estimated uncertainty of less than 1% of the dose in the high dose regions.

Conclusions
A MC model of the Xstrahl 200 orthovoltage unit has been validated. This model will be used for dose calculations in the ORTPS. Additional investigations are being done to improve agreements between MC-calculated and measured dose profiles in the heel effect regions for 50 cm FSD applicators.

Key words
Monte Carlo, Orthovoltage, Treatment Planning System, EGSnrc, 3D Slicer, SlicerRT

O-125

VALIDATION OF ADAPTIVE IRRADIATION PROCEDURES FOR MR-GUIDED RADIOTHERAPY USING A NOVEL DEFORMABLE PHANTOM

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Radiation Oncology – Treatment Delivery

Introduction:
In MRgRT, interfractional anatomical changes can be corrected by treatment plan adaption. Due to the complex correction process, specific end-to-end tests must be performed that require new phantoms, which should include:
i. Flexible, reproducible positioning of organ-like inserts
ii. Anthropomorphic imaging contrasts (MRI, CT)
iii. 3D dose measurements
While (i) and (ii) are necessary to test deformable image registration algorithms (DIR), (iii) enables the verification of dose application and may be implemented using 3D polymer gels (PG).

Methods & Materials:
For this purpose, a phantom was designed with different anthropomorphic structures meeting the requirements (i)-(iii), which can be reproducibly rotated, linearly shifted and exchanged. It was applied on a clinical MR linear accelerator (MRidian, ViewRay, USA) to test parts of the online adaptive planning procedure for interfractional target deformation. A PG container was homogeneously irradiated within the phantom. The PG container was then replaced, rotated by a defined angle and a bony structure was replaced by an air cavity. The treatment plan was adapted accordingly, and the irradiation repeated. The pseudo-CT required for plan adaptation was generated by DIR of a previously acquired CT to current MR datasets.

Results:
First measurements showed a good performance of DIR algorithms for linear insert displacements but were not able to fully detect rotations. The PG evaluation showed a homogeneous dose response (<2%) in all irradiations performed. Due to the replacement of the bone structure by an air cavity, the dose was higher in the latter case as this was not correctly identified by the plan adaption procedure.

Conclusion:
The phantom could be used to test a DIR algorithm and simulate an adaptive treatment. Future experiments will focus on the 3D-dosimetric verification of adapted irradiation plans and the development of suitable end-to-end tests for the validation of complete interfractional adaptive treatments in MRgRT.

O-128

A MODEL TO SIMULATE OXYGEN TENSION IN AND AROUND A TUMOR CAPILLARY

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Radiation Oncology – Treatment Delivery

Introduction. As hypoxic cells are more resistant to photon radiation, it is desirable to obtain information about the oxygen tension (PO2) distribution in tumors prior to the radiation treatment. Mathematical models are typically used to assess these microscopic PO2 distributions since non-invasive imaging method are currently not able to provide quantitative high-resolution information. Many current models are very simplistic and do not consider intracapillary oxygen flow. In this work, the effect of considering this process , together with the corresponding oxygen flux through the capillary wall and diffusion-consumption in tumor tissue, is studied.

Methods and Materials. Three equations were solved with a Finite Differences Method implemented in Matlab in three subregions of a volume of interest containing one cylindrical capillary: i) Inside the capillary: advection equation, ii) through the capillary wall: flux/conservation equation and iii) in the tumor tissue surrounding the capillary: diffusion-consumption equation. The effect on tumor oxygenation of changing capillary radius and blood velocity is studied.

Results. Simulated PO2 distributions indicate PO2 drops of 0.01 to 0.07 mmHg/µm along a capillary, for the following values of capillary radius and blood velocity (r,v), respectively: (7.5 µm,0.8 mm/s) and (5µm,0.4mm/s). In general, the change in PO2 is larger for smaller capillaries and slower blood flow. For the first case, the number of tumor cells oxygenated by one single capillary is 29% larger than for the second case.

Conclusions.
Considering oxygen advection along tumor capillaries, the variation of radius and blood velocity has a non-negligible effect in the assessment of tumor oxygenation. Simpler 2D models already used for this purpose may be calibrated with our results, in order to make them able to assess a more realistic (effective) oxygenation status.

O-130

REAL TIME MOTION TRACKING WITH EPID BASED OPTICAL FLOW TECHNIQUES

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Radiation Oncology – Dosimetry

[Introduction] Intra-fraction tumour and organ motion during radiation therapy must be monitored to ensure optimal patient treatment and safety. The tumour motion can be accounted for in many ways: (1) by increasing the ITV, (2) the use of gating or breathing restrictions and (3) beam and tumour alignment. Increasing the ITV increases the dose to healthy surrounding tissue while gating and breath hold techniques decrease treatment efficiency. Direct tracking systems using implanted fiducial markers are invasive, and lung cancer patients are at risk of a pneumothorax. Indirect systems do not pose a health risk, but weak correlation between the secondary signals and the tumour have been reported.

[Methods & Materials] We have demonstrated the feasibility of tracking an uncontoured-target using the motion detected by an Electronic Portal Imaging Device (EPID) at 2.5 frames/sec, within both a moving treatment aperture and with a rotating gantry. Tracking was achieved using a weighted optical flow algorithm. Portal images sequences were acquired on a 6MV linear accelerator and an optical flow algorithm was used to calculate the tumour velocity and position. Lung tumour motion was simulated using a 3D printed tumour moved by an actuator controlled by LabView. Tumour motion taken from the breathing patterns of seven lung cancer patients was simulated.

[Results & Conclusions] The optical flow algorithm tracked motion with an average accuracy of better than 0.5 mm for both a static treatment gantry with a moving aperture and with a rotating gantry. Motion at the edges of the irradiated field were detected with a tracking error of -0.4 ± 0.3 mm and a precision of 1.1 mm. These results demonstrate that real-time EPID tracking with an optical flow algorithm is a viable approach to improved dosimetric efficiency and patient safety.

O-133

SMALL FIELDS DOSIMETRY: DIFFERENT DETECTORS COMPARISON

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Dosimetry – Reference quality

A photon beam becomes a Small Field when lateral charged particle equilibrium is not reached regardless of the collimating system or the detector type being used. Thus, the conditions required by the cavity theory to relate ionization to dose, are not satisfied. Additionally, both partial focal spot occlusion and volume averaging are important effects to be considered when measuring narrow fields. The present work is aimed to analyze and compare measurements performed by using different small field detectors, according to the new IAEA-AAPM TRS483 protocol recommendations.

Two different diodes (SunNuclear EDGE and PTW T60017 Diode E), a diamond detector (PTW microDiamond 60019), and a micro-ionization chamber (PTW PinPoint 31016) were used. Measurements of dose profiles, percent-depth dose (PDD) curves, and output factors were obtained using a SunNuclear 3D Scanner. A Varian TrueBeam™ linac, at Fundación Centro de Medicina Nuclear y Molecular Entre Ríos (CEMENER), was used to generate 0,5 to 3 cm square jaw collimated beams of 6 and 10 MV, both with and without flattening filter. For output factors, the ratios of detector readings were multiplied by correction factors. For dose profiles, size of penumbra and full widths at half maximum were analyzed and compared. In the case of PDD, consistency of curves for each detector according to energy and field size was observed.

For output factors, it was verified that solid-state detectors need smaller corrections than the ionization chamber. In the case of dose profiles, the curves obtained with diodes showed the steepest penumbra values, minimizing the volume averaging effect. For extremely small field sizes, PDD curves were affected not only by sensitive volume averaging effect, but also by detector housing size. In that regard, the best results were obtained by using detectors with the smallest housing, such as EDGE and PinPoint.

O-135

DOSE INDEX ESTIMATES FOR A GE OPTIMACT580 SIMULATOR

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Radiation Oncology – Dosimetry

The goals of this work were to estimate and study the dose values received by cancer patients in a Simulator by x-ray computed tomography (CT-Simulator). The study shows the results of dosimetric measurements using the methodology recommended by the AAPM and those recommended by the manufacturer. The electrometer readings were taken in dose mode and corrected for temperature and pressure. The CTDI100, CTDIw and CTDIvol values were estimatedaccording to AAPM protocols respectively. The estimated values were compared with the doses reported by the manufacturer, shown on the console (CTDIvol) for the two tests.

It shows how dose measures for both abdomen and head are very close to those published for this kind of equipment as well as those recommended by the manufacturer and published in the reviewed literature. The average weighted CTDI values were 34.06 mGy and 18.07 mGy for head and abdomen respectively. CTDIvol values of 38.15mGy and 20.24mGyare also obtained for head and abdomen respectively. These dose values are acceptable for this kind of equipment and for the acquisition protocols used in clinical practice. In the comparison of these results, it is essential to take into account the protocols and the parameters of image acquisition since these are directly related to the final dose, fundamentally associated with the voltage of the x-ray tube and the product of the tube current x time product, two important factors to consider for a later adjustment and optimization of the protocols.

O-138

ESTIMATION OF THE ABSORBED DOSE IN EYE LENS IN PATIENTS TREATED FOR THYROID PATHOLOGIES WITH I-131 IN NUCLEAR MEDICINE

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Nuclear Medicine

Introduction. One of the main treatments against thyroid cancer involves the incorporation of a radioactive material such as I-131 in the patient. The radiation emitted by this material has therapeutic effects, however, due to the penetrating power of the ionizing radiation, an undesired secondary component (scattered radiation) is generated that can affect radio-sensitive organs. The eye lens is a component of the eyeball, highly sensitive to ionizing radiation, so it is important to study the scattered radiation that can reach this organ in a thyroid treatment with I-131. Methods and Materials. For this study, a batch of TLD-100 thermoluminescent dosimeters was used to estimate the radiation dose in this organ. The dosimeters were characterized under ISO 12794 and NPL Report standards. Also, batch repetitiveness, homogeneity and linearity studies were carried out to construct a calibration curve by irradiating the materials with a 60Co source. In this study, we analyzed 20 patients with metastatic tissue remaining after surgery, to which the radioactive material was added orally. The activities of the supplied radionuclide were 50, 100 and 150 mCi. Results and Conclusions. An average eye lens absorbed dose of 21 mSv was obtained in this study. The experimental data reveal that the dose absorbed in eye lens is below the threshold dose for the production of cataracts due to ionizing radiation, however, the doses received in this organ can be considered high, so unwanted biological effects could appear at the long of the time.

O-157

THE U NAPOLI – UC DAVIS – U VARNA VIRTUAL CLINICAL TRIAL FOR 3D X-RAY BREAST IMAGING

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Diagnostic Radiology –Dosimetry

Introduction The groups at Universities of: Naples (Italy), Davis (USA) and Varna (Bulgaria), are collaborating in a Virtual Clinical Trial (VCT) for dosimetry and image quality assessment in computed tomography dedicated to the breast (BCT), which is based on about 100 digital phantoms of the uncompressed breast from clinical BCT scans acquired at UC Davis.

Methods and Materials The voxels (0.20-0.40 mm by side) of reconstructed BCT slices were segmented into air/gland/adipose tissue/skin and input to a GEANT4 code which produces computer simulated projections of the uncompressed breast with defined X-ray source spectra, at equivalent doses comparable to that of clinical scans. Using a mechanical compression module produced by U Varna we produce an analogous set of compressed digital breast phantoms for simulating image acquisition in digital mammography and in digital breast tomosynthesis. Synthetic reconstructed CT slices are then compared with Davis' clinical CT scans at 80 kV.

Results We produced 3D maps of the glandular dose distribution in the digital phantoms, then calculating the mean glandular dose per unit air kerma and the dose volume histogram in the breast. We also calculated synthetic BCT datasets (reconstructed via FDK or iterative algorithms) at 49 kV and 80 kV, as the sum of the primary and scatter contributions. The comparison of the computer simulated and clinical CT scans at comparable dose levels allows the assessment of differences between scans at different tube potentials and potential changes in the glandular dose distribution.

Conclusions A VCT is ongoing, based on digital phantoms derived from clinical scans using dedicated breast CT. The dataset of about 100 anatomically-realistic, uncompressed breast data sets are processed to produce additional phantoms of the compressed breast, allowing exceptional flexibility for breast imaging research and evaluation of breast CT, digital breast tomosynthesis and mammography in the context of a VCT.

O-164

RESIDENCE IN PHYSICAL PHYSICS WITH UNIVERSITY ACCREDITATION - CHALLENGES AND EXPERIENCE

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Education and Professional Issues

Introduction

In Latin America, there are several educational institutions that offer theoretical training in Medical Physics, but none of them contemplate their subsequent structured clinical training.
For this reason the Residency in Medical Physics of Fundación Médica de Rio Negro y Neuquén and the Universidad Nacional del Comahue has been implemented, being the first in Argentina accredited by a University.

Methods and Materials
The residence was created following the recommendations of the IAEA through its technical documents HHR N ° 1 and HHS N ° 25, using TCS documents 56, 37, 47 and 50 as theoretical bases.
The structure and contents were complemented according to the theoretical training requirements established by the Nuclear Regulatory Authority (ARN) of Argentina for recognition as a training career for the obtaining of individual permits as specialists in Radiotherapy Physics and / or Nuclear medicine.
The Universidad Nacional del Comahue through the regulatory disposition of the Faculty of Medicine determined the final format and structure of the residence.
It was essential the collaboration of companies in the areas of Diagnostic and Nuclear Medicine through Siemens, the participation of Elekta in Radiotherapy and PTW in quality control in all areas.

Results
We currently have two first and second year residents, with a total duration of 3 calendar years, rotating through the areas of Diagnostic Imaging, Nuclear Medicine and Radiotherapy according to the recommendations of the IAEA.

Conclusions
The incorporation of external professors with professional experience and expert advice from the IAEA were key points to achieve its implementation.
It is important to bear in mind that the creation and consolidation of a Residency in Medical Physics in the region is a dynamic process of continuous growth, especially due to the limitations in infrastructures and technologies existing in the region.

O-173

FEASIBILITY OF AN INDEPENDENT DOSIMETRIC VALIDATION FOR THE SMALL ANIMAL RADIATION RESEARCH PLATFORM (SARRP) WITH A CHEMICAL DOSIMETER FRICKE

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Radiation Oncology – Dosimetry

Small animal irradiators through translational research are radiobiological support for the most modern radiotherapy techniques. For SARRP-Small Animal Radiation Research Platform, with x-ray photon beams (220 kVp), current reference dosimetry performed by the vendor follows the recommendations of the AAPM TG-61 (farmer ionization chamber-IC and solid water phantom). Currently, there is not independent dosimetry standardized for SARRP. The objective of this work is to evaluate the feasibility of performer an independent dosimetry with the chemical dosimeter Fricke. The Fricke solution with many desirable dosimetric characteristics has been shown for many authors to be a feasible option for the absorbed dose standard for different beam qualities.

In this study, half value layer-HVL for 220kVp/13 mAs was measured to be 0.66 mm Cu. Effective energy was calculated to be 63.61 keV, and G-value (Fe3+) for absorbed dose to water was 1.441x10-6 ± 0.012 mol/J. Time of irradiation was calculated using the Point-Dose-Calculator (PDC-vendor software), to give 20Gy with two parallel oppose beams at the isocenter with a 3x3 cm2 field size, PDC uses the data from manufacturer commissioning. Fricke solution was distributed inside the PMMA holder (n=5), similar in geometry to the farmer IC and positioned inside a small water phantom. Absorbed dose to water was measured with a farmer IC (PTW-NE2571) in the same setup (n=5).

Very good agreement between Fricke and IC was obtained. The mean dose measured with Fricke dosimeter was 21.793 ± 1.636 Gy and 21.460 ± 0.003 Gy with IC, the deviation between dosimeters was 1.6%. Deviation from calculated dose was 8.9% and 7.3% respectively, in agreement with our previous results obtained with a PTW-PinPoint 3D Chamber in water. The presented dosimeter has been shown to be a good potential independent dosimeter for SARRP, with the option to extend to x-ray small photon fields in further studies.

O-174

MONITORING OF ANATOMY CHANGES DURING MULTI-FRACTIONAL RADIATION THERAPY

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Radiation Oncology – Treatment Delivery

Introduction: Patient’s anatomy may change significantly during radiation treatment. Our routine practice for evaluating the necessity for plan adaptation is presented.

Methods and Materials: Megavoltage CT (MVCT) scan is performed prior to every fraction of radiation treatment on helical tomotherapy unit in our center. Planned Adaptive software is used for QA purpose and calculation of the dose distribution in the MVCT study imbedded into original planning CT. In the case of significant changes observed by radiation therapists, Planned Adaptive procedure is repeated and both dose-volume histograms and point dose values are compared with the ones obtained for the first fraction.

Results: For the Head and Neck cases treated with VMAT on Varian linacs in 2018, 16.5% of patients were re-scanned and new plans were created. For the patients treated in the same period on tomotherapy with implementation of the proposed Planned Adaptive evaluation, only 2.9% of head and neck cancer patients were required to be re-scanned and new plans developed. Off-line consultation with the treating radiation oncologist was crucial in determining the need for plan adaptation. Both patient’s clinical status and the number of remaining fractions were taken into account for the final decision on whether to adapt the initial plan. Re-contouring of the organs with changed anatomy was done only in the projects of evaluating volume change as a function of time, but was not necessary for decision of adaptation.

Conclusions: Planned Adaptive software was shown to be an effective tool for evaluation of the dosimetric significance of observed anatomy changes during radiation treatment on helical tomotherapy. A comparative analysis of dose distributions calculated for the first fraction and for the fraction of suspected large variation in anatomy can save resources in a busy clinic.

O-177

POSTOPERATIVE ENDOMETRIAL CANCER TREATMENTS WITH ELECTRONIC BRACHYTHERAPY SOURCE. COMPARISON TO IR192 AND CO60 HIGH-DOSE-RATE BRACHYTHERAPY SOURCES

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Radiation Oncology – Brachytherapy

Introduction: To compare the first 200 endometrial cancer patients treated in our center with cylindrical applicators and Axxent (Xoft Inc.) electronic brachytherapy and equivalent planning made for Ir-192 source and Co-60
Methods and Material:
200 patients previously treated with Axxent (50 kV source) have been replanned with Ir-192 and Co-60 source. The calculation for three types of source were performed on BrachyVision (Varian Inc.) treatment planning system.
The prescription was 5 Gy per fraction. 3 fractions or 5 fractions depending on previous radiotherapy treatment.
Planning parameters of a planning target volume (PTV) countoured from the cylinder surface to 5 mm along the active length were evaluated. V150 and V200 data for PTV and D2cm3, V50% and V35% for organs at risk (OAR) were evaluated, the percentage volume receiving 35% and 50% of the prescription dose, respectively, and D2cm3, highest dose to a 2 cubic centimetre volume of an OAR. Results for bladder, rectum and sigmoid are showed.

Results:
We may observe a reduction in dose at V35% and V50% in all OAR and also a reduction in D2cm3 occurs. PTV parameters increase in the case of Axxent ,as reported previously, but only one case of vaginal mucositis with grade≥2 has been reported in our center. All patients were treated between 2015 and 2018, enough time to develop early problems.
Conclusions:
Preliminary results are very optimistic about the adequacy of Xoft equipment for treatment of endometrial cancer with a clear reduction of the physical dose in organs at risk and no development of acute mucositis except one patient despite the considerable increase V150 in the treatment volume.
Further studies will be necessary to take into account the RBE in treatments such sources.

O-184

METHODOLOGY FOR THE INTEGRATION OF SPECT WITH EEG INVERSE SOLUTION IN THE LOCATION OF THE EPILEPTOGENIC ZONE IN DRUG-RESISTANT EPILEPSY

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Nuclear Medicine

Introduction: The goal of this work is to propose a methodology that combines the non-invasive functional neuroimages of electroencephalography (EEG) and SPECT for the identification of the epileptogenic zone (EZ) in the surgical evaluation of patients with drug-resistant non-lesional epilepsy.
Methods: This methodology consists of: i) estimation of the sources from the inverse solution (IS) of the ictal EEG; ii) application of the SISCOM (Subtraction Ictal SPECT Co-registered to MRI) methodology; and iii) estimation of the IS of the ictal EEG but using the output of the SISCOM as a priori information for the estimation of the sources. The methodology was implemented retrospectively in five patients to evaluate its capacity to identify EZ. A gold standard and a coincidence analysis based on measures of sensitivity and specificity were used to assess the accuracy of the EZ estimated by the methodology.
Results: In the patients with good postoperative evolution, the estimated EZ presented a spatial coincidence with the resection site represented by high values of sensitivity and specificity. For the patient with poor postoperative evolution, the methodology showed a partial incoherence between the estimated EZ and the resection site. In cases of multifocal epilepsy, the method proposed spatially extensive epileptogenic zones.
Conclusions: The results demonstrate the ability of the methodology to identify EZ in cases that had good post-surgery evolution, as well as partial incoherence between the estimated EZ and the resection site in a case of poor post-surgical evolution. The novelty of the work is based on the estimation of the sources of ictal EEG from an inverse solution method using the SISCOM result as a prior. This methodology contributes to identify EZ, the correct identification of EZ and eloquent regions has an impact on the decrease in invasive records during surgery and at surgical outcome.

O-185

DEVELOPMENT OF AN AUTOMATED TOOL FOR PHANTOM AND COLLIMATOR SCATTER FACTORS TABLE GENERATION

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Radiation Oncology – Dosimetry

Introduction: the commissioning process is a demanding and time consuming task. As part of this process, output factors have to be measured in order to create the models in treatment planning systems (TPS). Varian Eclipse™ TPS require a bi-dimensional output factor table containing both X and Y field sizes. In particular, the commissioning of Varian TrueBeam™ linear accelerator (linac) presents an additional challenge since it has up to 5 photon energies with flattening filter and 2 energies without flattening filter.
Methods and Materials: in this work, we developed an application that can read a text file generated by Sun Nuclear PC Electrometer in Data Logging mode, and a RT Plan exported from Varian Eclipse™ and automatically create the bi-dimensional table in the format required to be imported in Eclipse™ Beam Configuration. The irradiation was done in a Varian TrueBeam™ linac in automation mode. Two methods were implemented, one by the evaluating accumulated charge and another by inspection of the current. We measured the 27 output factor tables and compared them with the Varian representative data
Results: The acquisition time for an entire table was approximately 10 to 15 minutes., finding very good agreement (<1%).
Conclusions: this method is a fast alternative to generate the output factors tables, making it possible to reduce the commissioning process time from several days to a few hours.

O-188

QUALITY ASSURANCE FOR CO-60 HIGH DOSE RATE BRACHYTHERAPY

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Radiation Oncology – Brachytherapy

Introduction: In high dose rate remote afterloading brachytherapy, quality assurance strongly depends on the accurate determination of the source strength, dwell time, and also on the position and transit time of the source. In order to check these parameters in a remote afterloader with Co-60 sources, two devices for well-type chambers were designed, constructed and characterized.

Methods and Materials: QA Cerrobend and tungsten inserts were built for HDR brachytherapy equipped with Co-60 sources. They consisted in a cylinder with a transverse spacer of acrylic at a precisely known distance from the source. The distance of the source to this acrylic window characterizes the response of the detector to the signal. We used a Co-60 HDR afterloading system (E&Z BEBIG 60 Co HDR Co0-A86, Berlin, Germany) and a well-type chamber (PTW 33004, Freiburg, Germany). Acrylic windows of different thickness were tested in order to optimize the signal. The dwell position step was 1 mm and a Vernier caliper fixed to the holder allowed to select different steps. Background current with no window was subtracted in order to determine the source position accuracy. An optimum window and several characteristic points of the response curve were obtained for each holder. From the readings at these points, it was possible to determine the accuracy of dwell positions and transit time.

Results: With Cerrobend and tungsten, respectively, we obtained a sensitivity of the source position better than 2% per mm and a precision of 0.14 mm, a sensitivity and precision of 1% per mm and 0.13 mm and the transit time with a relative precision of 8.3% and 51%.

Conclusion: This methodology may provide an easy and precise way to periodically check source position for HDR Co-60 sources in brachytherapy up to an accuracy of ±0.14 mm.

O-192

DEVELOPMENT OF A 3D-PRINTED HETEROGENEOUS UPTAKE PHANTOM FOR THE ASSESSMENT OF TUMOR VOLUME DELINEATION METHODS USING FDG PET/CT IMAGES

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Nuclear Medicine

Introduction: Tumor volume delineation based on PET image segmentation has gained increasing attention in radiotherapy. This interest is triggered by the clinical implementation of dose-painting techniques, which aim to deliver non-uniform dose-distributions inside the tumor, based on the metabolic activity of the PET images. Here, we describe the challenges faced when designing a Lego-like anthropomorphic, heterogeneous uptake phantom. We also describe the subsequent construction of three inserts for the NEMA image quality phantom.

Methods and materials: We designed a Lego-like female pelvis phantom to evaluate PET segmentation methods in heterogeneous cervical tumor-like activity distribution patterns, near areas of high bladder uptake. Several challenges were faced when attempting to divide it into parts that could be obtained using 3D-printing, as well as when gluing these parts together. These challenges led to the design of three inserts, which could be placed inside the NEMA phantom. The first insert is a smaller version of the female pelvis phantom, described above. The second, shaped like a bicycle chain, contains concentric and non-concentric chambers, allowing us to obtain controlled heterogeneous uptake volumes. The third one is empty, and can be filled with materials of different water absorption indices, resulting in tumor-like uptake patterns.

Results: The PET/CT images obtained from the three inserts ranged from uniform activity distributions to uncontrollable, heterogeneous uptake patterns, similar to those found in patients. We were also able to analyze different tumor to background ratios. In addition, the "bicycle chain" insert allowed us to model several controlled heterogeneous uptake patterns.

Conclusions: The designed inserts may be used to simulate different FDG uptake pattern distribution. This would allow us to assess PET segmentation methods for heterogeneous volume delineation, which may then be used in dose-painting radiotherapy applications. Further work will seek to assess alternative construction methods for the Lego-like phantom.

O-193

DEVELOPMENT OF A SEMI-AUTOMATIC SEGMENTATION TOOL FOR THE EVALUATION OF PET IMAGE BASED TUMOR VOLUME SEGMENTATION: PRELIMINARY RESULTS

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Nuclear Medicine

Introduction: Dose-painting has led to a growing interest in tumor volume delineation based on PET GTV image segmentation, including any heterogeneities found within the tumor. Despite the use of this novel method in several countries, radiotherapy treatment planning in Argentina is generally based on CT-only images and assume uniform dose delivery inside the GTV. Here, we describe the preliminary results in the development of a semi-automatic tool for tumor volume delineation and the assessment of this tool using PET/CT images of patients and of specially designed phantoms.

Methods and materials: We designed a tool to segment PET/CT images using methods described in the literature. The chosen algorithms included: fixed- and adaptive-thresholding, gradient- and texture-based segmentation, supervised clustering, and manual delineation. The performance of the tool was assessed by comparing the manually drawn GTV in CT-only and PET/CT images, with those obtained by PET segmentation methods, paying special attention to any heterogeneous areas. The volumes were drawn by a dual accredited radiotherapy and nuclear medicine physician, who also evaluated the results. This analysis was carried out on uptake patterns obtained in FDG-PET/CT images of NEMA spheres, in phantoms developed in-house, and a range of different tumors.

Results: The GTVs based on the PET/CT images, which were drawn both manually and with the aid of the program, were smaller than those drawn manually by the physician and based solely on the CT images. This is in agreement with previous findings. The segmented GTV, and the heterogeneities within it, were consistently well-delineated by gradient- and texture-based segmentation.

Conclusions: Our results show that it may be feasible to carry out the delineation of both GTV and heterogeneus areas within it using our program. Although preliminary, these results show that the best segmentation method to use depends on patient’s pathology, and tumor to background ratio.

O-196

THE ROAD TO FIRST PATIENT TREATMENT ON ELEKTA'S UNITY MR-LINAC

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Radiation Oncology – Treatment Delivery

Introduction: Our institution installed the first Unity MR-Linac systems in North America and was the first to treat patient with it. In this presentation, we will review and share our experience about the process for clinical operation of this system.

Methods: The steps leading to patient treatment on the Unity MR-Linac were reviewed and analyzed, including site planning and preparation, system installation and initial assessment, staff education and training, development of policies and procedures, system commissioning, design and evaluation of QA procedures, and development of a workflow. Each step was reviewed and successfully completed with improvements and potential pitfalls identified and discussed.

Results: Clinical implementation of an MR-Linac system was a complex task that requires expertise in multiple domains. A multidisciplinary team approach was absolutely critical in order to ensure successful clinical implementation and operation. MRI-guided RT is an evolving technology in many aspects which requires continuous development and innovation by the medical physics community in order to realize the full potential of such paradigm changing technology.

Conclusion: Clinical implementation of the Unity MR-Linac system required a collaborative, multidisciplinary approach and involved several groups of staff with cross-domain expertise. It was critical to prepare and educate staff; assemble the right people together into an implementation team; and establish the right processes, tools and safety policies early to ensure the success of clinical operation.

O-199

EPIDEMIOLOGIC STUDY OF OCCUPATIONAL LOW DOSE EXPOSURES AND THE DESIGN OF FUTURE CANADIAN COHORT STUDIES

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Radiation Protection

The goal of this work was to perform an epidemiologically driven literature review regarding the health effects of occupational low dose exposure. A scoping review was conducted with pre-defined inclusion and exclusion criteria for previously published systematic reviews on the topic as well as primary studies. The body of research was found to be a dense network of overlapping studies across specific types of occupational cohorts. Five occupation specific cohorts were used throughout this study: medical personnel, nuclear industry workers, uranium miners, Mayak cohort and other. Methods of dose reconstruction varied across studies and even when personal dosimeters were used, they often only represented a subset of the study cohort. Information from questionnaires on work history practices, including facility type, number of years worked, and types of procedures performed were used to generate artificial personal dosimeter data when individual badge measurements were not available. Several health outcomes have been reported across the various occupational cohorts. Earlier studies focused on mortality (all causes and specific causes including cancer). Mortality comparisons between cohorts and the general populations have found lower standard mortality ratios - described as the healthy worker effect. More recent studies have focused on disease incidence including exploration of association between radiation dose and circulatory diseases. However, studies continue to experience challenges that result from the lack of information about potential lifestyle con-founders that influence the reported associations. The results of the review will be presented as well as a data quality proposal for the utilization of the Canadian National Dose Registry (NDR) database for the study of occupational exposure in Canada.

O-200

WORLDWIDE IMPLEMENTATION OF DIGITAL IMAGING IN MAMMOGRAPHY: REPORT FROM AN IAEA WORKGROUP

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Diagnostic and Interventional Radiology – General

Introduction:
In 2016, the IAEA published document HHS28 "Worldwide Implementation of Digital Imaging in Radiology" supporting the introduction of digital imaging in general radiology. In response to the need to advise Member States, and recognizing that there was no practical guidance on how to make potential transitions toward digital mammography, a workgroup was formed in 2017 with the objective to investigate the topic and develop relevant guidelines.

Methods:
The workgroup consisted of medical physicists and a radiologist with experience in the technical and organizational requirements of high-quality breast cancer imaging. Recommendations were in the form of a transition "roadmap" to guide a facility from its current operational state to one with the potential to provide better results.

Results and conclusions:
Recommendations describe transitions that are desirable and possible, given the limitations of available resources at a site. Guidelines on the Worldwide Implementation of Digital Imaging in Mammography, expected to be published in 2019, are intended to assist policy decision makers, planners, program administrators and professionals working in health care in establishing or upgrading capabilities for diagnostic or screening mammography. Specific attention is given to the transition between technologies, including retrofitted solutions (either for computed(CR) or digital(DR) mammography). Although this can be a financially realistic and reliable solution, the ease of transition is sometimes misleading and if the process is not carefully planned and implemented, it can easily lead to suboptimal performance.
Guidelines include examples of decision trees, for medical imaging facilities of different size and levels of technical development, suggesting how to move forward toward providing higher-quality mammography. These can guide informed decision making on the initiation or upgrade of services. The publication analyses implementation scenarios, describing viable and realistic solutions for different facilities with different needs, capacities and resources, and provides information on resources and requirements for different technologies.

O-201

IMPROVEMENT OF DOSE DISTRIBUTIONS IN VOLUMETRIC MODULATED ARC THERAPY (RAPIDARC) WITH JAW TRACKING TECHNIQUE FOR LATERALIZED TARGETS

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Radiation Oncology –Treatment Planning

Introduction: Jaw tracking technique (JTT) in RapidArc treatments allows blocking unwanted leakage radiation. For patient's lateralized targets, keeping the isocenter centered can be helpful to avoid collisions, spare couch motions and treatment times. Nevertheless, in these cases the standard, static jaw technique (SJT) could result in more healthy tissue dose. This work compared dosimetric differences between JTT and SJT in RapidArc treatments for lateralized targets with isocenter in patient's midline.

Methods and Materials: Four pancreatic SBRT standard plans were replanned with JTT. Plans were created using a 6X beam of a TrueBeam STx and Eclipse v15.1 (Varian). PTV's D95%, D2% and Paddick's conformity index (CI) were compared. V5Gy, V10Gy, V20Gy and normal tissue's Dmean were compared. Portal images were taken for verification.

Results: The variations of PTV's D95% and D2% between JTT and SJT plans averaged 2% with a standard deviation of the same order. The first two cases, with the most lateralized targets, presented almost no change in CI while the other two improved 38% and 18%. Increased dose ring shaped areas were observed in the first two SJT plans. Dose in those areas decreased from 7.13 Gy to 5.44 Gy and from 10.4 Gy to 6.53 Gy with JTT. Portal images of those SJT plans showed radiation leakage between closed opposed leaves with a peak about 30% of the maximum fluence. Dmean reduction with JTT compared to SJT in all plans averaged 11% with standard deviation of 7%. Almost all V5Gy, V10Gy and V20Gy values decreased an average of 11,7% with JTT in comparison with standard plans, with a standard deviation of 11.1%. An isolated V10Gy value actually increased 5%.

Conclusions: JTT plans were capable of delivering better dose distributions for all cases, either due to improved healthy tissue protection or better PTV coverage.

O-209

END-TO-END TESTS WITH SRS MAPCHECK FOR FRAMELESS RADIOSURGERY IN THE RADIOTHERAPY DEPARTMENT OF CLINICA ALEMANA DE SANTIAGO.

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Radiation Oncology – Dosimetry

Introduction
Radiosurgery is a complex treatment technique, where high doses of radiation are delivered to small volumes in one or a few sessions, which requires high precision in the delivery of doses, whose process involves several steps, such as image, planning and treatment. At each stage, rigorous quality controls must be carried out to ensure its efficiency and fidelity.
Materials and methods
The SRS MAPCHECK is a phantom specially designed to perform end-to-end tests on radiosurgery techniques quickly and safely, checking the overall fidelity of the treatment. In the Clinica Alemana, the radiosurgery technique without stereotactic frame (Frameless) was implemented with multileaf (MLC Agility), with a Linac Elekta Synergy Performing these tests to ensure all steps of the treatment administration process. First, the phantom was characterized by checking its response (according to) to field size (small fields), dose rate, and angular dependency. Then, the designed tests were performed, starting with checking the matching accuracy between CT/MR images (fusion), following the reproducibility of positioning using XVI imaging system. The algorithm for the calculation of the Treatment Planning System (TPS) Monaco was then verified through dose distribution analysis with Gamma factor and criteria 1 mm and 1%, also absolute dose measurements.
Results and Conclusions
Given the results obtained, the implementation of the Frameless radiosurgery technique in the Radiotherapy service of the Clinica Alemana of Santiago is in accordance with international standards. All parameters evaluated in the treatment process indicate that the planned dose distributions match spatially and dosimetrically with those delivered. Whereas, the minimum size of the lesion should be 5mm and the stretcher angles used for the plan must be within ± 45 °, multiple lesions can be verified as long as they are not too far from the isocenter and are within the area of 7x7cm2.

O-211

RADIOSURGERY CONICAL COLLIMATORS COMMISSIONING BASED ON TRS 483

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Radiation Oncology – Quality Assurance

Radiosurgery is a complex radiotherapy technique requiring high levels of precision due to the high dose delivered in few fractions over a small target volume surrounded by critical structures. In order to protect such structures and achieve a high dose gradient, the technique can be administered using conical collimators generating small fields. This modality implies dosimetric difficulties and challenges, for which the new Code of Practice IAEA-AAPM TRS 483 has been recently developed.

The aim of this project was to commissioning the Varian ICVI radiosurgery system, including seven conical collimators ranging 4 mm to 17.5 mm, to be used in a TrueBeam STx® accelerator with 6 MV and 10 MV beams, with and without flattening filter, and with Eclipse™ Cone Planning software. Dose profiles, tissue maximum ratios and output factors were measured following the new recommendations and using Edge™, microDiamond™ and Diode E™ detectors, as well as the 3D Scanner™ phantom, and the results were compared with the manufacturer's reference data. After calculation model was created, calculated profiles and dose depth curves were validated against measured data using different gamma criteria. An End-to-End test was also carried out using PinPoint® 3D ionization chamber and the recently released SRS MapCheck™, as well as the StereoPhan™ phantom, for which special considerations of material had to be made.

Relative dosimetry curves passed gamma criteria of 2%1mm in lowest energies. A disagreement of up to 10% compared with reference data could be observed in the output factors, which were calculated employing the output correction factors introduced in the new protocol. After End-to-End test using ionization chamber, the cones equal or greater than 7.5 mm showed differences within 2% between the measured and the calculated dose. The smaller cones were later validated using SRS MapCheck™ for 6 MV beam and showed differences within 3%.

O-213

APPLYING TG-218 METHODOLOGY TO LARGE FIELD VMAT QA USING A GANTRY-RESOLVED EPID-BASED TECHNIQUE

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Radiation Oncology – Quality Assurance

Introduction: The purpose of the study was to evaluate the performance of a gantry-resolved EPID-based QA method for patient-specific QA of large VMAT fields using process-based limits per TG-218.

Methods and Materials: A gantry-resolved EPID-based QA method was used for patient-specific QA of 35 large VMAT fields (field size range from 17x30cm2 to 30x40cm2) used for GYN cancer treatments. All fields were measured with two EPID models and two photon energies, accounting for a total of 140 measurements divided into 4 different groups (processes). The method created pseudo-3D dose distributions from stacked portal images acquired on TrueBeam Linac using dosimetry (integrated) acquisition. Predicted portal dose distributions were calculated based on MU information contained in the image headers. Gamma pass rates for pseudo-3D and composite 2D dose distributions were used to calculate process-based tolerance and action limits following the TG-218 methodology (3%/2mm/10%threshold criteria). For the pseudo-3D distribution, the gantry angle accuracy requirement was given by an angle-to-agreement (ATA) criteria of 3º.

Results: All gamma pass rates for gantry-resolved pseudo-3D distributions were within the recommended universal action limit of 90%, and average pass rates were higher than 95% for all processes. Gamma analysis of 2D distributions produced average gamma pass rates close to 99% and an overall performance superior to Varian’s Portal Dosimetry. All calculated tolerance limits were stricter than the action limits and no process displayed an out-of-control behavior. The differences in performance among the processes (EPID models and energies) illustrated they are affected by different sources of variation. The calculated process-based tolerance and action limits complied with TG-218 recommendations.

Conclusion: The method has shown its suitability for use in patient-specific QA of large VMAT fields. The results met the recommendations of TG-218. The variability among different processes indicates that improvements are possible to obtain stricter process-specific tolerance and action limits.

O-221

TO INVESTIGATE AND VALIDATE OPTIMAL PLANNING STRATEGY, RAPID DOSE DELIVERY METHODOLOGY IN GAMMA KNIFE RADIOSURGERY (GKSRS) FOR ACOUSTIC NEUROMA TUMORS.

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Radiation Oncology – Treatment Delivery

Introduction:
To investigate and validate optimal planning strategy, rapid dose delivery methodology among forward, inverse and inverse modified planning in Gamma Knife Radiosurgery (GKSRS) for acoustic neuroma tumors.
Methods and Materials:
Seventeen patients with acoustic neuroma tumor were planned for GKSRS using (1)forward planning(FP), (2)inverse planning(IP) and (3)inverse modified planning(IMP) methods in Leksell Gamma Plan (LGPVersion10.1) with TMR10 algorithm. All patients were scanned in MRI (GE, USA) with following scanning parameters: T1W images-MPRAGE sequence, FOV-256mmx256mm, matrix size-512mmx512mm, slice thickness-1mm. The prescription dose was 12Gy at 50% for all cases. Validation of all three planning strategies was performed by simulating treatment in an inhouse made phantom with EBT3 film insert. As a first step, X-ray CT was done with phantom using following scanning parameters: FOV-256mmx256mm, Tube Voltage-120kVp, slice thickness-1mm. The acquired CT images were imported into TPS and co-registered with MRI of patients for target/critical organ delineation. The phantom with EBT3 film was mounted in GK couch for film measurement.
Results and Discussion:
Mean tumor volume for seventeen patients was 7.2cc. The mean coverage Index (CI) for FP, IP, IMP were 96.47±2.35, 96.06±0.90, 95.76±1.44 and mean beam ON time (in minutes) were 51.6±14.6, 76.9±17.0, 60.5±16.0. The TPS calculation versus film measurement showed that for gamma pass criteria of 3%/3 mm, 2%/2 mm and 1%/1 mm, pixel pass rate was 98%, 97%, 92% for FP, 81%, 74%, 60% for IP, 99%, 99%, 97% for IMP respectively. Line profile comparison between TPS and film measurement dose for FP, IP, IMP showed a dose difference of 5%, 12%, 5% respectively. Brainstem (BS) dose was minimal in FP and IMP whereas IP delivered dose twice to BS than FP.
Conclusion:
Overall results show that IMP based planning is an efficient, time saving strategy which has the potential for implementation in a busy radiosurgery clinic.

O-224

SMALL FIELD DOSIMETRY OF ROTATIONAL PHOTON BEAMS: A FEASIBILITY STUDY

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Radiation Oncology – Dosimetry

Introduction
The new code of practice for small field dosimetry TRS-483 addresses static photon beams only. Nevertheless, current practices with such beams are more frequently applied to rotational beams. Plan verification of radiosurgery treatments, using very small cone shaped beams, could require the application of field output correction factors, that have been reported in the TRS-483 for static beams; the feasibility of using such factors in rotational beams is assessed.
Methods and Materials
The Monaco treatment planning system (TPS) has been recently commissioned for stereotactic treatments in an Elekta Synergy linac, using add-on cones, defining field sizes from 5 to 35 mm diameter. The field output factors generated by the TPS were verified for static, orthogonal incident beams, using the recommendations of the TRS-483, comparing against the results of several PTW detectors, including unshielded diodes (60017 and 60018) and microdiamond (60019). For verification of rotational beams, a single co-planar arc was planned and delivered for each cone size, using a cylindrical phantom, model PTW IMRT Matrix T40026. The detectors were placed at the isocenter, in the phantom’s central hole.
Results and conclusions
Main issues related to using TRS-483 field output correction factors in rotational beams, incident on cylindrical phantoms, were associated to the centring of the detector and the orientation of the beam regarding the solid-state detectors. CBCT and EPID improved the accuracy of centring, but still, it can be the main cause of measurement uncertainty. Results showed that TRS-483 correction factors are applicable to rotational beams, if accurate centring is achieved. The effect of perpendicular incidence on the detector showed negligible impact when using the microdiamond detector, while systematic discrepancies appears with silicon diodes, showing a reduced output factors. TRS-483 for relative dosimetry can improve accuracy in absolute dose verifications for radiosurgery treatment with very small fields.

O-226

RECONSTRUCTION OF TOTAL BODY COMPUTED TOMOGRAPHY- ROBOCOT: A PATIENT-SPECIFIC VIRTUAL WHOLE-BODY CT SCAN GENERATOR FOR ASSESSING PERIPHERAL ORGAN PHOTON DOSE.

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Radiation Protection

Purpose: In order to being able to assess peripheral photon dose in patients undergoing radiotherapy, information about organs' position and geometry is necessary. However, planning CTs are usually restricted to the region surrounding the PTV and do not include the majority of the patient's organs. In this work, a Reconstruction Of total BOdy COmputed Tomography –ROBOCOT- tool for generating patient-specific virtual whole-body CT scans has been developed. For that purpose, ROBOCOT uses the patients' planning CTs and the ICRP-110 reference computational phantoms.
Method: Some of the capabilities of MATLAB and its Image Processing Toolbox are used to convert a CT image and one of the computational phantoms (male or female) to the same format and finally to make a rigid image registration. A user-friendly graphical interface has been developed to aid those steps.
Result: Through the graphical interface, the user can load the patient's CT image and the corresponding reference computational phantom and then visually select the region of the phantom corresponding to the patient CT image. After that, an automatic rigid registration takes place, producing a virtual whole-body CT representative of this patient's geometry and including the segmentation and identification of the organs specified in the ICRP Publication 110. The interface has been integrated with PERIPHOCAL, an analytical model for assessing peripheral photon dose, also implemented in MATLAB. The image registration and the dose calculation were validated with the anthropomorphic phantom ATOM for a prostate cancer treatment.
Conclusion: A tool for calculating patient-specific photon dose to out-of-field organs during radiotherapy, based on the generation of a virtual CT image, was developed.
BSN is in debt to Conicyt (Fondecyt N1181133). I.E. acknowledges the support of Conicyt (Fondecyt N111505601).

O-227

ASSESSMENT OF ORGAN-SPECIFIC OUT-OF-FIELD DOSES AFTER A THREE-FIELD IRRADIATION BASED ON MONACO ALGORITHMS AND MONTE CARLO

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Radiation Protection

Purpose: Treatment Planning Systems (TPS) are not designed for out-of-field dose calculations. Large errors (up to 70%) have been reported even for modern Collapsed Cone (CC) and anisotropic analytic algorithm (AAA) algorithms. To our knowledge no reports exist on the accuracy of the Monte Carlo (MC) and the CC algorithms as implemented in the MONACO® TPS with regard to out-of-field dose estimation. This study compares the EGSnrc MC simulation with a conventional plan by MONACO® TPS.

Method: BEAMnrc was used to create a model of an Elekta Axesse™ accelerator head operating at 6 MV. The model was validated with measurements with a semiflex chamber in water. A simple 6MV three-field plan centered at the right lung was considered. DICOM and EGSPHANT files of the reference computational phantom ICRP-110 were generated for dose computation with Monaco® and the dose scoring utility DOSXYZnrc, respectively. Distances (in craneo-caudal direction) from the center of mass of 13 organs to the 50% isodose were calculated. Dose volumetric information for these organs were generated with MONACO® and the EGS4nrc MC simulation.

Results: Compared to the MC simulation, both algorithms underestimated the mean and minimum doses to organs beyond 4 cm outside the 50% isodose. Differences in average dose were up to 90%. Generally, CC performed better than MC in the TPS. For some organs, local maximum doses reported by CC were overestimated due to an artifact of the CC algorithm which could be visualized as isodosis beyond 1% bearing a strong resemblance to the incident ray. We did not find that the underestimation worsened for increasing distances to the treatment fields.

Conclusions: The found differences motivate out-of-field dose estimation by experimental measurements and/or specific analytical models.
BSN is in debt to Conicyt (Fondecyt N1181133) and PUC (P1702/2017). I.E. acknowledges the support of Conicyt (Fondecyt N111505601).

O-228

FILMAT: AN OPEN SOURCE USER-FRIENDLY TOOLKIT FOR RADIOCHROMIC FILM DOSIMETRY

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Radiation Oncology – Dosimetry

Introduction: Radiochromic film dosimetry is frequently carried out using costly pieces of software which, for clinical safety and commercial reasons, hide the functionality under closed-software architecture. These features may compromise the flexible usage required by academic/research purposes. This work presents the implementation and validation of FilMat, an open source and user-friendly toolkit for an efficient and costless implementation of radiochromic film dosimetry.
Material and methods: FilMat is written in Matlab under a Graphical-Unit-Interface which assures an efficient workflow and smart visualization of plots. The code includes the generation of a calibration curve and the conversion from film images to dose maps. Furthermore, it creates dose profiles along any axis as well as a 2D γ-index (with global/local reference points) analysis for comparison of absolute/relative dose distributions under a chosen criteria. For the latter, FilMat features a DICOM import module allowing the automatic registration with dose files from the TPS. The γ-index analysis results (for 3% -3mm criteria), for planned and measured dose files, by FilMat and the commercial Verisoft®-PTW- were compared.
Results: A set of fitting functions were implemented. An interesting feature is the option of generating a calibration curve combining two different methods (Samuel Peet, 2016) depending on dose level. Thus, for measurements under dose gradients, uncertainties in the low-dose region are diminished. It also comprises advanced tools such as a multichannel method (fundamentally superior to the traditional single channel method) to convert film images to dose maps. Performance test of FilMat with Verisoft® revealed small differences between the numbers of points passing the criteria (1.6%) with both systems.
Conclusion: An open-source and user-friendly software has been created for efficient analysis of radiochromic films. Advanced tools such as an optimized calibration and multichannel conversion methods should ease academic and research work.
BSN is in debt to Conicyt (Fondecyt N1181133).

O-234

CHARACTERIZATION OF THYROID DOSE IN STANDARD MAMMOGRAPHY STUDIES IN THE HOSPITAL CLÍNICO UNIVERSIDAD DE CHILE

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Radiology – Radiation Protection

There is currently controversy over the use of leaded thyroid protector in mammography studies. Their use is being justified by the increase in thyroid cancer in women and the use of X-rays in these examinations, generating confusion in patients who attend centers that do not have this device. In the mammography unit of the del Hospital Clínico Universidad de Chile, the skin dose at the level of the thyroid gland of 309 patients was measured (mean age: 53,6 ± 8,6 years and mean BMI: 30,1 ± 4,6) that were performed in 2018 standard mammography studies (4 projections) in a Siemens Mamomat 3000 associated with AGFA CR system, under informed consent and established inclusion criteria. Two TLD glasses type UD 807 Panasonic located over skin at the level of each thyroid lobe were used and read on a UD7900-M device of the same brand. The dose in the gland was calculated as one tenth of the dose measured in skin of each lobe, and finally averaged. Descriptive analysis was carried out with the help of STATA 12. A skin dose of 0.19 ± 0.15 mGy and 0.20 ± 0.18 mGy was observed in right and left lobe, respectively. No statistically significant difference was observed between the means of these doses (t=-0.9669, d.f= 616 con p<0.05). The average dose in gland was 0.198 ± 0.015 mGy, which implies a extremely low risk of thyroid cancer according with BEIR VII (1.6%/Gy as excess risk in the lifetime), which would not justify the use of thyroid protector, according with the statement of several international organizations.

O-241

DEVELOPMENT OF A DYNAMIC ANTHROPOMORPHIC THORAX PHANTOM FOR RADIOTHERAPY QUALITY ASSURANCE

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Radiation Oncology – Quality Assurance

Introduction
We invented a dynamic anthropomorphic phantom, with expandable chest and deform-able organs in 2014. It has been developed by Australian institutions after winning the Australasian College of Physical Scientists and Engineers in Medicine David Robinson Innovation Award 2016 and its intellectual properties protected globally. This paper describes the development process of the inventive device.

Method
A dynamic phantom capable of simulating patient's thorax motions inside and on surface is in great need. Through collaborations between professional designer, artists and clinical institutions with government financial supports, a dynamic phantom was architecturally designed then prototyped as an electromechanical, computer-driven and remote-controlled device. Deformable organs included in the thorax, e.g. heart, lung and diaphragms were digitally modelled and artistically fabricated. Advanced 3D printing technologies were employed to produce the human-like ribs and heart with great similarity. Series validations of functions and features of the phantom were conducted on CT and 4DCT in clinical environment. Of importance, the device has been used to assist new technologies development by a World-leading manufacturer in Europe.

Results
It is evident that this breathing phantom can simulate patient's chest motions in details, the skin and breast are deform-able, the heart and lung behave like human's movement when simulating both free-breathing and deep-inhalation breath-hold (DIBH) modes. Built-in fiducial marks and tumors can represent thus simulate the clinical targets in stereotactic body radiotherapy (SBRT) and DIBH treatment processes, hence the phantom, can be used as equipment commission and end-to-end (E2E) pre-treatment verification for SBRT of lung cancer and DIBH of left breast cancer.

Conclusions
A clinical orientated purposely-built dynamic breathing phantom has been invented and is available for clinical research and training purposes. With continued improvement, this Australian invention will be commercialized and can benefit many patients in undertaking advanced radiotherapy treatments with higher standard and complication-less outcomes.

O-244

SKIN-DOSE MAPPING FOR PATIENTS UNDERGOING INTERVENTIONAL RADIOLOGY PROCEDURES: CLINICAL EXPERIMENTATIONS VERSUS A DOSE ARCHIVING AND COMMUNICATION SYSTEM

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Diagnostic Radiology –Dosimetry

INTRODUCTION: During an 'Interventional Radiology (IR)' procedure, the patient's skin-dose may become very high for a burn, necrosis and ulceration to appear. To prevent these deterministic effects, accurate calculation of the patient skin-dose mapping is essential. We developed a model that reconstructs the magnitude, shape, and localization of irradation fields on patient's skin. In case of critical dose exceeding, the system generates alerts. The reconstruction is based on the geometric and dosimetric information provided by the DICOM files for each acqusition incidence. We present the results of its comparison with clinical studies.
MATERIALS AND METHODS: Two series of comparison of the skin-dose mapping of our model with clinical studies were performed. At a first time, clinical tests were performed on patient's phantoms. Gafchromic films were placed on the table of the IR machine under PMMA plates that simulate the patient. After irradiation, the film darkening is proportional to the radiation dose received by the patient's back. After film scanning and analysis, the exact dose value can be obtained at each point of the mapping. Four experimentation were performed, constituting a total of 34 acquisition incidences including all available exposure configurations. At a second time, clinical trials were launched on real patients during real 'Chronic Total Occlusion (CTO)' procedures for a total of 50 cases. Gafchromic films were placed on the back of the patients. Comparison on the dose values, distribution, and shape of the irradiation fields were performed.
RESULTS: The comparison between the dose value shows a difference less than 15%. Moreover, the geometrical accuracy of our software is excellent: all fields have the same shape, size and location (uncertainty < 5%).
CONCLUSION: This study shows that our software is a reliable tool to warn physicians when a high radiation dose is reached and then deterministic effects can be avoided.

O-245

FEASIBILITY OF DEFORMED MR IMAGES IN THE ACCURATE DELINEATION OF GROSS TUMOUR VOLUME IN LIVER STEREOTACTIC BODY RADIOTHERAPY.

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Radiation Oncology –Treatment Planning

Introduction:
Accurate delineation of tumour in SBRT of hepatocellular carcinoma (HCC) is highly necessary because of high dose per fraction. MR images complement CT in the delineation of gross tumour volume (GTV). An acceptable matching of MR by rigid registration is difficult due to difference in patient positioning and breathing levels. In this study, we have attempted to validate and incorporate deformed MR images for accurate tumour delineation in liver SBRT.
Methods and materials:
Ten patients who had underwent SBRT for HCC and had MRI as part of imaging process were selected retrospectively. Deep inspiratory breath hold (DIBH) CT was acquired for treatment planning and liver acquisition volume acquisition (LAVA) MR sequence to aid tumour delineation. MR images were aligned with CT rigidly (RR) over the region of interest. GTVs were delineated separately on both CT & MRI and GTVRR was generated by combining CT and rigid MR volumes. In such cases the inherent registration errors lead to a increased tumour volume. To improve the delineation accuracy, we have tried MR to CT deformation (DIR). Prior to clinical use, the SmartAdapt system was validated by ImSimQA. MR images were then deformed to DIBH-CT to obtain GTVDIR. GTVRR was compared against GTVDIR while liver volumes generated by RR and DIR were compared with CT by conformity index (CI), mean distance to conformity (MDC) and dice similarity index (DSI) metrics.
Results:
CI of 0.63±0.22, MDC of 2.29±1.21 and DSI of 0.81±0.16 were obtained for GTVRR against GTVDIR. CI of 0.78±0.06 & 0.69±0.11, MDC of 6.03±2.73 & 8.48±3.49 and DSC of 0.92±0.04 & 0.88±0.06 were obtained for liver by DIR & RR respectively against CT.
Conclusion:
The SmartAdapt system was validated for MR to CT deformation and accurate & concise contours could be obtained using deformed MR images thereby reducing normal tissue toxicity.

O-247

XPEKTRIN, AN EASY TO USE AND HIGHLY DISTRIBUTABLE X-RAY SPECTRA SIMULATOR IN GENERAL RADIOGRAPHY

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Dosimetry – Reference quality

A user-friendly application based on Microsoft Excel, Xpektrin, was developed to simulate X-ray spectra in general radiography using the TASMICS model of Hernandez and Boone.

Using as inputs air kerma (Kair) and Half-value layer (HVL) measurements, Xpektrin allows the calculation of several radiometric and dosimetric quantities, such as the entrance surface air kerma (Ke) and the skin dose (Dskin), depending on the exposure factors, filter material type, filter thickness, focus-skin distance and field size.

Xpektrin was validated against the Matlab toolkit SPEKTR 3.0, using dose and HVL measurements of X-ray tubes from three different hospitals. It was found good correlation in both applications between the experimental measurements and the calculated HVL and Kair values with Pearson coefficients $R^2 > 0.99$ in all cases. However, experimental and calculated HVL have better agreement with Xpektrin (median percent difference -0.4%, -0.04% and 0.01%) than SPEKTR 3.0 (median percent difference -1.8%, 2.2% and -7.09%), particularly for the tube with greater filtration thickness.

Using Xpektrin, Ke was determined for adults in PA chest and AP lumbar standard projections according to the typical exposure conditions from each hospital. It was found that the calculated Ke values for both projections (PA chest: 0.19, 0.30, 0.15 mGy and AP lumbar: 5.23, 6.69, 7.63 mGy) are within the dose reference level range described in the literature (0.14 - 0.3 and 3.8 - 10 mGy, respectively).

Xpektrin may be used in radiology departments to establish local dose reference levels or as part of a dosimetric record system. In addition, due to its simulator characteristics, it can be useful as a pedagogical tool. The use of Excel allows Xpektrin to be highly distributable and easy to use, without the need for programming skills.

O-248

DEVELOPMENT OF A GANTRY-RESOLVED EPID-BASED FRAME-BY-FRAME PATIENT-SPECIFIC VMAT QA METHOD

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Radiation Oncology – Quality Assurance

Purpose: Develop a gantry-resolved EPID-based method for patient-specific QA using integrated acquisition in TrueBeam clinical mode, and test it on large VMAT fields.

Methods: We developed a QA method using MATLAB that creates gantry-resolved pseudo-3D dose distributions from stacked portal images acquired on TrueBeam Linacs using dosimetry (integrated) acquisition mode. Predicted portal dose distributions were calculated based on MU information contained in XIM image headers. An independent calibration procedure was established, including a 2D profile correction map. Gamma index calculations were performed with a two-step calculation procedure that resamples steep dose gradient regions for improved calculation accuracy. Post-processing was used to address two acquisition artifacts: header ΔMU variations that do not reflect signal intensity variations, and banding patterns on acquired frames. Gantry angle accuracy requirement is given by angle-to-agreement (ATA) criteria. The method's performance was assessed with gamma analysis (3%/2mm/3˚/10%threshold criteria) of 35 large VMAT fields using two EPID models and two photon energies.

Results: The improved gamma index calculation increased pass rates by an average of 2.8%, with many cases displaying increases of 6% to 8%. MU variations were reduced to less than 1% for irradiations with a constant dose rate, and smoothing effects on variations caused by dose rate changes were small (up to 1.5%). Banding patterns on central portions of the fields were almost eliminated without smoothing field borders. The resulting average pass rates were 95.4%, 97.8%, 98.6% and 96.2%, and no result was inferior to 90%. Analysis took around 6 to 8 minutes per field.

Conclusion: Our method presented excellent results for gantry-resolved gamma index analysis of VMAT fields. The two-step improved gamma calculation greatly improved pass rates and reduced variation in the results. Processing of acquisition artifacts enabled our method to be used in clinical dosimetry acquisition mode without the need of external acquisition hardware.

O-249

A STUDY ON VMAT PLAN COMPLEXITY AND PATIENT-SPECIFIC MEASUREMENT RESULTS

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Radiation Oncology – Quality Assurance

Introduction
Patient-specific dosimetric measurements are often performed prior to VMAT treatments due to the nature of the complex delivery. While considerable resources are dedicated to this practice, relatively few clinically significant errors are captured. In this study, the relationship between plan complexity and measurements based on Gamma analysis was investigated to determine if there is a significant correlation between certain plan complexity parameters and Gamma passing rates (GPRs).
Methods and Materials
43 clinical VMAT plans that have been planned in Pinnacle [V9.10] and treated on two Varian TrueBeam STx linacs were randomly selected retrospectively for this study. Plan complexity metrics such as Monitor Unit Factor, Plan Aperture Irregularity, Average Field Width (AFW), Modulation Complexity Score and Small Aperture Score (SAS) were extracted for each plan. Measurements were performed using the IBA MatriXX array detector in a polystyrene phantom. Comparisons between measured and planned dose distributions in phantom geometry were evaluated by Gamma analysis. Both measurements and analyses followed the AAPM Task Group 218 recommendations. Spearman's Rank correlation coefficient (rho) was used to assess plan complexity parameters and GPRs.
Results
Of the plan complexity metrics investigated, the two parameters with the most significant correlation with the Gamma passing rates using the evaluation criteria of 3%/2mm, 10% dose threshold are AFW and SAS (20mm). AFW has a monotonic increasing relationship with GPR (rho = 0.76, $P < 0.001$), where SAS (20mm) has a monotonic decreasing relation with GPR (rho = -0.69, $P < 0.001$). Threshold values of approximately 1.5 and 0.74, respectively, were determined to ensure a GPR > 90%.
Conclusions
Plan complexity metrics, AFW and SAS (20mm), were found to correlate significantly with measured GPRs using 3%/2mm with rho's = 0.76 and -0.69, respectively. They can be used to reduce the amount of patient-specific VMAT measurements by determining suitable threshold values.

O-259

PERFORMANCE STUDIES OF LGAD SILICON DETECTORS FOR APPLICATIONS IN CHARGED PARTICLE THERAPY

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Radiation Oncology – Dosimetry

Introduction
Silicon sensors based on the Low Gain Avalanche Diode (LGAD) technology, characterized by enhanced signals and excellent time resolution, are investigated as a possible alternative to overcome speed and sensitivity limitations of the gas detectors currently used for beam monitoring in charged particle therapy.

Methods and Materials.
Two prototypes of beam monitoring devices with dedicated LGAD strip structures produced by FBK (Trento, Italy) are under development. One device will be used to identify single beam particles and count their number up to high rates. A custom electronic VLSI chip was produced for its readout, employing the enhanced signals of LGAD detectors for fast operation (>100 MHz/channel) and high efficiency. A second device takes advantage of the LGAD high time resolution (~35 ps in 50 μm) to measure the beam energy from the time of flight of protons in a telescope of two thin strip sensors.

Results
The detectors developed for the two applications were tested with proton beams at CNAO (Pavia, Italy) and at the Trento proton therapy facility (Italy). Their counting capability was assessed and their performance characterized in terms of radiation resistance, response linearity and reproducibility. With the current strip structure, the counting inefficiency is < 1 % up to 108 p/cm^2. Dedicated pile-up mitigation algorithms were studied and implemented to increase the maximum counting rate. Timing measurements from a telescope of two strip sensors provide an energy resolutions of 1 MeV at 227 MeV.

Conclusions
The encouraging results suggest to continue the investigation of LGAD technology for future clinical applications, where the high sensitivity and fast response time of silicon sensors will be useful for beam monitoring in high speed or low dose delivery schemes. Future prospective of developments of LGAD detectors for imaging applications in charged particle therapy applications will also be discussed.

O-261

THE FUTURE OF MEDICAL PHYSICS: A CASE STUDY OF ZAMBIA

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Education and Professional Issues

The last few decades have seen tremendous growth in the health sector in Zambia. At the beginning of the 21st century, policies were developed and resources allocated, leading to the establishment of the first radiation Centre in the country; Cancer Diseases Hospital (CDH). Among the key personnel needed to run this kind of specialized hospital are medical physicists (MPs). As of January 2019, the country had less than five medical physicists on the Health Professions Council of Zambia (HPCZ) register.

In 2018, CDH had recorded about 2500 new cancer cases corresponding to a 25% increase from the past years. In order to accommodate this rise in patient load, two radiotherapy centres and smaller satellite radiotherapy departments, attached to the Central hospitals, are envisioned. Furthermore, a planned Centre for Nuclear Science and Technology (CNST), hosting Radiotherapy and Nuclear Medicine facilities. These increase therefore, necessitates the procurement of more diagnostic and therapeutic equipment. Subsequently, requiring a substantial number of MPs commensurate with the International Atomic Energy Agency (IAEA) staffing recommendation.

Growth of Medical physics in Latin America, North America, Europe, Asia, Australia and Africa was looked at and a comparison to Zambia undertaken. The IAEA tool was used to estimate the recommended staffing requirements of MPs and a comparison with the prevailing situation done from 2006 to 2019. Future projections and trends were also analysed to offer a much clearer perspective.

Results showed that the current growth in MPs is below the recommended threshold, the future trends are also indicative of a deficit which will likely not be met in the next 10 years. The following conclusions were made; the need to develop local curricula, improve enumerations and career prospects.

O-265

AN INNOVATIVE SYSTEM FOR PREVENTING RADIOLOGICAL RISK FOR STAFF IN THE OPERATING THEATER

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Radiation Protection

Introduction: Interventional procedures are performed in the operating theater under X-ray guidance. The international radiation protection organizations, recommands that access to a room containing X-ray facilities must include signage to prevent unnecessary exposure.
Materials and methods: We developed an innovative solution, named “DOSALERT”, that responds to all related challenges.
DOSALERT consists of two boxes that interact with each other by radiofrequency. The first box “Detectbox” is placed in the intervention room and plugged in the amplifier, it can detect the energy levels of the image intensifier. The second box or “AlertBox” is placed outside the room, above the block room for example. It informs about the danger of exposure thanks to a luminous signage. DOSALERT answers to 3-exposure scenarios: (1)if the image intensifier is powered-on and emits X-rays, the Detectbox detects the X-ray emission and informs the staff outside the room about the existing danger tharough a flashing red light emitted by the Alertbox. (2)The intensifier is powered on but it does not emit X-rays, so the signaling is flashing orange and the nurse outside the room can enter, knowing that the amp is powered. (3)the amplifier is not powered-on, so the signaling is flashing yellow: the operation is complete and the cleaning team can perform its role.
Results: The detection rate is 100%: DOSALERT detects the slightest shot. The probability of false alarm is less than 10exp-5: the risk of a false alarm is very low. It detects low energy emissions (low voltages : 70 - 150 Kvp). Tests show that it detects low photon rates (amperages between 2 and 10 mA). Finally, shots made in pulsed and continuous transmission modes are also detected, as well as image and visualisation mode. Tested on all amp brands such as siemens GE philips ....
Conculsion: Our system is a reliable tool.

O-266

QUANTIFICATION OF RADIODERMATITIS THROUGH IMAGE PROCESSING: A FEASIBILITY STUDY

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Radiation Oncology – Treatment Delivery

Radiodermatitis rating is currently done qualitatively using the "RTOG Scoring Schema." At present, there is no quantitative method to assess the degree of injury that is affecting the skin throughout Breast Cancer radiotherapy used in the clinical setting. This study proposes a novel method using digital, polarized light images to evaluate erythema. Breast cancer patients were randomly chosen with different skin colour, tumor types, treatment type, and were followed up throughout their treatments. Circularly polarized light digital images of the patients were taken along the treatment. For each day, pictures were taken in different positions in different setups. Image registration between images of different days, for the same patients, was done using anatomical regions, skins marks, and tattoos in the border of the treatment field. The ROIs chosen for RGB color-space analysis were the ones that reached at least grade 1 during treatment. Each erythema was independently evaluated by physicians using the RTOG schema so that it could test and validate the image method under development. Different groups were analysed: white , brown skin, and dark skin. All three groups included hypofractionated vs. conventional treatment. It was verified that the RGB normalized intensities decrease as the radiodermatitis grade increases and that brown skin presents a more pronounced decrease. The most sensitive channel to radiodermatitis grade was the green one. The most statistically significant sensitivity in the image method was found in the differentiation between radiodermatitis grade 0 and 1 for the white and brown skin patients. The present study demonstrated a novel approach to evaluate radiodermatitis quantitatively. Despite similar past attempts in the literature, they all lack in the number of patients and the diversity of patients. This work presented a simple methodology that has to be further developed as an objective radiodermatitis quantification methodology to help the physician practice.

O-269

VALIDATION OF THE ELECTRON MONTE CARLO ALGORITHM

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Radiation Oncology – Dosimetry

The present work evaluated the electron Monte Carlo algorithm (eMC) available in Varian EclipseTM planning system for the use of electron beams. This study was done in order to define the best calculation options with which clinical test should be performed in the planning system.

The evaluation was carried out in two stages, first evaluating the algorithm in homogeneous medium and second in heterogeneous medium. The tests were performed for 4 electron energies 6, 9, 12 y 15MeV. The influence of varying parameters such as calculation grid, uncertainty, type and level of smoothing was analyzed.

The test in homogeneous medium were made with extended SSD, oblique incidence, shaped fields, irregular surfaces with a water phantom; In heterogeneous medium, solid water sheets and various materials such as cork, air, PMMA were used, simulating different regions of the body.

In each of the scenarios, PDDs, dose profiles and planes were measured. To perform these measurements, 3D-SCANNER automatic scan phantom, microDiamond detector and 2D-array of MapCHECK2 diodes were used.

Applying the gamma evaluation criteria, it was observed that in homogeneous medium the algorithm satisfies the criterion 3%3mm in more than 95% of the points analyzed and for heterogeneous medium the same agreement was obtained, but being more flexible in the comparison criterion.

Once these tests were realized was possible to conclude that when using a calculation grid of 2mm, uncertainty of 2% and Gaussian-smoothing medium-level, results obtained are clinically acceptable both in calculation time and in dose precision.

With the tests carried out, it was concluded that the eMC is suitable for use in the clinical setting, simulating in an appropriate way the dose distribution in basic and complex configurations. However, it is recommended to be cautious in its implementation with low energies, because still presents differences between the measured and the calculated.

O-277

PEDIATRIC PROTOCOL OPTIMIZATION FOR CHEST CT SCANS IN THREE RADIOLOGICAL SERVICES

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Diagnostic Radiology –Dosimetry

Introduction
Radiological exams are increasingly used in the clinic for diagnostic analysis of different types of pathologies. In particular, the number of Computed Tomography (CT) studies has grown exponentially in the last decades, especially pediatric ones. In addition, the risks of exposure to ionizing radiation are higher in children. The above implies the necessity to optimize the protocols used in this technique, especially for pediatric patients.

Methods and Materials
From the variation of the tension, tube current and beam thickness, regarding on the pitch factor, optimized protocols have been suggested to reduce the dose and improve image quality for two years old patients in three radiological services. All the tests were performed using a PMMA phantom designed to represent the thorax of a patient with these characteristics. For optimization, the percentage noise index has been kept below 1%.

Results
Three optimized protocols have been obtained for tomograph 1, three for tomograph 2 and two for tomograph 3. Except for two of them, protocols suggested have been reduced the doses with respect to the pediatric protocols used in the services. CTDIvol values have been found between 2.42 mGy and 9.84 mGy. Also, all of them produced an acceptable diagnostic image quality.

Conclusions
The protocols presented will optimize the acquisitions of images for each of these technologies. They cannot be applied directly to another technology and guarantee the same optimization result. If this were done, the dosimetric response - image quality would be different.
Parameters proposed for each protocol should be modified depending on the patient in question; protocols using modulated current can be an option to achieve these objectives.
For pediatric acquisitions of children of 2 years old, voltages below 120 kV are the most recommended. In case of existing voltages 100 kV and 80 kV, these are the most recommendable.

O-281

IMPLEMENTATION OF QUALITY ASSURANCE PROGRAM IN RADIODIAGNOSIS

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Diagnostic Radiology –Dosimetry

INTRODUCTION
The aim of a quality assurance program is to ensure that the images have an optimal diagnostic quality with minimal exposure of the patient to the radiation source. It is the basis for the development of an independent quality system, without the need of selftests provided by the manufacturers, and allows not only to guarantee the safety of patients but also to reduce maintenance costs by administrating corrective tasks in advance.

METHODS AND MATERIALS
For the implementation of the program, specific equipment from PTW are available and it is divided into stages: Survey of the department; Constancy tests; Elaboration of the manual of standards; paper less quality assurance and implementation of dose chart.
It involves the departments of Computed Tomography, Mammography, Continuous RX, Densitometry, Orthopantomography, and Conventional Radiology. In each of them, the corresponding protocol or international quality guideline is applied, such as the Spanish Protocol for Quality Control in Radiodiagnosis.

CONCLUSIONS
The main challenge of the implementation of the program was the change in the quality culture at all levels at the institution.
Up to now, the implementation has been completed in the department of Computed Tomography, in which it was observed that the acquisition protocols had not been optimized since the commissioning. In this instance, the goal of optimizing clinical protocols for an average patient was fulfilled, which implies in all cases that the voltage used does not exceed 110 kV since above this value the doses received by the patients is up to 10 times greater than for smaller voltages without a decisive improvement in the image quality.
After this stage, we are in a position to begin the study of our population for the determination of dose reference levels.

O-282

RADIATION DOSE FOR PEDIATRIC CT: 4 YEARS OF IMPROVEMENT

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Diagnostic Radiology –Dosimetry

Introduction:
Since the radiation dose indexes became available, quality programs begin to reduce the radiation dose given to the patients. In pediatric imaging registry, follow-up, and reduction of radiation dose index is one of the main concerns in all radiology departments, due to the possibles long-term consequences. The purpose of this study is to show the improvement in the reduction of radiation dose index for pediatric CT in a 4 year period at a third level academical institution.

Methods and Materials
A cross-sectional study was made between 2015 and 2018 in the Fundación Santa Fe de Bogotá hospital in Bogotá, Colombia. Random data by year from radiation dose indexes (CTDIvol and DLP) from a brain and abdominal CTs in patients under 17 years old were collected. For data analysis, effective diameter groups were made. A univariate and bivariate analysis was made using SPSS version 25.

Results
A total of 910 pediatrics CT were collected, 544 (59.8%) brain CT and 366 (40.2) abdominal CT. Distribution of the effective diameter groups from brain CT was 0-14cm 33 (6.1%), >14-15.5 cm 132 (24.4%), >15.5-17 cm 109 (20.1%), >17-18 cm 268 (49.4%); for abdominal CT was 0-14.5 cm 12 (3.3%), >14.5-18 cm 60 (16.4%), >18-22cm 188 (51.4%), >22-25cm 106 (29%). A t student t showed a reduction of mean CTDIvol and DLP in 2016, with a p-value < 0.001, this reduction was consever in 2017 and 2018. ANOVA test showed a reduction of the radiation dose index between groups.

Conclusion
There was an evident reduction in the radiation dose index in 2016; this reduction was due to the inclusion of a quality program for radiation doses in pediatric imaging on our institution. This program is based on protocols for control and improvement in each procedure. A medical physicist leads the quality program.

O-298

PSQA IN RADIOSURGERY: EVALUATION OF DETECTORS AND IMPLEMENTATION

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Radiation Oncology – Quality Assurance

Radiosurgery is a radiotherapeutic technique based on the delivery of a single high-dose application to a small specific volume. Therefore, pre-treatment patient-specific quality assurance (PSQA) is highly recommended. PSQA verifies the concordance between the treatment generated in the treatment planning system (TPS) and the one delivered by the linear accelerator, by means of dose comparison. In this work, four detectors were contrasted: Gafchromic EBT3, ArcCHECK, EPID and SRS MapCHECKTM. Verification was performed upon three pathologies (meningioma, multiple metastasis and schwannoma), using three different techniques (VMAT, IMRT and Dyn Arc), employing EclipseTM TPS. Analysis of the separation of the micro-MLC in each control point was carried out. Evaluation of the different techniques using each of the detectors was performed with three independents gamma criteria: 1mm/3%, 1mm/5% and 2mm/3%. Results showed that the greater the number of MLC's leaves with separation less than 0.5 cm, smaller the number of points that fulfilled the gamma evaluation criterion, especially for complex techniques such as VMAT, where the deviation showed a maximum. As a conclusion, it was determined that 1mm/3% with 95% of approval and 2mm/3% with 97% of approval were the best options for PSQA in radiosurgery in CEMENER. The optimal detector to be used is SRS MapCheckTM, since measurements were made in dose units and ready-to-use, it evaluated gantry and collimator movements and couch shifts of up to ±45. In addition, measurements could be directly compared with the ones taken with Gafchromic EBT3 films finding a very good agreement. Also, it was suggested VMAT treatments should be executed using field sizes greater than 0.5 cm.

O-302

APPLYING THE NEWS ANALYSING CRITERIA FOR IMRT TREATMENT PLAN VERIFICATION

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Radiation Oncology – Quality Assurance

Treatment verification for IMRT techniques play an important role to evaluate differences between planned and delivered doses, in clinical practice, those differences are predominantly assessed implementing the gamma-index method. Tolerances and acceptance criteria are neither well defined nor consistently applied across centers.
Several reports discuss the patient specific IMRT QA due to poor sensitivity and specificity of the gamma method. In recent years, in combination with the development of devices for measuring dose distributions, novel metrics for the gamma-index calculation are being implemented in clinical routine. For the gamma-index evaluation, the pass/fail criteria must be defined based on the follow calculations parameters: Dose Difference DD (%), Distance to Agreement DTA (mm), dose normalization value (local or global), increased tolerances and suppressing doses. In this work gamma-index 3D (3mm/3% criteria) and volume analysis, are studied to evaluate 15 Head & Neck (H&N) and 15 prostate plans, calculated with an Eclipse TPS, and delivered with a TrueBeam LINAC (Varian M.S). Quality control plans were measured with the Octavius4D 1500 system (PTW, Freiburg-Germany).
As analysis parameters affect the gamma results in all the associated anatomical regions, we have evaluated the practical relevance and clinical impact of rejected points.
The mean of points passing the initial acceptance criteria is better than 98.2% for H&N and 98% for prostate, 96.9% for H&N volume analyses and 91.7% for prostate cases.
Thereafter we have investigated variations on dose normalization criteria in combination with low dose region tolerances and the resolution of calculation grid and their impact on the gamma histogram. From our study, we can suggest that it is important to establish acceptance criteria depending on the anatomical region in the pursuit of making decisions to improve the IMRT QA acceptance analyses.

O-303

CLINICAL IMPLEMENTATION OF IGRT: PROTOCOLS AND ASSOCIATED DOSES

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Radiation Oncology – Dosimetry

IGRT provides an efficient way of delimitation, planning and positioning the patient. However, we must consider the cost-benefit relationship and the ALARA philosophy in case ionizing radiation in medical imaging is required. Although the doses delivered are smaller than those for therapy, radiosensitive organs and large portions of the body are irradiated. The IGRT protocols provide a safe way to achieve high accuracy in the treatment, reducing geometric variations, and provides an evaluation of appropriated CTV-PTV margins extension. Therefore, we sought to obtain specific IGRT protocols and establishing reference levels for IGRT exposures.
A retrospective analysis was performed on a 37 prostate cancer (PCa) patients and 31 head and neck (H&N) patients. We proposed IGRT positioning protocols for PCa and H&N patients. Such strategy consisted of averaging the positions of the treatment couch in the first sessions and taking images scheduled in subsequent sessions. Additionally, we measured and compared the associated doses with the acquisition of planar and CBCT (CBDIw method) images; PTW solutions for low energy x-ray were required for such purpose: the Nomex system and the CTDI phantoms. We calculated the effective doses using the wT factors suggested by the ICRP and by Hyer et al.
We have implemented two protocols for H&N, when the tumor had had variation and when it was required to irradiate a surgical bed; the effective doses imparted by were 0.90 mSv and 0.43 mSv, respectively. The effective dose for PCa patients was 48.90 mSv. Couch displacements were restricted to 3mm and 5mm and used as action levels. Finally, we suggested new CTV-PTV margins, which represented a reduction of 1 – 2mm, according to Van Herk Formula.
Early results have suggested a reduction of CTV-PTV margins. However, these margins are still being evaluated as more data are collected.

O-310

ACTUAL DOSE DELIVERED AND PATIENT-REPORTED OUTCOMES

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Radiation Oncology – Quality Assurance

Background:
It is well established that the radiotherapy dose-volume (DV) parameter and treatment outcomes are related, both for tumor control and for normal tissue complications. However, the expected DV-outcome relationship for any given tumor or normal tissue is seldom borne out in clinical practice. We hypothesized that there are two likely reasons for this: (1) the dose that is planned is not necessarily the dose that is delivered, and (2) the outcomes that are recorded by physicians are often not fully representative of true patient experience.

Methods:
With our hypothesis in mind, we built a research program to study (a) actual dose delivered to radiotherapy patients and (b) capture patient-reported outcomes (PROs).

(a) To measure actual dose delivered, we built a DVH registry and a dose re-calculation pipeline with which we can calculate daily-delivered dose using daily cone-beam CT (CBCT) scans.

(b) To capture PROs, we built a novel patient portal smartphone app (opalmedapps.com) and integrated it into our clinic's waiting room management system. Patients are sent a symptom questionnaire to their smartphones at the time of check-in asking them validated questions regarding possible treatment-related symptoms.

Results:
Using a retrospective data set of 20 prostate cancer patients treated with 60 Gy in 20 fractions, we have demonstrated that daily CBCT dose re-calculation is feasible and we have shown that for some patients the delivered dose to the rectum is significantly different to the planned dose.

Using a prospective cohort of head and neck cancer patients, we have demonstrated that PRO capture using a smartphone app at the time of check-in is feasible and acceptable to patients.

Conclusion:
We have demonstrated that it is possible to measure actual dose delivered and to collect PROs, both of which we believe more accurately reflect the true dose and outcomes of radiotherapy.

O-312

CRANIOSPINAL IRRADIATION WITH VOLUMETRIC MODULATED ARC THERAPY: PLANNING METHOD OF THREE-ISOCENTER AND FIELD OVERLAP-JUNCTION AREA DOSE VERIFICATION

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Radiation Oncology – Treatment Delivery

Introduction: Craniospinal Irradiation delivered with 3D CRT methods result in the high-dose gradients between the matched fields have the potential to create unintentional high and/or low doses in the spinal cord when even a small setup error is introduced. We have developed a VMAT technique with three isocenters and two overlap-junctions.

Methods and Materials: Three patients were set up in a supine position with thermoplastic facial mask and body VacLoc bag. Planning CT was performed with 3mm slices. The planning target volume (PTV) was countered to include the whole contents of the brain and spinal canal with a uniform margin of 5 mm. VMAT plans generated whit 7 fields. A Elekta Synergy linear accelerator equipped with collimator, 160-leaf MLC was used to implement the treatment plan using 6MV beams.

The area of overlap-junction was 3 cm. The QA was conducted with a Map Check and Arc Check, the plans were generated in Monaco TPS . The analysis was performed using SNC Patient software. QA evaluations were performed using Gamma index (3% in difference dose and 3 mm in distance to agreement). The gamma index to approve plan must be equal or superior at 95%. In addition were verified the absolute dose, measured using a pin point ionization camera in a phantom RW3 PMMA, the difference between points must be less than 3%. In CSI also is very important made the same analysis in an overlap-junction area.

Results:$p= 0.12$ ($p>0.05$) for variation of absolute dose, taking net differences between values without correction and+/- 5 mm.

$p=0.24$ ($p>0.05$) for values of gamma index.

Conclusions: The Craniospinal irradiation with VMAT generate a treatment plan homogeneous and conformal to PTV, showing that it is less sensitive to possible longitudinal shift in the range of +/- 5mm that a 3D CRT plan.

O-313

NEUTRON-INDUCED CARCINOGENIC EFFECTS

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Radiobiology

Background:
Human exposure to neutron irradiation is generally tightly controlled such that the carcinogenic risk to individuals and populations is very low. Patients undergoing high-energy (>10 MeV) radiation therapy, however, represent a population group for whom whole-body neutron exposure cannot be controlled. Such patients are thus at risk for second radiation-induced malignancies. The risk is difficult to calculate for two reasons. First, the radiobiological effectiveness (RBE) of neutrons is poorly understood and varies as a function of energy. Second, the measurement of neutron spectra, particularly in the vicinity of high-dose-rate radiotherapy linear accelerators, is very difficult. With the above in mind, we have built a research program to (a) better measure neutron spectra and (b) better understand neutron RBE.
Methods:
(a) Using the Nested Neutron Spectrometer (NNS, Detec Inc, Gatineau, Canada) incorporating a He-3 detector in current mode, we have demonstrated that it is possible to quickly (one hour or less) measure a neutron spectrum in a radiotherapy bunker. (b) Using a combination of Monte Carlo and track structure modelling (similar to the ANDANTE group), we are attempting to better understand the biophysical basis of the energy-dependent RBE of neutrons.
Results:
To date, we have conducted neutron spectral measurements around photon, electron and proton beams and we have put in place a modified Maximum Likelihood Estimation Maximization algorithm to improve the neutron spectrum unfolding process.
We have developed a Geant4 and Geant4-DNA simulation pipeline to model DNA damage at the nanodosimetric level and are currently using it to examine DNA damage as a function of neutron energy.
Conclusion:
We have put in place a program to accurately and quickly measure neutron spectra in radiotherapy and to better understand neutron RBE using Monte Carlo and track structure modelling.

O-318

PROTECTION OF THE EXPOSED WORKER: EFFICIENCY OF THE LEAD APRON IN RADIODIAGNOSIS

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Radiation Protection

Introduction

The use of radiological protection elements such as lead aprons will always be important for any institution that uses ionizing radiation. In this work the effectiveness of the use of leaded aprons in a conventional radiology service, nuclear medicine and PET-CT was studied.

Methods and Materials
Using the NIST database, for three spectrum of radiation sources used in a diagnostic imaging service (RX, Tc-99m and F-18), the attenuation percentage of a leaded apron was determined. These calculations were contrasted with Monte Carlo (MC) simulations using the PENELOPE code, for which simplified exposure conditions were simulated in the three scenarios. The MC calculations allowed to establish the spectrum of photons that arrive to the user without and with shielding, as well as the percentage of attenuation. Finally, the calculations were validated with experimental measurements in the simulated configurations.

Results
For Tc-99m and F-18 the experimental, simulated and theoretical data represent high correlation with a relative error of less than 3.8% respectively, while for experimental versus simulated RX scattering data the error is 13.8%. From the simulated results we find scattered beam attenuation in: RX 83.2%, Tc-99m 72.26% and PET-CT 7.4% respectively. These results are in agreement with the experimental measures, with a maximum difference of 5%. The discrepancies are presented in the experimental data with the theoretical efficiency in RX with a difference of 30.4%.

Conclusions
We must work on the evaluation and validation of the experimental data for the RX spectrum in order to strengthen the correlation of the data.
The use of the apron in conventional radiology considerably reduces the dose received by users, in nuclear medicine although the efficiency is so significant is debatable its use in specific tasks, while in PET-CT is not justified by the low efficiency of the shielding.

O-319

CONNECTIVITY CONFIGURATION USING GRAPHITE FOR A THREE-DIMENSIONAL ELECTRONIC DETECTOR ARRAY

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Radiation Oncology – Quality Assurance

A high spatial resolution three-dimensional (3D) electronic detector array for intracranial and extracranial dose verification in radiation therapy is under development. It consists of 31,560 submillimeter size diode detectors arranged in an isotropic configuration within a semi-spherical volume of 20 cm diameter. Detector readout is based on an active matrix configuration and a 200 micron thick wire lines will be used to connect the detectors. Monte Carlo (MC) simulations using Penelope and Peneasy were performed to determine the dosimetric effects that copper and graphite wires could have on detector readout. The MC simulations consisted of calculations of percent depth-doses (PDDs) in a 20 x 20 x 20 cm3 water phantom with five 200 micron thick layers at 6, 8, 10, 12, and 14 cm depths and in water only. The MCs used 100 micron bin size and ran for 1 week per calculation, on average. The PDDcopper showed a 23.5% dose increment due to backscattering at 0.3 cm before the layer, and 7.2% dose reduction at the layer's central point, both compared to PDDwater. The PDDgraphite showed a comparable dose distribution to PDDwater immediately before a layer and an 8.3% dose reduction at the layer's central point compared to PDDwater. Experimental validation of these results are underway, meanwhile, the MC data provides an initial justification for using graphite as a connectivity material in the 3D detector array. In conclusion, graphite should reduce perturbations effects during dose measurements, which would limit the use of dose correction factors in the raw data and increase accuracy. Finally, the high-spatial resolution 3D detector array will an innovative system for dose verification in radiotherapy. It will have an active matrix detector readout design, graphite connections and provide measured 3D data, which are features not currently available in the market.

O-321

ESTABLISHMENT OF COMPUTED TOMOGRAPHY DIAGNOSTIC REFERENCE LEVELS IN THE NATIONAL INSTITUTE OF CANCEROLOGY.

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Radiology – Radiation Protection

The present work aims to implement the reference levels for the practice of Computed Tomography at the National Cancer Institute (INC). Being the INC a reference entity that works for the control and care of cancer through research and development of public health actions (REF), it must be the manager of radiological protection to the patient, in line with international recommendations of organizations working for radiological protection such as the ICRP and the IAEA. It is intended to perform in the modality of CT, with respect to its dosimetric magnitudes in pediatric population of 10 years and adult reference person based on CTDI_vol and DLP dose reports of the patient's images of a specific year approximately 1490 images of the population and specific examinations, with current protocols and evaluate the dose adsorbed on physical simulators with thermoluminescent dosimetry TLD to evaluate the relevance of the acquisition techniques currently used in the development of TC practice in the INC. In addition, perform the dose evaluation and perform dose optimization with an image analysis and physical parameters together with the clinical evaluation of anthropomorphic physical simulators and evaluation of the quality of the image.

O-324

DETERMINATION OF REFERENCE LEVELS DOSE INDEX IN COMPUTED TOMOGRAPHY (CTDIVOL) AND PRODUCT DOSE LENGTH (DLP) IN EXAMINATIONS OF THORAX, ABDOMEN AND ABDOMEN AND PELVIS AT THE NATIONAL CANCER INSTITUTE

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Radiology – Radiation Protection

Obtaining the reference levels. A sample of the TC conducted in 2016 is reviewed in order to determine the range of reference levels in adult men, adult women, children aged 8 to 12 years served in the institution in that period. This consultation will be carried out in the institutional platform, where CTDI and DLP are reported for chest, abdomen and pelvis images. Approximately the number of TC is 20,000 in the year, so the review of 1470 reports is expected. Subsequently, the del CTDI measurement was performed on phantom of TC dosimetry and pencil ionization chamber and the traceability was verified with the equipment dose report. Radiation dose measurement is carried out with current protocols in the computed tomography image acquisition in the INC, using Thermoluminescence dosimeters (TDL), distributed uniformly in specific points of the thorax, abdomen, abdomen and pelvis region. Adult woman, adult man and thorax region, 10-year-old abdomen on anthropomorphic physical simulator. Finally, the optimization of acquisition parameters is performed by modifying the tomograph parameters of mAs, Kv and Pitch. Once the minimum value of mAs is obtained with which diagnostic quality is reached. This quality assessment is done in conjunction with the radiologist on anthropomorphic physical simulators and the medical physicist on physical imaging simulators to ensure an adequate diagnostic quality and an optimization of the institutional dose.

It is important to establish new institutional reference levels after optimization and monitor these values.

O-326

DESIGN AND FABRICATION OF HUMAN BONE (PELVIS) USING 3D PRINTER

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Biomedical Engineering

Three-dimensional (3D) printing is an additive manufacturing technique, which allows the fabrication of patient-specific scaffolds with high structural complexity and design flexibility, and gains growing attention. Human bone is very essential for medical study and research. However, human bone preservation is a complex and costly process and the preserved bone erosive with time. This research aims to design and fabricate human bone (Pelvis) by Poly lactic acid (PLA) material with same geometry and anatomical structure by 3D printer. The anatomical structure and geometry of Pelvis has been collected from CT data. The bone was designed by AutoCAD 3D by using CT data. After comparing designed bones with original bones, designed bones is converted to Stereo-lithographic file by a slicing software (breaks the model surface in slices) and then fabricated by a 3D printer. However, the fabricated bones is exactly similar to the real bones with same anatomical structure and geometry. 3D printed human bones is cheap, long lasting and environmentally safe. This 3D printed bones enhance the medical study and research by its degrading behavior.

O-330

TOLERANCE DOSE OF NORMAL TISSUE TO NONCONVENTIONAL SCHEDULED RADIOTHERAPY

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Radiation Oncology – Treatment Delivery

The use of hypofractionation and dose escalation has been increased recently, because they show high local control rate. Despite that, the tolerance dose (TD) of normal tissue has not been sufficiently investigated beyond the conventional schedules. We aim to set TD independent of prescription dose and for any number of fractions (N). We used radiobiological modelling to extend Quantec TD, which is widely accepted for conventional treatment, for nonconventional schedules. We apply the model for lung but can be applied to any organ.
Quantec model is limited for a prescription dose of ≤60 Gy and 30 fractions. To extend it for prescription doses ≥60 Gy, we translate the perception dose condition to an additional volume dose restriction, which is that the tolerated volume at 60 Gy is close to zero (V60 ≤0.5). So, the TD can be considered to be independent of the prescription dose. Then, we scale up the normal lung DVH for a random sample of 24 NSCLC until the NTCP reaches 20%. We release the restriction on V60 but to compensate that we increase the restriction on the V20. The average V20, V60, mean dose (Dmean) are taken to be the TD for normal lung. To extend Quantec TD for any N, Wither formula (WIF) was used to find the equivalent dose for 15, 20, 60 Gy and the volume restrictions are kept the same.
The new dose volume restrictions were found to be V20≤ 16%, V60≤ 7%, V250 ≤ 0.5% and the Dmean ≤15.6 Gy. We verify that NTCP ≤ 20 %, when these conditions are imposed. From these conditions, the tolerance dose at any N were derived to be VEQ20≤ 16%, VEQ60≤ 7% , VEQ250 ≤ 0.5% and the Dmean ≤ EQ15.6 Gy, where the equivalent dose was calculated using WIF at N.

O-331

PRELIMINARY ASSESSMENT OF INTER- AND INTRA-OPERATOR VARIABILITY OF QUANTITATIVE ULTRASOUND PARAMETERS USED IN BREAST CANCER DIAGNOSIS

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Non-ionizing applications

Introduction: Ultrasound Radiomics is being investigated for breast cancer diagnosis and prognosis. It is based on the extraction of highly reproducible quantitative biomarkers from ultrasound images to build large data bases to be used in clinical decision tools. Previous studies have focused on describing the lesion margin due to its high positive predictive value for malignancy. Here we present a preliminary comparison of the inter-operator (InterOP) and intra-operator (IntraOp) variability of parameters describing the lesion margin and Quantitative Ultrasound (QUS) parameter describing echo amplitude statistics.
Methods: 10 patients with suspicious breast lesions were enrolled in our protocol. Acquisition of radiofrequency (RF) echo signals from each patient was performed by three radiologists using a linear array transducer on a research-enabled Siemens ultrasound system. Each radiologist performed three acquisitions, allowing patient repositioning between acquisitions. B-mode and QUS images based on the Nakagami M parameter (related to echogenicity) were reconstructed from RF data. InterOP and IntraOp were compared between the lesion margin (manually drawn) and the mean value of M within the lesion. Discrepancy of lesion boundary and M were quantified as the fractional discrepancy between lesion areas (FMargin) and mean M values (FQUS) from a pair of images over their mean. Statistical significance between IntraOp (among acquisitions) and InterOp (among radiologists) discrepancies was assessed with a Wilcoxon rank sum test.
Results: All lesions were biopsy-confirmed to be invasive ductal carcinoma. Median [95% Confidence Interval] of FMargin was 27.1 [26.3-27.8]% for IntraOp and 30.6 [30.0-31.1]% for InterOp, with $p<0.0001$. In the case of FM, IntraOp and InterOp were 15.5 [14.7-16.4]% and 16.5 [15.9-17.1]%, respectively, with $p<0.01$.
Conclusion: Our results indicate that the InterOp and IntraOp variability of the Nakagami M parameter was less than half the variability of the B-mode contour, suggesting QUS analysis might be more reproducible than B-mode margin parameters.

O-332

EVALUATION OF INTER-/INTRA-FRACTIONAL POSITIONAL ERROR USING 3D PATIENT SURFACE GUIDANCE IN DEEP BREATH-HOLD LEFT BREAST IRRADIATION.

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Radiation Oncology – Treatment Delivery

【Purpose】
In recent years, radiotherapy with deep breath-hold technique is widely used to reduce radiation dose to the heart. We use a 3D patient surface guidance to ensure the state of deep breath-hold and the reproducibility of posture. In this study, we evaluated Inter- and Intra-fractional variation of deep breath-hold left breast irradiation.

【Method】
Fourteen patients with left breast cancer who had breast irradiation using surface guidance system (VOXELAN HEV-600 M / RMS Ver. 1.0.5 (manufactured by ERD) were analyzed (age: 39-49 y.o., median 45 y.o.). From the electrical portal imaging device (EPID) image obtained during treatment, the distance between the irradiation field edge and the breast skin surface was measured at three points in the upper, middle and lower regions. The inter-fractional variation for 14 fractions was calculated by finding the error of the distance of three ROIs in the first irradiation and 2nd ~ 15th fractions respectively. Correlation between EPID and VOXELAN was compared in phantom exams and patient data.

【Result】
Inter-fractional variation was 3.1% for differences of 4 mm or more, 9.2% for differences of 3 mm or more, 25.9% for differences of 2 mm or more. Intra-fractional variation was 0.7% for differences of 3 mm or more, 5.2% for differences of 2 mm or more. The difference was smaller than 99% or more than 3 mm. In Phantom, the correlation coefficient was 0.99, and a significant positive correlation was confirmed. The correlation coefficient for each patient was between 0.62 and 0.99, the average value was 0.79, the P value was 0.031 or less in all cases, and a significant positive correlation was confirmed.

【Conclusion】
The obtained values by VOXELAN and EPID were satisfactory matched. Observing patient body surface with VOXELAN is useful to maintain the reproducibility of breath-hold without radiation exposure.

O-337

DOSIMETRIC ANALISIS IN PEDIATRIC CATHETERISM

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Diagnostic Radiology –Dosimetry

Background:
The amount of fluoroscopic procedures and studies has been significantly increased during the last decades and its more frequent application to pediatric patients make dosimetry a concern. The objective is to measure the skin dose in hemodynamic procedures in pediatry and observe the relation between these readings and the calculated values in the console dose report.

Evaluation:
The C-Arm is a Philips Allura Clarity FD10. The dosimeters are nanoDots (Landauer) with OSL technology and Al_2O_3 as its active material. To analyze the measured dose we use a MicroStar reader.
The nanoDot is applied with adhesive tape to the patients in the highest assumed dose spot.
Once the procedure is completed the skin dose in the nanoDot is read within 24 hours.
These dose values are then related to the air kerma (KA) and product dose-area product (DAP) estimation made by the equipment software.
For the evaluation the weight ranges recommended by the ICRP are taken into account.

Discussion:
100 children were studied, aged 3 days to 18 years and weighing between 3,1 kg and 75 kg. The readings resulted between 1,02 mGy and 89,29 mGy. The total kerma and PDA reported by the software ranged from 9,19 mGy to 547 mGy and 760 mGycm2 to 35411 mGycm2 respectively. A linear tendency was observed between the nanoDot readings and the air kerma (R^2=0,804, R=0,897).

Conclusions:
The measured dose was inferior to the KA calculated by the C-Arm's Software and to the adult size reference levels for fluoroscopy.
NanoDot dosimeters are a useful tool for the direct measurement of skin dose in pediatric fluoroscopy.

O-344

OBSTACLES IN IMPLEMENTING ADVANCED RADIOTHERAPY AS REVEALED THROUGH IROC'S END-TO-END PHANTOM PROGRAM

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Radiation Oncology – Quality Assurance

Introduction: The Imaging and Radiation Oncology Core (IROC) provides end-to-end phantoms to institutions world-wide for clinical trial credentialing. These phantoms are treated like a patient by the institution, and the planned versus delivered dose distributions are compared in different phantoms for advanced radiotherapy including IMRT, moving target, SBRT, and SRS.
Methods: Phantom results from 2012-present were evaluated to understand the performance of institutions in delivering advanced radiotherapy. The rate at which acceptable deliveries were achieved was quantified for the established criteria of 5-7% point dose disagreement and 5%/3mm to 7%/4mm gamma analysis (varies by phantom). For those cases that failed to meet criteria, the patterns of failure were qualitatively examined and categorized, including missing the target, systematic dose errors, etc. Finally, for cases with dose errors, we developed and performed independent recalculations to understand the nature of these errors.
Results: More than 2000 phantom irradiation results were evaluated. Pass rates were only: 90% for IMRT, 87% for moving lung, 82% for SBRT, and 84% for SRS. For highly modulated treatments (IMRT and SBRT), failures were primarily because of systematic dose errors: the correct dose distribution was given to the correct location, but the dose was incorrect (69% of IMRT failures and 56% of SBRT failures). For the low-modulation moving lung treatments, only 22% showed systematic dose errors, whereas 50% of failing irradiations missed the target in the direction of motion. The SRS phantom showed a mixture of dosimetric errors and localization errors. Dosimetric errors in modulated treatments were found to have suboptimal treatment planning system calculations, implicating weaknesses in beam modeling.
Conclusions: Different advanced radiotherapy techniques are associated with different primary failure modes. This work highlights several of those failure modes, and provides a cautionary tale in particular about the challenges of beam modelling for modulated radiotherapy.

O-345

DOSIMETRIC EVALUATION OF CARDIAC SUBSTRUCTURES ON LEFT BREAST CANCER RADIOTHERAPY: IMPACT OF DOSE CALCULATION ALGORITHM AND TREATMENT TECHNIQUE

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Radiation Oncology – Dosimetry

Introduction: This study evaluates the dosimetric impact of respiratory movement, treatment techniques and dose calculation algorithms, to the dose to the heart and cardiac substructures during radiotherapy. Methods and Materials: Dose metrics were evaluated for a cohort of 10 patients treated with a field in field technique. Plans were calculated on a random respiratory phase CT (RPCT) using a pencil beam (PB) algorithm, and then recalculated on a 4DCT of the patient. For these patients 4DCT optimized and deep inspiration breath hold (DIBH) plans were evaluated. The impact of dose calculation algorithms was also analyzed for PB, collapsed cone (CC) and Monte Carlo (MC). Additionally, an in house developed respiratory phantom with TLDs was used to complement the dosimetric study. The impact of the calculated dose variations was assessed using a linear estimation of relative ischemic disease risk. Results: The left ventricle (LV) was the substructure receiving the highest mean dose, on average 61±21% larger than the mean heart dose (MHD), calculated on the RPCT. Due to the respiratory motion, MHD was underestimated by a 26.7±8.1%. Regarding the treatment technique, by implementing DIBH, MHD and LV dose reductions of about 40% and 50% were achieved, respectively. For the 4DCT optimized plans, MHD and LV doses were also reduced, but to a lesser extent. For the phantom, it was shown that all algorithms underestimated the out of field cardiac dose. For the PB implementation the discrepancy between TLDs and calculated point doses reached a 60%. In terms of ischemic disease risk, considering movement increased the relative risk in about 20% with respect to conventional planning, while DIBH plans reduced this risk in about 30%. Conclusion: Our findings motivate the implementation of heart protecting measures and promote a more accurate determination of the dose to the heart and its substructures.

O-346

SIMULATION OF TUMOR RESPONSE TO RADIATION CONSIDERING HYPOXIA INDUCED DEATH DUE TO VASCULAR DAMAGE ON 3D VASCULAR ARCHITECTURES

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Radiobiology

Introduction:
High radiation doses (> 8–10 Gy) induce a vascular damage that has been suggested to be one of the possible causes for the increased response of tumors to hypofractionated radiotherapy. The hypothesis is that vascular damage would produce reduced blood perfusion and indirect tumor cell death due to severe hypoxia. The purpose of this work is to develop a model of vascular damage considering realistic 3D vascular architectures (VA) to assess the possible role of vascular damage after high dose radiotherapy.
Material and Methods:
Tree-like tumor VAs of 1 mm^3 with 4% vascular fraction are generated and the diffusion-consumption equation is solved to calculate oxygen distributions. Vascular segments are deactivated using a serial-parallel model considering published endothelial radiosensitivity parameters. Vascular damage produces tumor oxygenation decrease and cells entering a severe hypoxia status die according to a hypoxia-death model based on experimental results. The OER modified LQ model is used to calculate RT surviving fractions (SF). The impact of these mechanisms on tumor response is studied at different dose levels, analyzing the effect of hierarchy in the tumor vasculature.
Results and Conclusions:
Radiosensitivity and hypoxia-death parameter values were adjusted in a model without hierarchical death to reproduce SFs observed on FSaII fibrosarcomas in mice irradiated from 10 to 30 Gy (Song et al. Int J Radiat Oncol Biol Phys 2015;93:166-72). At 20 Gy, the VA functionality decays to a ~5% 2 days after radiotherapy, recovering to a ~40% after 5 days. At this dose level, the SF due to vascular damage amounts to ~35%. When hierarchical inactivation of the VA is simulated, hypoxia induced SF is drastically decreased, reaching ~5%. This study is a stepping stone towards the consideration of vascular damage during hypofractionated treatment planning.
A.G-A. acknowledges the support of Conicyt (Fondecyt N11170575).

O-347

ORGAN DOSE IN CT: A COMPARISON BETWEEN THE RADIMETRICS ENTERPRISE PLATFORM ESTIMATION AND TLD MEASUREMENTS USING AN ANTHROPOMORPHIC PHANTOM

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Diagnostic Radiology –Dosimetry

Purpose: Dose-length product is not an accurate representation of the organ dose to individual patients, particularly if tube current modulation is used. RadimetricsTM Enterprise Platform (REP) calculates organ dose from pre-run MonteCarlo simulations on a set of the Christy-Eckerman phantoms). The goal was to compare organ doses estimated by REP with organ dose measured using thermoluminescent dosimeters (TLD) on an anthropomorphic phantom during CT examination.
Method: A male 701-D ATOM phantom with 268 holes for TLD-chips dosimetry distributed in 22 internal organs was used. The phantom weights 73 kg and consists of the head and torso only. A whole-body scan was carried out in a Siemens Biograph64 mCT (acquisition parameters: 120Kv, 99.7mAs in average). TLDs had been previously cross-calibrated to a FC65-G in a 120kV beam of a Philips X-ray tube SRO33100 (6.141 mm Al at the calibration depth). Estimated organ doses from REP were compared to measured values for 17 organs in common by the two methods.
Results: In average, REP overestimated organ dose in 40% approximately (except for intestine for which REP underestimated by around 3%). Greatest difference was observed for the eyes, for which estimation to measurements ratio were more than threefold. As REP estimation is based on pre-run simulations for various scan protocols with different parameters (such as kVp) for a set of phantoms, differences between the body mass of the ATOM phantom and the Christy´s adult phantom might explain some of the differences observed.
Conclusion: Reasonable estimation of organ dose for a whole-body CT using REP was obtained (ratio of REP estimations to measurements of 1.5). Further analysis should be performed for other protocols where the accuracy of organ dose estimation for organs outside the scan range can be tested.
BSN acknowledges the support of Conicyt (Fondecyt N1181133).

O-350

A COMPOUND REFRACTIVE LENS FOR MEGAVOLTAGE RADIATION ONCOLOGY LINEAR ACCELERATORS

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Radiation Oncology – Treatment Delivery

Purpose: Conventional wisdom in medical physics holds that the megavoltage X-rays used in radiation oncology cannot be manipulated. However, advancements in the field of x-ray optics over the last two decades may prove this is no longer the case. By creating a compound refractive lens to collimate and focus mega-voltage x-rays, radiation oncology linear accelerator beams can be more effectively controlled.

Methods: The test will consist of recording an open field, a blocked field, and the lens field If successful, we expect to see a “barbell” pattern insofar as the central lens field has been collimated while the outside blocked and open fields remain divergent. A success would also show larger dose gains and smaller penumbra in the lens field compared to the open and closed fields. The original CRL design consisted of cylindrical holes drilled into aluminum with the interstices between the holes functioning as the lens. We will use the same design for our prototype and characterize it with three parameters: focal length, transmission, and gain. This lens will be created by an KNMF in Germany and tested on a LINAC at a Genesis Healthcare Partners.

Results: As this experiment is ongoing, any and all preliminary results will be presented at the meeting.

Conclusion: If successful, this lens will result in higher dosage gains, smaller penumbras, reduced normal tissue irradiation, and better field conformality, all of which lead to better patient outcomes.

O-352

TOWARDS ESTABLISHING NATIONAL DRLS FOR CT IN CHILE: THE FIRST STEP, COMPUTED YOUR OWN INSTITUTION DRL OR TYPICAL VALUE.

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Diagnostic Radiology –Dosimetry

DRLs are a useful tool in the process of optimization, and although in Europe and the US National DRLs are wildly available, it is difficult to find records of radiation dose delivered in Latin America and there for is no formal establishment of NDRLs or RDRLs.

The first step for establishing National DRLs is to be able to access Local DRLs or “typical value”. Local data should be obtained from a representative sample of typical patients. With larger numbers of patient doses available from electronic data collection methods no big constrains on patient type should be done. If this is not an option and the number of patients for whom data are collected is limited it is important to have some standardization of patient size. A group of at least 30 patients within the agreed weight range is preferable for CT procedures.

Methods and Materials,
DRLs for 1 of the most frequent CT exams at our hospital was computed by three different methods, the first approximation (M1) is taking into account all patients of 2018 were information of patient diameter is available (used as reference), the second methods (M2) only using “average size patients (patient diameter between p25 and p75), and the third method using 30 average patients taken on a define observation time. For all three method DRL were computed as the median of the data distribution.

Results
DRL M1 661 mGycm, M2 654 mGycm (less than 2% difference with M1), M# 642 mGycm (less than 3% difference with M1).

Conclusions.
The three methods used show no big differences for CT ABDPELVIS WO&W IVCON protocol. The study will be performed for the 5 more frequent protocols done at our institution. Using only 30 average patients by protocol, by institution is an accessible first step towards establishing NDRLs in Chile.

O-362

DOSIMETRY STUDY OF A LOW COST MATERIAL FOR USE AS A BOLUS IN RADIOTHERAPY.

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Radiation Oncology – Dosimetry

Introduction
In the practice, to optimize skin radiotherapy, materials such as bolus are used, but in some cases air gaps that change the dosimetry are generated. In the literature, different materials have been proposed for use in radiotherapy of difficult anatomical regions such as medial canthus or auricular pavilion. Monte Carlo (MC) simulation is an alternative study in detail the irradiation of different materials and their dosimetric response.
In this work, a material was contructed and characterized through simulation, experimental measurements and CT for use and implementation as a bolus in radiotherapy. Dosimetric characteristics are compared with two paraffins used in radiotherapy some centers, also evaluating the formation of Air Gaps and Fractures in this materials.

Material and Methods
Different plates of a flexible and transparent material with density 1.08 g/cm3 called BolusCM was constructed. Also plates of different paraffyn was constructed. This materials was irradiated with electrons of therapeutic energies and PDDs were measures.
In order to analyze abnormalities formed in the process, CT was made to the plates and HU were measures.
Using Geant4 the materials and interaction of electron beams were simulated. For diferent energies PDD's were calculated in detail.
The Montecarlo results were comparated with experimental measurements and other characteristics taken from CT

Results
BolusCM material is flexible, at environmental conditions or high dose radiation no changes.
The PDD's for three materials were measures and from CT the HU were obtained. In the paraffyn 1 and 2, and BolusCM were measures 70 HU ± 5 HU, 83 HU ± 7 HU and 100 HU± 3 HU respectively. With MC Method the PDDs in water, Paraffyin and Bolus CT were obtained.

Conclusions
The Bolus CM Material shows homogeneity, allowing uniformity in the deposited dose. This Material can be used and implemented as a bolus in radiotherapy.

O-364

QUANTITATIVE ANALYSIS OF THE DOSE DELIVERED ACCURACY IN RADIOTHERAPY TREATMENT USING IMRT TECHNIQUE IN HEAD AND NECK TUMORS USING ANTHROPOMORFIC SIMULATOR

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Radiation Oncology – Dosimetry

The dose administered to the patient in treatments of radiotherapy verification has a great importance for the patient safety. Head and neck tumors represents more than a quarter of the diseases treated in the hospital, losing only to breast and prostate tumors. Due to the number of organ at rick that are present in the region, the concern becomes even greater. Thus, in order to verify the IMRT technique validation efficiency using an anthropomorphic phantom with different materials simulating the head and neck heterogeneities developed in-house , the endto-end tests quality control from head and neck radiotherapy treatments, the Nasopharingeal Carcinoma were chosen, were quantitative evaluated using an A16 Exradin micro ion chamber and the dose were delivered by a Varain Clinac IX . Verifying the dose delivery in the volume of interest and adjacent volumes, and evaluating the uncertainties associated with the absolute dose calculation in different areas. The radiotherapy treatments planning using the IMRT technique showed a relative deviation between the absolute dose calculated by TPS Eclipse and the absolute dose measured with the ionization microchamber lower than 3% at all studied regions points. In the Lung, Cervical, Marrow and PTV70 regions the relative dose deviation were 2.24%; 0.21%; 2.47% and 1.73%, respectively. Therefore, It can be concluded that, from the use of a composed by different materials anthropomorphic simulator characterizing different heterogeneities, the quality assurance verification from the absolute dose process in head and neck tumors treatments using the IMRT technique can be assessed by assuring an expanded relative uncertainty of approximately 6.6% in the absolute dose calculation with a confidence interval of 95.45% and ensuring the reliability of correct dose delivered to the patient.

O-368

DETERMINATION OF AMORPHOUS SILICON PANEL PRECISION TO DETECT CYBERKNIFE M6 BEAM QUALITY SHIFTS

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Radiation Oncology – Quality Assurance

Cyberknife uses small radiations fields, quality assurance devices resolution should be very high in order to obtain reliable measurements. QASC, Standard Imaging®, uses Amorphous silicon (aSi) panels which are of the highest resolution detectors in the market combined with a new software that has been so far scarcely used in clinical mode in order to measure small field beam parameters.

Quantifying the reliability of the above mentioned device is the objective of this work, precision and accuracy determination will be discussed.

The methodology involves usage of the aSi-panel in a daily basis, during approximately 7 months, with a reproducible image processing set up, to measure inline and crossline beam parameters, with a record of the baseline image then analyse further results in comparison to this starting point.

Preliminary results for flatness, symmetry, penumbra and field size, have shown a very high device performance for very well studied beam parameters; e.g. for Inline profile: baseline 6.69 %, average 6.61%, standard deviation 0.09%, maximum difference 0.3 %, difference between maximum and minimum 0.38 % and variation coefficient 1.36 %.

Compliance to the objective, from measured aSi-panel to processed statistical data, the statistical process used proved the aSi-panel to be of very high precision and able to detect small changes in the radiation beam. These results lead us to continue evaluating the accuracy and sensitivity of the device by making more measurements in the water tank. In a few months it will be possible to establish a relationship between the behaviour of the aSi-panel and measurements obtained in the water tank. We would then be able to restrict usage of the water tank to occasions when the aSi-panel analysis fails.

O-371

TIME-DRIVEN ACTIVITY-BASED COSTING FOR COMPETING TREATMENTS USING DIFFERENT TECHNOLOGY SOLUTIONS

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Radiation Oncology – Treatment Delivery

Purpose: Equitable access to radiotherapy (RT) must be a reasonable health care goal worldwide. Low to middle income countries face challenges: lack of professionals, reimbursement schemes and public policies. Given costs of delivering advanced RT care remain poorly described, we report results of time-driven activity-based costing (TDABC) for competing treatments and opens way for discussions on how to account for and utilize resources.
Methods: TDABC is a cost calculation technique that iteratively allocates resource costs to products based on activity consumption weighed by treatment complexity. Process maps were developed for each phase of care from the initial visit to end of treatment through 2 years of clinical practice using Cyberknife Stereotactic body radiation therapy treatments (SBRT), Radiosurgery (SRS), Elekta Volumetric Arc therapy (VMAT), Tomotherapy (TOMO) and conformal RT (3D).
Results: Substantial cost variation was observed, with costs ranging from TOMO, to SBRT. TOMO was notably cheaper than VMAT, SRS was cheaper than VMAT. Cost savings attributable to shorter procedure times and fewer fractions despite of higher initial capital costs. Both equipment costs and quality assurance contributed to the high cost of SBRT, where machine quality assurance (QA) and patient specific delivery quality assurance (DQA) costs range up to 54% when single fraction. 3D was only 20% cheaper than TOMO, largely because of workflow. RT costs are predominantly determined by personnel 38% and equipment cost 39%. Machine usage activities consume most: treatment delivery 65%, QA 12% and DQA 8%.
Conclusion: TDABC analyses cancer services and provides insights into cost-reduction and value. It impulsed evaluating practice changes in the 3 major cost drivers: fractionation, QA and DQA. Our aim is to develop a model that establishes direct relationship between equipment, human resources, fractionation and quality assurance. Unlike benchmarks estimating number of Linacs/ million people, we vouch for considering the whole patient workflow.

O-376

EVALUATION OF CALCULATION OPTIONS OF EMC ALGORITHM

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Radiation Oncology – Dosimetry

INTRODUCTION: The electron Monte Carlo dose calculation algorithm (eMC) available in Eclipse Treatment Planning System is a fast implementation or macro Monte Carlo algorithm. The eMC algorithm has been commissioned at Instituto Nacional del Cancer. Prior to clinical use, the different adjustable calculation options have been studied, in order to fully understand the changes implied in each one of them. The calculation options evaluated are statistical uncertainty, grid size, smoothing method and smoothing levels.

METHODS AND MATERIALS: The evaluation was done in Varian Eclipse v13.6 for a Varian iX linear accelerator, for one beam energy and one applicator size. Each one of the calculation options was changed at a time and some plan parameters were compared. These parameters were calculation time, monitor units and dose distribution.

RESULTS It was found that calculation time is greatly affected by changes in statistical uncertainty. Also, dose distribution looks different for the various calculation options. Therefore, care must be taken in selecting calculation options and dosimetrists should be consistent in their selection for different plans. Also, radiation oncologists should be aware of altered appearance of dose distribution when they evaluate isodoses curves and target coverage for eMC, in comparison with other electron beam calculation algorithms.

CONCLUSION: A complete understanding of new algorithms is needed when selecting dose calculation options. Dosimetrists and physicians need to be aware of differences within the algorithm for proper plan evaluations.

O-378

REFERENCE TEST SET TO VALIDATE MAIN DOSIMETRIC PARAMETERS OF A TPS COMMISSIONING

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Venezuela

Radiation Oncology – Dosimetry

INTRODUCTION
In order to detect systematic deviations in dose calculation, we have developed a couple of sets of tests to use as a reference to validate the proper acquisition of dosimetric data and the corrected feed of the Treatment Planning System (TPS). The main parameters to compare by other users are the Monitor Units of these test sets calculated by a Matlab code, which reads the planning data from an RT Dicom file. This code follows the formalism and get the dosimetric data from the AAPM Task Group 71 report, for a 6 MV linear accelerator.
METHODS AND MATERIALS
The first test set was composed of 20 treatment fields that were planned with basic setups, which were calculated by the Matlab code and compared to the AAA Algorithm within the Eclipse TPS fed for this research, with the preconfigured data provided by the manufacturer. These fields are intended to facilitate the audit of the data measured and entered into the TPS, as well as the calculation it performs in main parameters such as: i) the absolute dose value; ii) beam quality within the TPS; (iii) adequate measurement and use of physical wedge factors entered; and (iv) the dynamic wedge factors calculated by the TPS.
The second test set is based on the phantom propose by the TG119, which is composed of different structure mocks of Head and Neck and prostate. The user has to make a couple of 3D standard plans following specific instructions.
RESULTS AND CONCLUSIONS.
We verify 3 different linacs and we get differences smaller than 2.5% respect to the expected MUs for all evaluated fields. The use of this methodology can substantially detect systematic errors of a TPS commissioning, because we are using a completely independent reference set of dosimetric data to the MU comparison.

O-379

CHARACTERIZING 3D PRINTER IN A HIGH DOSE RATE (HDR) BRACHYTHERAPY CENTER.

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Radiation Oncology – Brachytherapy

Introduction.
3D printing has generated great interest in the brachytherapy community due to its versatility in the manufacture of different customized applicators and the increasing availability of this technology.
This study aims to present a characterizing process for a 3D printer in a HDR Brachytherapy Center.
Methods and Materials.
A 3D printer Creality Ender 3 and dark gray polylactic acid (PLA) were used to make the applicator, using a defined configuration for printing in all cases.
Different applicators devices were printed, using a 20% infill, and were contrasted with their commercial devices. The evaluation was made measuring with EBT3 radiochromic films located in a fixed position on one side of the applicators, for both 3D impressions and commercial applicators, evaluating depth dose profiles based on source distance.
Results.
Differences in dimensions between the designed applicator and the resulting impression were less than 1.0 mm.
Using computed tomography, it was found that 3D impressions show a reasonable uniformity in their internal structure.
In radiochromic films, differences of less than 5.0% in dose in the first 10.0 mm near the source were found. However, differences decreased gradually as a function of distance until becoming lower than 1.5%.
Conclusions
3D printing provides a viable and economical method in the manufacture of applicators, presenting dosimetric differences of less than 5% in the first millimeters compared to commercial applicators. These applicators can be used in Brachytherapy treatments, (aiming) for personalized treatments for each patient.

O-380

QA WITH A PORTAL IMAGING DEVICE FOR CO-60 HDR BRACHYTHERAPY

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Radiation Oncology – Quality Assurance

Introduction: In high dose rate remote (HDR) afterloading brachytherapy, quality assurance (QA) strongly depends on the accurate determination of position, transit time and velocity of the source. In order to check these parameters in a remote afterloader with Co-60 sources, a portal imaging device was constructed and characterized.

Methods: QA portal imaging device was built for HDR brachytherapy equipped with Co-60 sources. It consisted in an aluminum chassis with three different web cameras to detect the emitted radiation. We used a Co-60 HDR afterloading system (E&Z BEBIG 60 Co HDR Co0-A86, Berlin, Germany). Original photons from the source were attenuated in a thin copper surface to generate electrons. Attached to this surface there was an emulsion where electrons produced photons in the visible range which were reflected by a 45-degrees mirror and detected by the cameras. The images were analysed with Matlab R2013b. Noise was subtracted from the images and geometric positions of the source were determined. Then transit time and velocity of the source were obtained.

Results: We obtained some preliminary results. Sensitivity of the source position was better than 0.6 mm per pixel for all cameras. All transit times were also consistent and around 0.6 seconds. Source velocities were 87 mm/s for two cameras and around 100 mm/s for the other.

Conclusion: Preliminary results indicate that this methodology may provide an easy and precise way to periodically check source position, transit time and velocity for HDR Co-60 sources in brachytherapy with good accuracies.

O-386

REDUNDANT DOSE CALCULATION BASED ON A RADIOLOGICAL RAY TRACING PATH AND EXPERIMENTAL DATA

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Radiation Oncology – Quality Assurance

Radiotherapy dose calculation engines like Monte Carlo and alike have increased the trust on the planning outcome of IMRT and VMAT techniques. It is not unreasonable for redundant dose calculation algorithms to improve their complexity and correctly calculate highly modulated IMRT or ARC plans. Given the undeniable trust in semi empirical redundant calculations an algorithm based on Venselaar methodology and radiological ray tracing path was developed. Using a transformation based on radiological path that accounts for the distance of a dose point to all the tomography voxels, we traced the plan information to typical measurements done in water while maintaining a high precision. The developed software listens to the DICOM communication between the TPS and the record and verify system to automatically output a calculation. We used the treatment planning of more than 50 patients accounting for different oncology pathologies and treatment modalities. Using the Monte Carlo engine present in Elekta's Monaco TPS, the dose of several interest points was compared. The difference between both algorithms was lower than 3% for off axis interest points located in risk organs and lower than 2% on the isocenter. We believe the automatization and precision of this algorithm makes it an excellent redundant tool for the new highly complex treatment modalities of radiotherapy.

O-397

QUALITY CONTROL WITH FLATPANEL 1500 IN SURFACE TREATMENTS WITH HIGH DOSE RATE (HDR) BRACHYTHERAPY

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Red AUNA, Peru

Radiation Oncology – Quality Assurance

The objective of this study is to provide a viable method for the quality control of surface treatment plans. Dosimetrically 15 treatments of superficial Brachyrapia of high dose rate with the applicator H.A.M of Ecker & Ziegler were reviewed. The applicator was reconstructed three-dimensionally and planned with the planning system HDR plus 2.6.5 without the need for tomographic images.
The treatment was delivered by a HDR Multisource charging equipment from Ecker & Ziegler with a Co-60 source. The passage of the fountain is arranged in 5mm stops and separated by 1cm. The plans were analyzed using the Flat Panel 1500 and analyzed through VeriSoft software, the observation of the maximum surface dose of the applicator (in contact with the skin) and the prescribed dose at the depth requested by OSL.
The uncertainty of performing surface treatments with HDR was the distribution of doses, hot spots, so an OSL dosimeter placed in the center and at the ends of the treated area was used.
A coverage between 90% and 100% of the surface to be treated was observed with maximum points of 150% of the prescribed dose evenly distributed over the surface of the applicator (0.5cm from the trajectories of the source).
The reading of the OSL dosimeters had a difference of 3% in the maximum points and in the center smaller 1%.
After all this analysis we can say that an easy and objective dosimetric analysis can be carried out with the Flat Panel 1500 that covers the treatment needs.

O-399

DOSIMETRIC ANALYSIS OF INDIGENOUSLY MADE INTRACAVITARY AND INTERSTITIAL (IC+IS) GYNECOLOGICAL APPLICATOR IN IMAGE-BASED BRACHYTHERAPY

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Radiation Oncology – Brachytherapy

Aim: To evaluate the dosimetric parameters of indigenously developed applicator for the Carcinoma Cervix
Methods and Materials: Teflon cylindrical applicator was made with holes for needle insertion based on the virtually created applicator in TPS. For commissioning of the needle and applicator, the autoradiograph was performed on Gafchromic film. The applicator has the provision for inserting 19 needles (straight and angulated) and a central tandem. For validation of the applicator, various HRCTV (High risk clinical target volume) (n=21) were made with clinically correlated dimensions and it has the maximum extension of 4.2cm (Right), 4.9cm (left), 3cm (anterior) and 2.8cm (posterior). Brachytherapy dose plans were generated based on the Point A prescription and the source positions were activated on the reconstructed needles for the HR-CTV. Manual dwell time optimization was performed and 8% to 20% loading time was kept for the needles. Dosimetric parameters of V90%, V98%, V100%, V200% and TRAK (total reference air kerma at 1m) values were analyzed for different HR-CTVs.
Results: In autoradiograph, the active source position is 6mm from the needle edge. The volume of the HRCTV ranged from 13.9cc to 98.8cc (mean 57.9cc, SD 21.7cc).The mean of V90% and V98% was 97.3% (SD 2.6%) and 95.85(SD 3.5%) respectively. The mean value of V100% and V200% is 95.25 (SD 3.6%) and 53.1% (SD 9.4%) respectively. The mean TRAK value is 0.5302cGy (SD 0.039 cGy) for 6Gy and varies from0.459cGy to 0.603cGy depending on volume of HRCTV.
Conclusion: Our indigenously made intra-cavitary and interstitial brachytherapy applicator can able to create the volume dose distribution for different HRCTVs. At the same time this applicator can create the Point A based dose distribution along with lateral and anterior-posterior dose extension. It can fulfill the clinical requirements for extended target volumes in the case of Carcinoma Cervix.

O-402

INITIAL EXPERIENCE: QUALITY CONTROL IN INTRACRANIAL STEREOTACTIC RADIOSURGERY

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Radiation Oncology – Quality Assurance

Introduction
Radiosurgery is a technique used to radiate small intracranial lesions at very high doses. These injuries are usually located in regions very close to risk organs that require a high degree of precision. Due to this, the determination of the isocenter of radiation (IR) and its dimensions has a considerable relevance in the quality of the administered treatment. The so-called Winston-Lutz test (WL) is a method of quality control that allows us to verify both the position and the dimensions of the IR with respect to the mechanical isocenter (IM) in a linear electron accelerator. In parallel, the start of the technique in our National Institute of Neoplastic Diseases (INEN) in 2018, led to a thorough study of the geometric variables involved.

Materials and methods
In the National Institute of Neoplastic Diseases (INEN) there is a linear accelerator of 6 MV, Elekta, Sinergy model, with Agility multileaf systems, with portal dosimetry system and a pointer (ball baring), acquisitions were made of images using the portal for the WL test, these images were then analyzed in a dosimetry software (RIT v6.6.64).
The WL test was used a cone, which served to reduce the gloom of the radiation field, several acquisitions were made with variable angles of stretcher and gantry, the radiation field size was 5x5 cm2, the images were obtained in the Iview.

Results and conclusions
The results show a variation of the isocenter of less than 1 mm, which is accepted according to the American protocol TG-142, the WL test allows to guarantee the high degree of precision of delivery of the dose and a good quality in the treatments.

O-403

OPTIMIZATION OF MEDICAL EXPOSURE IN PEDIATRIC NUCLEAR MEDICINE PROCEDURES

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Nuclear Medicine

Introduction: Pediatric studies in nuclear medicine provide valuable information for the diagnosis and monitoring of different pathologies. Many efforts are currently performed to reduce the irradiation levels of pediatric patients without affecting the image quality. The most relevant clinical protocols were evaluated and optimized in two NM services, emphasizing on the morpho-functional kidney studies with 99mTc-DMSA.

Methods: The activity administered to 67 pediatric patients (scintigraphy) was randomly evaluated from 99mTc-DMSA, 99mTc-MDP and 99mTc-MAG3 studies, divided by age groups of 0-5, 5-10 and 10-18 years; the absorbed doses were also estimated and evaluated. These values were compared with recommendations from international organizations (SNMMI and EANM). The exams that showed the highest levels of irradiation were the 99Tc-DMSA scans. The optimization process of DMSA-99mTc studies was based on using acquisition techniques that simulate fractions of the administered dose (1/5, 2/5, 3/5 4/5 and 5/5). These images were evaluated by two independent observers experts on renal studies. The optimal levels of activity to be administered were defined.
Results: It was identified a significant increase in the levels of activity administered with respect to those recommended. Renal studies with 99mTc-DMSA showed the highest levels of administered activity in the three age groups studied (149%, 103% and 57%, respectively). These values were lower in the case of bone scintigraphy with 99mTc-MDP (93%, 68% and 43%, respectively) and renal studies with 99mTc-MAG3 (31%, 12% and 22%, respectively). Optimization studies performed for 99mTc-DMSA allowed to decrease the activity administered to infants without affecting the quality of studies, with the consequent decrease in radiation doses absorbed in more than 34%.
Conclusions
It was possible to optimize the pediatric doses in static renal studies with 99mTc-DMSA in the two participating institutions. Currently, a similar analysis is in course in order to optimize the 99mTc-MDP and 99mTc-MAG3 scintigraphic studies.

O-404

INTER-COMPARISON OF TOOLS FOR QA OF 4D POSITIONING IN ADAPTIVE RADIOTHERAPY

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Radiation Oncology – Quality Assurance

Introduction: In external beam radiotherapy, advances in technology have enabled the possibility of transitioning from basic 2-dimensional treatment planning and delivery (2-D radiotherapy) to a more sophisticated approach with 3-dimensional conformal radiotherapy (3-D CRT) and 4-dimensional respiratory motion (4D). Similarly, technology advances have meant that verification of the positioning of the patient with radiographic film analyzed after treatment (“off-line”) has progressed to advanced imaging of the patient volume at the time of treatment with immediate “on-line” corrective strategies. Intrafraction motion is an issue that is becoming increasingly important in the era of image-guided radiotherapy. Intrafraction motion can be caused by the respiratory, skeletal muscular, cardiac, and gastrointestinal systems. For the determination of these movements, different systems for capturing images have been developed, which can be generated by megavoltage or kilovoltage beams. Materials and Methods: In order to optimize the positioning process and determination of these internal movements, an intercomparison was made between different quality control tools of the 4D positioning. A dynamic phantom (CIRS Dynamic Thorax Phantom) was used to acquire images with the iView in Movie mode and with XVI in Motion View mode and Symmetry mode. From the images taken, the calculation of the overlays was made, which were compared with those reported by the CIRS manual. Results and Conclusions: The discrepancies obtained for the different tools are within the tolerance reported by the consulted bibliography. As a conclusion, for the realization of the QA of the 4D positioning, it was possible to establish a protocol in which the XVI was used on the first day of treatment and in the remaining days the iView.

O-408

PATIENT DOSE MANAGEMENT IN X-RAY CT: EXPERIENCE FROM YALE HEALTH SYSTEM IN THE UNITED STATES

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Diagnostic Radiology –Dosimetry

CT diagnostic procedures are associated with relatively high radiation doses required to obtain acceptable diagnostic quality images. Introduction of recent CT technologies helped adjust CT acquisition protocols to a more acceptable dose levels with reduced risk to patients. CT dose adjustment and modulation can be achieved using several techniques including auto mAs and kVp, dual energy CT, a wide range of statistical iterative reconstruction algorithms, better patient positioning and the use of gated cardiac studies. We use radiation dose management system, Radimetrics™, to query/retrieve the CT exam's "Radiation Dose Structured Report" (RDSR) for comparison and further analysis. Using data from more than 300,000 CT examinations at our institution we could identify CT doses higher than established benchmarks for multiple master and sub master CT protocols and correct for protocol appropriateness, scanners inadequacies and operator deviations from standard operations including patient variations. We will present samples of our approach to investigate, correct practices and update acquisition protocols to help reduce CT doses.

O-409

PROGRESS IN MEDICAL PHYSICS CAPACITY BUILDING IN AFRICA – THE FAMPO PERSPECTIVE

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Education and Professional Issues

Background:
FAMPO is the Federation of African Medical Physics Organizations. It is the African chapter of the International Organization of Medical Physics, IOMP. FAMPO has membership from 30 countries in the region and for countries without a medical physics society individual membership is possible.
There are currently about 500 – 600 Medical Physicists in Africa, but many African countries do not recognize medical physics as a profession. Only Ghana and South Africa register medical physicists with a national authority or a Health Professions Council.
Objective:
Current projections estimate that by 2035 22.000 medical physicists are required to cover the need in radiotherapy alone in low-and-middle-income countries (LMIC). It is therefore an urgent need to progress the concept of clinically qualified medical physicists and to increase clinical training and the number of trainers.
Methods:
The Education and Training Committee (ETC) of FAMPO could provide ‘certification’ of various courses (academic and/or clinical training). The ETC can work on accreditation mechanisms for regional training programmes and look into partial training capabilities. The International Atomic Energy Agency has offered use of an online platform to capture achieved competencies.
The Professional Development Committee (PDC) of FAMPO is envisaged to start registering clinically trained medical physicists one they have undergone training at an accredited training site.
It is imperative that the ETC and PDC work independently.
Results:
The ETC and PDC are currently both collecting relevant data and working on a grandfather clause for registration.
Conclusion:
In this way FAMPO hopes to help address the dire shortage of medical physicists in Africa.

ICMP 2019 / ALFIM 2019

POSTER PRESENTATIONS

P-004

ANALYSIS OF ANGULAR AND SPACE DISPLACEMENTS IN THE REGISTER OF IMAGES IN TOMOTHERAPY

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Radiation Oncology – Quality Assurance

At Centro Estatal de Cancerología of Durango, Mexico, a TomoTherapy HDA was installed in June 2016. From that date until now, more than one thousand patients have been treated and more than 24 thousand treatment sessions have been delivered. As part of the training in the management of this image-guided radiotherapy technology, a phantom was designed, it was named EVA.
This phantom includes different densities and Hounsfield Units similar to the human body.
The aim of using this mannequin is to find correlations between translations and rotations manually applied to it and the translations and rotations corrections detected by the TomoTherapy Image system. In this work we present the measurements made with the phantom EVA and a brief analysis of them.
These measurements have allowed us to determine the enormous importance of the correct choice of the image technique depending on the treatment site to obtain a correct image registration and to make sense of the suggested corrections.

P-005

RADIOBIOLOGIC COMPARISON OF TEARDROP TECHNIQUE FOR BREAST CANCER RADIOTHERAPY TREATMENT PLANNING ON A TOMOTHERAPY SYSTEM

Higmar Herrera, Uvaldo Reyes

Centro Estatal de Cancerología de Durango, Mexico

Radiation Oncology –Treatment Planning

Breast cancer in Mexico is the first cause of death in women. Radiotherapy has proven to be a great tool to control such ailment and TomoTherapy a relatively new technology to accomplish it. To obtain good clinical outcomes, tight dosimetric constraints are placed on organs at risk to maximize TCP and minimize NTCP. The teardrop technique helps meeting this constraints by placing a virtual block over the ipsilateral lung and part of the heart but it contributes to lengthen the treatment time. We present our experience in using this technique and compare its radiobiological estimations with similar plans without it.
Seven patients diagnosed with breast cancer were planned twice, with and without the teardrop technique. Dose-Volume histograms were obtained on Tomotherapy Planning System and analyzed on Albireo Target Cygnus X1 to get UTCP and fEUD parameters. Matlab Statistics Toolbox was used to examine the results significance through bootstrapping of Student's and Wilkinson's tests. The heart, both lungs and contralateral breast were considered. The same statistical tests were applied to the treatment delivery time.
UTCP for unblocked plans ranged 0.910 - 0.952 with a mean of 0.925, while the same parameter for teardrop plans ranged 0.920-0.964 with a mean of 0.939. fEUD ranged 0.423-0.562 and 0.492-0.612; mean delivery time was 344.7±84.8s and 496.8±70.5s for unblocked and blocked plans respectively.
This observed differences were significant with 95% confidence ($p<0.05$).
Although a 2% difference was observed for UTCP all constraints were met, but it was easier to accomplish it with the teardrop that also permitted a 10% gain in fEUD. This came with a 40% increase in delivery time which is still below our 10 minute allocation established internally.
The teardrop technique was observed to have a net radiobiological benefit with little impact on patient scheduling.

P-006

COMMISSIONING OF MONACO TPS FOR 3D RADIOTHERAPY USING THE THORAX CIRS PHANTOM, BASED ON THE AIEA TECDOC 1583

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Radiation Oncology –Treatment Planning

In the application of radiotherapy for planning and calculating doses, so-called planning treatment systems are used, which help specialized personnel to prescribe dose, number of sessions of a treatment and the configuration of radiation beams to maximize the dose to the tumor and decrease it to healthy organs.
In this work the commissioning of the Monaco treatment planning system was carried out based on the technical document of the IAEA 1583, which dictates step by step how to carry out the commissioning using CIRS thorax phantom.
A curve of Hounsfield units vs electronic density was obtained for the AcQsim simulator tomograph, which is linked to the planning system, a series of verification cases was planned with all the calculation algorithms that the Monaco has to do a dose verification using a FARMER type ionization chamber comparing the measure obtained with what was calculated by the system, finally a comparison was made between the two calculation algorithms available in the Monaco, Collapsed Cone and Monte Carlo XVMC, based on the measurements made in the verification cases and only in the cases without wedge, since the Monte Carlo algorithm does not have this function available.
It was concluded that the planning system is apt to apply treatments without the use of wedge in both calculation algorithms. With wedges it shows failures that require a more exhaustive investigation.
The Monte Carlo XVMC algorithm is recommended because it is within a tolerance of 3% in almost all cases of dose verification performed, unlike the Collapsed Cone.

P-007

DIAGNOSTIC REFERENCE LEVELS FOR COMMON X - RAYS PROCEDURES IN PERU

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Radiation Protection

Reference levels for common X-ray procedures have been established in various countries.
In Peru, during quality control tests, these international reference levels establish the tolerance of surface dose, which is the basis for different protocols.
However, more studies can be carried out to evaluate the national reality and the different parameters for exposure techniques such as kV, mAs, type of equipment (conventional or digital), etc.
In this work two radiographic procedures were taken into account, general X-rays (fixed and mobile) and intraoral X-rays (fixed, mobile and portable).
An Unfors RaySafe Xi detector was used; the kerma (Kair) was measured at a distance - focus of the detector that varied depending on the procedure, and was subsequently corrected to calculate the surface dose as mentioned in the Arcal XLIX protocol. The data used in this document was collected over a period of 3 years (2015-2017).
In addition, for each X-ray machine, only the last evaluation made during this period was taken into consideration.
The results hope to achieve a new standard that reflects local practice and addresses the problems of the "Bonn Call for Action" in Peru.

P-009

ESTABLISHING LOCAL DIAGNOSTIC REFERENCE LEVELS (LDRL) FOR A TYPICAL FLUOROSCOPIC EXAMINATION IN SOME RADIOLOGICAL IMAGING INSTITUTIONS IN GHANA

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Radiation Protection

The primary aim of this work was to propose local diagnostic reference levels for fluoroscopic examinations in some selected radiological imaging facilities in Ghana. The work also aimed at investigating the distribution levels of patient radiation dose received during fluoroscopic examinations for subsequent improvement of optimization. The materials used for the research were, Piranha kit, KAP meter and Fluoroscopy machine. The research was done at two public hospitals (coded Facility A and B), located in the Greater Accra Region, between December 2017 and June 2018. Prior to the starting of this research a series of quality control tests were performed using the Piranha kit to assess the machine output. The patient data and dose descriptors collected during the work included, gender, age and Kerma-Area Product. The Diagnostic Reference Levels (DRLs) was estimated for each facility using the 75% percentile. A total of one hundred and sixty-nine (169) patient dose data were collected for this study. DRLs was established for the frequently performed procedures which includes, hysterosalpingogram (HSG) and barium swallow (BaS) examinations. The DRLs for KAP and screening time values estimated for hysterosalpingography was 6.0 Gy.cm2 and 0.60 minutes and Barium swallow was 12.1 Gy.cm2 and 1.4 minutes for Facility A respectively. The DRLs for KAP and screening time values estimated for hysterosalpingography was 4.1 Gy.cm2 and 0.50 minutes and Barium swallow was 11.2 Gy.cm2 and 1.2 minutes for Facility B respectively. There was variation of values observed across facilities and were attributed mainly to difference in protocols and techniques used in the two facilities. Due to the variations in DRL values, standardization of protocols across facilities as a means to increase optimization is recommended.

P-011

ASSESSMENT OF DOSE – AREA PRODUCT OF COMMON RADIOGRAPHIC EXAMINATIONS IN SELECTED SOUTHERN NIGERIAN HOSPITALS

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Diagnostic Radiology –Dosimetry

Over the years, radio graphic examinations is the most used diagnostic tools in Nigerian health care system but most diagnostic examinations carried out do not have records of patient doses.
Lack of adequate information on patient doses has been a major hindrance in quantifying the radiological risk associated with radio graphic examinations.
This study aimed at estimating dose – area product (DAP) of patient examined in X – ray units in selected hospitals in Southern Nigeria.
The standard projections selected are Chest Posterior-Anterior (PA), Abdomen Anterior-Posterior (AP), Pelvis AP, Pelvis Lateral (LAT), Skull AP/PA, Skull LAT, Lumbar Spine AP, Lumbar Spine, LAT. Measurement of entrance surface dose (ESD) was carried out using thermoluminescent dosimeter (TLD). Measured ESDs were converted into DAP using the beam area of patients.
The results show that the mean DAP ranged from 0.17 to 1.71 for chest PA and abdomen AP respectively Gycm2. TheresultsobtainedinthisstudywhencomparedwiththoseofNRPB-HPEwerefoundtobehigher. Theseareanindication of non-optimization of operational conditions.
Keywords: Dose – Area product, Radiographic examinations, Patient doses, optimization.

P-016

METROLOGICAL CARE IN RADIOMETRIC SURVEY IN MAMMOGRAPHY: LABORATORY ANALYSIS OF BEHAVIOR OF FIELD EQUIPMENTS

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Dosimetry – Reference quality

A review about Radiometric Survey in Mammography (RSM) in terms of national and international regulations and recommendations, specifications of radiation meters, besides field and calibration laboratories practices shows that there is not many specific information about how RSM tests really works. Laboratorial tests performed in a wide range of field meters, submitted to calibration tests under ISO N 25 and 30 conditions (most of them have no matched energetic range), and compared also with ISO N 60, 80 and 100 calibration results, which them have matched specifications. The result of this work suggests that some RSM performed in Brazil, with nonspecific chambers and calibration, can have underestimation of around 30% in those measurements. Then, specific calibration tests should be indicated to those equipments used in RSM tests aiming to improve metrological reliability in these tests.

P-018

VULVAR CANCER: DOSIMETRIC COMPARISON OF ADVANCED 3D CONFORMAL RADIATION THERAPY TECHNIQUE WITH ANTEROPOSTERIOR AND POSTEROANTERIOR IRRADIATION TECHNIQUES

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Radiation Oncology – Treatment Delivery

Introduction:
The commonly used technique of radiation therapy for vulvar cancer consists of anteroposterior (AP) and posteroanterior (PA) fields. This is the first study that reports the dosimetric comparison between the AP-PA techniques and the new 3D advanced conformal technique (3D-ACT) based on the multiplicity of treatment fields in patients with squamous cell cancer of the vulva in the postoperative setting.
Materials and Methods:
This comparative planning study was conducted on 15 patients with vulvar carcinoma treated with adjuvant radiation therapy at the National Institute of Oncology in Rabat, Morocco. Three treatment plans were performed, corresponding to three techniques, namely photons with source-skin distance inguinal supplement, modified segmental boost technique, and 3D advanced conformal technique. For each plan, the dose-volume histogram was used to generate planning target volumes (total and inguinal PTV) and organs at risk (bladder, rectum, bowel and femoral heads) parameters.
Results:
The 95% isodose volume was significantly reduced with the advanced conformal technique ($P<0.0001$) without compromising the total PTV coverage ($P= 0.94$). This technique resulted in the best conformity and homogeneity index. The 3D-ACT decreased significantly the PTVs D max and D mean ($P<0.0001$), and offered better homogeneity for inguinal PTV (i.e., 1.07 ± 0.01, $P<0.0001$). The 3D-ACT decreased the rectum absorbed dose, V40 (volume receiving $\geq$40Gy), V45, and D max to 50.21 ± 27.21, 22.81 ± 10.22, and 46.56 ± 1.11, respectively. With regard to femoral heads, the 3D-ACT decreased the D max and V45 in comparison to the other two techniques.
Conclusion:
The 3D-ACT seems to be an alternative to the AP-PA irradiation techniques in postoperative setting when IMRT is unavailable.

P-022

DETERMINATION OF THE HIGH CONTRAST SPATIAL RESOLUTION BY MEANS OF THE MODULATION TRANSFER FUNCTION IN CBCT DENTALS

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Diagnostic and Interventional Radiology – General

Objetive: Evaluate the performance of the high contrast spatial resolution module of the Mora-Rizo phantom in dental cone beam CT (CBCT) scanners.
Method: For the evaluation of image quality metrics in dental CBCT, the Mora-Rizo phantom was developed at the University of Costa Rica. It has an MTF evaluation module, which consists of a copper wire of 0.22 mm in diameter inserted in a 16 cm diameter circumference of PMMA and 2.55 cm of thickness; the copper wire is angled to five degrees with respect to the central axis of the disc. Images with 3 different scanners using 80 kVp and 5mA technique factors, were analyzed using ImageJ software. Using a 60mm2 regions of interest (ROI) on the bright point of the wire, a matrix in shades of gray was generated, which is then subjected to a Fourier transform to obtain the Gaussian curve. The MTF at 10% is finally extrapolated from the curve. The Mora-Rizo phantom was validated using the PVC border and associated software of the QUART phantom (a commercial CBCT phantom).
Results: MTF obtained with Mora-Rizo phantom for the 3 equipments evaluated were: 2.8, 2.65 and 2.70 lp/mm and with the QUART phantom 2.70, 2.60 and 2.58 lp/mm. Both phantoms reported values greater than 2.5 lp/mm as expected by the manufacturers of the CBCT equipment.
Conclusions: The Mora-Rizo phantom is a low-cost device that allows QC checks in dental CBCT equipment. Data obtained are in agreement with those obtained with the QUART phantom. Available commercial phantoms are very expensive for low income countries and this new phantom allows, in one of its modules, the evaluation of spatial resolution, an IQ metrics that is not usually evaluated in CBCT QC programs due to lack of test object and associated software.

P-023

PATIENT DOSES IN INTERVENTIONAL CARDIOLOGY PROCEDURES

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Diagnostic Radiology –Dosimetry

Introduction: The aim of this study is to evaluate the dose received by patients undergoing Interventional Cardiology procedures in Hemodynamic services and to establish a follow-up of these patients from the check of a record of doses that exceed the references values for these interventional procedures.
Material and Methods: The research used the management of dosimetric data corresponding to diagnostic coronary angiography (CA) and percutaneous transluminal coronary angioplasty (PTCA) procedures, obtained of DICOM information provided by the equipment. The dosimetric quantities used were Kerma-Area Product and Entrance Surface Air Kerma, fluoroscopy time and number of images adquired.
Results: The value of the PKA in the PTCA was 104.92 Gy.cm2 compared to 45.4 Gy.cm2 in the CA, being lower than those determined in a study carried out in 2009 by the International Atomic Energy Agency, which reached 125 Gy.cm2 and 50 Gy.cm2 respectively. The results for the other quantities evaluated were: in the CA the fluoroscopy time was 6.5 minutes, the number of images 662 and the kerma of 812.6 mGy, whereas for the PTCA the fluoroscopy time was 17, 8 minutes, number of images 1364 and air kerma of 1773.7 mGy.
Conclusions: It was identified that 10.8% of cases exceed the value of 200Gy.cm2 for PKA during therapeutic procedures. In addition, it was verified that some of these patients were re-intervened, reaching values in the second moment superior to 100 Gy.cm2. The specialists of the service are aware of the need to optimize the practice and guarantee the radiological safety of the patient as well as to implement a monitoring protocol that provides the required surveillance in these cases.
Key words: Interventional radiology, diagnostic coronary angiography and percutaneous transluminal coronary angioplasty.

P-024

CHARACTERIZATION OF A SYSTEM OF COMPUTED RADIOGRAPHY DEDICATED TO THE OBTAINING OF MAMMOGRAPHIC IMAGES

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Diagnostic and Interventional Radiology – General

Introduction: The installation of new digital technologies on mammography services in Cuba began quite recently. The aim of this study is the characterization of a digital mammography unit based on a Radiography Computed System starting from the evaluation of its main technical parameters.
Methods and Materials: Recommendations of the manufacturer and the International Atomic Energy Agency (IAEA) were taken into account and applied on a Viola equipment, manufactured by General Medical Merate (GMM), which was provided with FCR Capsula XLII system produced by Fujifilm. The measurements performed were grouped into five categories: beam quality, automatic exposure control evaluation, the detector's performance, image quality and dosimetry.
Results: We were able to verify that the system complies with both national and international requirements implemented in our country, with the exception of the automatic exposure control evaluation tests, where the Signal Difference Noise Ratio (SDNR) value obtained for 70 mm of breast thickness is below the established tolerances.
Conclusions: It also demonstrates the feasibility in the application of this methodology to similar technologies to be installed in other services of the country.
Keywords: digital mammography; computed radiography.

P-025

CALCULATION SHIELD FOR AN INSTALLATION OF ORTHOVOLTAGE MACHINE, T-200 (WOMED)

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Radiation Protection

Introduction. For the installation of a surface radiotherapy equipment, in a relatively small room, it was necessary to calculate the shielding and remodel the room for the new use that was going to be used, the calculation was optimized, to guarantee the dose restrictions at each point and at the same time that it would not affect the area for its location. The methodology described in the IAEA Safety Reports No. 47 was the used one. Radiation Protection in the Design of Radiotherapy Facilities. Frequently they are used for shielding, concrete, lead, steel / iron for their well-known characteristics, here we propose the use of refractory brick, due to its properties (density 3.5 g / cm3) and the strict quality control that is carried out. Objectives: perform the calculation to determine the thickness of barriers using the before mentioned material and validate its use as a low-cost material, available in the country, mainly in those buildings that must be remodeled, for its easy handling and its characteristics. The equipment located, a T-200 of Wolf - Medizintechnik (WOmed), with voltages between 20 - 200 kV, (superficial radiotherapy). The calculations were made taking into account the characteristics of the existing walls, the location and orientation of the equipment, as well as the distance to the calculation point, according to the information provided by the manufacturer. The results show the required thicknesses for each of the barriers, (effective concrete thickness 2.35 g / cm3) and its equivalent in refractory bricks. It is concluded that all walls should be reinforced. The roof, being an area that has restricted access and taking into account the principle of optimization, without compromising the safety, we evaluate that it is sufficient to maintain strict control measures in the area.

P-027

FAILURES IN SAFETY DETECTED IN THE DEVELOPMENT OF BONE STUDIES IN GAMMA CAMERA IN NUCLEAR MEDICINE FRANK PAÍS HOSPITAL

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Radiation Protection

Due to the use of ionizing radiation in the specialty of Nuclear Medicine Diagnostics, it is necessary to take into account norms and measures to prevent the occurrence of any type of incident that is harmful to both TOEs, the public and patients. In this work, an evaluation of the safety failures detected during the development of bone studies in the nuclear medicine service is carried out Detailing the process, evaluating events and initiating events and failures that may cause radiological events or accidents. An estimation of their impact is made, and solutions are proposed to the problems encountered. From this work it was obtained that taking into account the 20 years of experience accumulated by the Department of Nuclear Medicine, the radiological events of higher risk are linked to the exceeding of the guidelines for diagnostic studies, followed by those associated with spillage of radioactive substances.

P-028

EVALUATION OF SAFETY IN INTERVENTIONAL RADIOLOGY USING THE CODE SECURE-MR-FMEA 3.0

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Radiology – Radiation Protection.

Introduction: Interventional Radiology is a sub-specialty of radiology where imaging techniques are used to perform minimally invasive procedures. The use of this technique has multiplied vertiginously in recent times, becoming also one of the medical applications that produces the highest doses of radiation to both the patient and the personnel involved in the procedure, as well as the possible occurrence of serious injuries. For this reason, an assessment of the risks associated with this practice was made. Objectives: Carry out the risk pattern of the practice of interventional radiology and identify the causes and consequences that can cause these unwanted events, whether for patients, workers or the public, from the installation of the equipment, to the post-treatment monitoring of the patient. Methods and Materials: We used the semi-quantitative risk matrix method, using the Cuban code SECURE-MR-FMEA 3.0, which is a tool that gives us the possibility to establish priorities in the risk management of a practice from the combined analysis of the frequency of an unwanted event, the probability of failure of existing barriers and their consequences. Results: The process map was prepared, identifying 6 stages with 80 initiating events, of which 90 % had an impact on the human factor. The results showed that the first risk assessment for the developed model, reports 30% of high risks, 35% of medium risks and 35% of low risks, and once the number of controllers increases the high risks decrease up to 0 % and there is an increase in medium and low risks of 47.5 % and 52.5% respectively. Conclusion: A risk analysis was performed on the practice of interventional radiology, where the main reasons that may trigger adverse situations and the vulnerable points related to this practice were identified.

P-029

THEORETICAL ARGUMENT FOR THE CONVERSION OF FMEA TO A RISK MATRIX

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Radiation Protection

Introduction: Currently two approaches are used for risk assessment in radiation medicine, namely, the risk matrix (RM) and the Failure Mode and Effect Analysis (FMEA) methods. Methods and Materials: A general description of RM and FMEA is shown, revealing each method's pros & cons, and the advantages of a coupled approach. The methodology for the conversion from one method to the other is described. Results: A theoretical analysis of their similarities and differences between them is presented. The rationality for coupling both methods is discussed, arguing on their positive and negative features for complementarily. Conclusions: The article demonstrates the feasibility of theoretically deducing a RM from a previous FMEA study.
Keywords: risk matrix, FMEA, defense measures, quality assurance.

P-030

ILLUSTRATION OF THE SYNERGY FMEA RISK MATRIX USING THE RISK STUDY OF THE IMRT PRACTICE

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Radiation Protection

Introduction: Studies of theoretical argumentation justify the complementarily between FMEA methods and risk matrix (MR).
Materials: Risk study of intensity modulated radiotherapy (IMRT) based on the FMEA methodology.
Methods: FMEA, MR and FMEA-MR conversion method.
Results and discussion: The article include several transcendent failures modes of the IMRT study as well as the corresponding accidental sequences resulting from its conversion. The structures of these sequences are discussed, in terms of defense measures, and their levels of risk.
Conclusions: The conversion of failure modes (FMEA) to accidental sequences (MR) shows some typical situations of risk control that constitute patterns of behavior of said application.
Keywords: risk matrix, FMEA, defense measures, failures modes, accidental sequences.

P-032

MECHANICAL, CHEMICAL, STRUCTURAL, AND RADIOLOGICAL CHANGES ASSOCIATED WITH DIETARY INTAKE OF NICKEL RECOVERY SLAG IN PIGEON BONE

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Biomedical Engineering

Slag from nickel smelting operations in the Sudbury basin has become ubiquitous. This material rich in heavy metals such as iron, upon ingestion has the potential to effect physical, radiological, chemical, mechanical, and structural changes in biological systems. In this work, we analyze the effects of slag ingestion through diet, on several quantitative and qualitative parameters of the tibio-tarsal bones in pigeons (Columba livia domestica). The specimens were divided into a control group provided a (normal) diet of clean limestone, and an experimental group fed slag-based grit, both for a period of one year. Their tibio-tarsal bones were then harvested for further analysis. Quantitative analytical methods included conventional density measurements, caliper-based cortical thickness measurements, bone mineral density measurements using Dual Energy X-ray Absorptiometry (DEXA), calcium and iron concentration measurements using mass spectrometry, and the determination of Young's Modulus and ultimate breaking strength (both in compression) using a universal testing machine (UTM). Qualitative microscopy studies, both optical and electron, including energy dispersive spectroscopy (EDS) was also carried out for both sample groups. A student t test (single tail) was used to compare means of the six quantitative parameters between control and experimental samples, and in all cases a statistically significant difference was found ($p \leq .05$). Microscopy and EDS analysis revealed structural differences in bone between the two groups. Engineering hardness testing of dietary components revealed that the experimental group diet contained components approximately twice as hard (Brinell and Rockwell hardness) as those in the control group diet. We conclude that slag ingestion through diet in the species examined, is associated with measurable changes in physical, radiological, mechanical, chemical, and structural properties of the tibio-tarsal bones.

P-035

THE USE OF DYNAMIC MEMBERSHIP FUNCTIONS ON IMRT PLANS

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Radiation Oncology –Treatment Planning

Purpose: The tuning for the weighting factors in the objective function for an IMRT plan is driven by humans to achieve an ideal dose distribution. This is done manually in a tedious and time-consuming process based on trial and error and user experience. In the past fuzzy inference system (FIS) relying on static membership functions were used to tuning the weighting factors. The aim of this work is to propose a method for self-generating membership functions using an unsupervised learning method.
Methods: A dynamic membership function generator was implemented to translate linguistic humans tag (i.e. High or low dose) for different types of organs (target volume, the organ at risk and normal tissue) into a degree of truth. The membership function was generated using an iterative algorithm implemented in MATLAB using three mains points: central, left and right vertex for different types of membership functions, such as triangular, Gaussian, sigmoid and s-shaped. Then, they were evaluated in a Fuzzy logic guided inverse planning system to optimize the optimal combination of weighting factors in the objective function for an IMRT plan.
Results: The performance of the algorithm was examined using the C-Shape TG119 IMRT phantom using the variations of weighting factors and mean dose versus the iteration number as well as dose volume histograms. Fuzzy logic guided inverse planning system is capable of finding the optimal combination of mean dose and weighting factors for different anatomical structures involved in treatment planning within 20 iterations.
Conclusion: It is possible to use a feasible way to automatically tune the weighting factors for an IMRT plan under the guidance of FIS using an unsupervised membership functions generator without human intervention other than providing the treatment plan parameters and set of constraints.

P-037

LOCAL DIAGNOSTIC REFERENCE LEVELS FOR RADIOGRAPHIC PROCEDURES AT HAMAD MEDICAL CORPORATION HOSPITALS IN QATAR

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Radiology – Radiation Protection.

Introduction: Surveys of dose estimates from different imaging modalities highlight the substantial variations in dose between some healthcare facilities for the same examinations or procedure. LDRLs were determined for different hospitals. The dose quantity used is air kerma-area product (KAP). The results indicated will be used for standardization of dose and reduction in variation in dose without compromising the image quality. The aim of this work is to establish local diagnostic reference levels (LDRL) for typical radiographic examinations in Hamad Medical Corporation (HMC) Hospitals.
Methods: The initial survey included 7 radiologic projections for patients undergoing standard radiographic examinations using digital radiography (DR) in 4 general hospitals within Hamad Medical Corporation (HMC) in Qatar: Hamad General Hospital (HGH), Al Wakra Hospital (AWH), Al Khor Hospital (AKH) and The Cuban Hospital (CH). These hospitals were selected for this project as it is the biggest healthcare provider in country. Data were recorded from different X-ray rooms in HMC hospitals. Air kerma-area product (KAP) were determined for the most common X-ray examinations namely: Skull, Chest, Abdomen, Lumbar Spine and Pelvis. The 75-percentile value for each examination was taken as the LDRL for each room. The average value for all the room was taken as the LDRL for each of the hospitals and compared with the national Diagnostic Reference Level.
Results and conclusion: the initial results showed that for the studied sample the average age was 46 years, the average weight of 85 kg and mean height of 160 cm. The most procedure performed during the time of this study was chest PA (28%), and the least procedure performed was skull AP/LAT (15%). The LDRL in all hospitals were found to be lower than the National DRL values. More detailed analysis will be provided upon completion of the work in the next three months.

P-038

USEFULNESS OF LOCALLY CONSTRUCTED PHANTOMS FOR THE VALIDATION OF PLANNED RADIATION FOR BREAST CANCER RADIOTHERAPY TREATMENT

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Radiation Oncology – Quality Assurance

GLOBOCAN estimates, indicate that 4645 new cases were diagnosed, and 1871 death occurred due to breast cancer in Ghana in 2018; making it a major public health problem. To ensure the facilities in Ghana implement quality control measures, this study was designed to determine and compare planned with actual doses delivered to the breast during treatment. This is to achieve this, the major limitation of the non-availability of phantoms was addressed by the construction of phantoms, using perspex and locally available materials that mimic organs of the female thoracic cavity.
Based on scanned images, two phantoms were constructed. Balloons, mango seed, cassava stick and candle were radiologically assessed and used as surrogates for the lung, heart, spinal cord and glandular tissue of the breast respectively. Higher photon energies from a 60Co and LINAC machine were targeted at the left breast of a standard and the two constructed phantoms. EBT3 film dosimeter was used to measure absorbed doses to the breast and non-target organs.
The deviations of delivered doses from planned doses when the standard anthropomorphic phantom, constructed phantoms A and B were used, ranged as follows, -0.05 – 0.03 Gy; -0.08 – 0.01 Gy; -0.14 – 0.01 Gy respectively, when the radiation was delivered by a Cobolt-60 machine. When the radiation was delivered by a linear accelerator systems, the deviations were -0.05 – 0.03 Gy; -006 – 0.07 Gy; -0.06 – 0.04 Gy respectively. The left lung and spinal cord received the highest and lowest unintended dose, 0.74±0.04 Gy (Co-60) and 0.78±0.01 Gy (LINAC), and 0.03±0.02 Gy and 0.05±0.01 Gy respectively.
The study has demonstrated that local materials are potentially useful for the construction of phantoms, which can be good substitutes for standard commercial phantoms in ensuring the safety of patients under-going radiotherapy treatment for breast cancer.

P-039

131I INTAKE SURVEILLANCE OF NUCLEAR MEDICINE WORKERS USING A THYROID PROBE "IN SITU"

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Nuclear Medicine

This research, propose and verify a monitoring procedure of 131I intake of nuclear medicine workers using the thyroid probe of the Nuclear Medicine Department. The counter used is a gamma probe with NaI(Tl)scintillationdetectorof30x30cm. The efficiency calibration was performed with a thyroid phantom, simulating the adult thyroid anatomical shape and volume, filled with radioactive solution of known activity of 131I (uncertain activities < 2.24%). The intake and the effective dose estimation were made following the steps suggested in the IDEAS - General Guidelines for the Estimation of the Committed Effective Dose from Incorporation Monitoring Data. The efficiency (E) was 3.76x 10-3± 1.15x 10-4 CPS/Bq, Minimum Detectable Amount (MDA)was46Bq. The probe system is capable to detect dose as low as 0,004mSv at 24h and 0,02mSv at 2h. A worker monitoring 131I intakes procedure was proposed and established, based on routine screening 2 and 24hours after to finish daily activities in the "hot lab", "administration routine" of 131I dose to patient, contaminated wastes manipulations, or in case of detected or suspected radionuclide intake. If the contamination is positive, confirmatory monitoring should be developed using the "probe" and the gamma camera if preliminary intake is greater than 75KBq for spatial uptake distribution. The committed equivalent thyroid dose will be evaluated taking into account the real thyroid mass, using the up-taking mass correlated with ultrasound and the real worker bio-kinetic behaviour. The use of probe, for this purpose, produces a significant reduction of dose estimation deviation caused by the thyroid mass, effective half-time and the time of intake. The measurement uncertainof100Bqthyroiduptakewas±15%. During14 months, the monitoring program has detected 2 intakes of 0.03 y 0.026 mSv, which using 15 days monitoring frequency could be undetected, proving its efficacy and appropriateness.

P-040

ESTIMATION OF VOLUMETRIC DOSE DISTRIBUTION IN I131 HYPERTHYROIDISM TREATMENT: PRELIMINARY RESULTS

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Nuclear Medicine

To estimate the 3D dose delivery deviations produced by prescribed activity during I131 Hyperthyroidism treatment, a computer Matlab application was developed and verified. It was design to execute: radiopharmaceutical curve fitting, cumulated activity calculations, functional thyroid mass estimation, to obtain the therapeutic planning activity to warranty the prescribed dose or to obtain the dose caused by prescribed activity, using a theoretical or “S” factors method. It also produces the 3D planning dose map and related dosimetry parameters. The developed system was verify successfully using a test image phantom and 6 known pharmacokinetics data. To test the clinical application were used 10 patient´s information (activity prescribed, I131 SPECT and biokinetics). The tridimensional thyroid volume cumulated activity and dose distributions were heterogeneous. 3D dose distribution showed standard deviations between 21,8-83,9Gy of mean dose calculated by “S” factors. The differences between mean dose calculated by theoretical and “S” factors were no significant and less than 10% ($p>0.05$), showing the system capability to proper dosimetry calculation. The biological effective dose (BED) showed significant difference between the same patient ($p\leq0.05$). The 3D dose distribution dissimilarities between “S” factors and theoretical methods took the maximum value of 23%, near to the thyroids boundaries tissue. Despite this difference is inside the typical uncertain range of dose determination method, the issue should be study deeply using Monte Carlo (MC) approach in order to clarify the voxel dose accuracy of the two methods. Conclusions: the 3D treatment planning dose distribution were completely no-homogenous, the significant difference observed should be study in the future more deeply in order to optimized the hyperthyroidism iodine treatment. This study found significant dose differences in the target volume to be treated, suggesting that average tissue dose could not be the best approach to develop a nuclear medicine thyroid treatment planning.

P-041

ESTIMATION OF THYROID'S DOSE UNCERTAIN DURING I131 HYPERTHYROIDISM TREATMENT PLANNING

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Nuclear Medicine

To estimate the thyroid's dose and its uncertain during I131 hyperthyroidism treatment planning, the information of ultrasound (US), gammagraphy (2D), SPECT(3D) images and I131 pharmaco-kinetic diagnostic measurement of 10 patients with their activity prescription were used. The thyroid average dose was estimated using hybrid methods based in US, 2D and 3D information (mass and biodistribution) combined with I131 kinetic evaluation using a thyroid probe. The thyroid dose distribution was calculated using a theoretical and "S" factors methods using 3D images and the probe data. The uncertain sources taking into account were grouped like: (1) measurement of the administered activity, (2) quantitative imaging activity and thyroid mass estimation (QI), (3) quantitative of I131 kinetic with the probe, (4) integration of activity measurements over the time of diagnose/treatment, (5) calculation of the dose from different methods. The overall uncertainty of the estimated thyroid dose was expressed with 95% confidence interval. The dependence of dose's combined uncertainty varied between methods for the same patient, but they had determinant parameters like uncertainty related to mass's determination method used, statistical of thyroid activity measurement, variation of body-thyroid dimensions and overlaying structures-tissue and the kinetic modelling parameters used. The dose uncertain of 3D SPECT and US mass determination combined with double exponential pharmacokinetic showed the values around 10%, meanwhile 2D gammagraphy/double exponential and US mass determination combined with one exponential fit or only one patient specific pharmacokinetic parameters were 16.2±6.4%, 11.1±2.8% and 29.4±14.6% respectively. The 3D dose distribution showed uncertain of 10.1±0.2% for theoretical methods and 9.8±0.2% by "S" factor method. The uncertain dose estimation can be implemented during hyperthyroidism I131 treatment planning, under patient specific bases. Those estimations can help the physician to select the most accuracy treatment and encourage the implementation of better prediction of treatment results.

P-042

INTRODUCTION OF RADIOGUIDED SURGICAL PROCEDURES: MEDICAL PHYSICS ASPECTS

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Radiation Protection

Introduction: With the purpose to warranty the safety introduction of radioguided surgery (RGS) procedures in Cuba, all the related medical physics (MP) technical details were reviewed and stablished with a quality management process philosophy. All the project was support by the IAEA National Project CUB6027.
Materials and Methods: the selected multidisciplinary team analyzed the national situation using a NM survey and all the related information available. The process map to setup the multi-disciplinary process, showing the primary and support management processes were generated, including all the medical physics details involved, as part of the multidisciplinary approach.
Results: The strategic planning included the MP human resource and the sustainability of the education RGS aspects, the develop of national quality control guidelines for the related equipment were stablished, the traceability process and legal issues were defined. The gradual introduction was planning: starting for 3 reference centers and it will continue with 6 hospitals more. The human resource education and training was planned using the principles of "train the trainers". A national specialized training course was accredited for the multidisciplinary team. The risk analysis was taking into account during the planning. The evaluation of different steps was systematic, patient orientated and outcome based. Aspects of radiation safety and patient protection were also integrated to the process.
Conclusion: the RGS were planed and stablished including all the MP related aspects. This approach ensures consistency in providing safe, high quality and high-level services to patients and staff. Increasingly the standardized clinical protocols and evidence-based medicine.

P-043

SAFETY ASSESSMENTS THROUGH THE USE OF THE RISK MATRIX METHOD IN NUCLEAR MEDICINE

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Nuclear Medicine

Introduction: The quality of the diagnosis and treatment in Nuclear Medicine are bound to different factors that needs to be kept in mind. The accidents happened in this area can affect to patients, workers and public, should be controlled the causes and consequences that could lead to them. It was our objective to carry out a security evaluation to a Department of Nuclear Medicine in a Cuban hospital, using the method Risk Matrix, to demonstrate their utility for it, keeping in mind the probability and magnitude of the potential exhibitions. Material and method: We use the software SEVRRA (realized by the National Commission of Nuclear Safety and Safeguards of Mexico), the module of nuclear medicine was developed by Cuban specialists. The method allows to identify the causes that can cause an accidental exhibition, keeping in mind the frequency of occurrence of the event initiator(EI), If the probability of flaws of existent barriers and the consequences graveness, facilitating the identification of the associate risk from the acceptance and setting in service of the equipment, the diagnosis and treatment, included the maintenance. We could identify which accidental sequences have bigger risk and to propose the measures that allow to reduce the same one. Results: The obtained profile showed that during the treatments, just 2(EI) classify with high risk (HR), these constitute 4% of the total of the analyzed initiators, 88% with medium risk (MR) and 4% low risk (LR). The diagnosis, 9% of (EI) classify as HR, and 75% MR and 15% LR, Conclusions: We should take an attitude of continuous surveillance on these initiators and to be attentative to the implied barriers in this analysis are always active to guarantee the safety, of the patients, workers and public: don't pass to be part of the high risk initiators.

P-044

INVESTIGATION OF A BRAZILIAN MINERAL TO ACT AS OSL NATURAL DOSIMETER

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Radiation Oncology – Dosimetry

Introduction: Natural and synthetic dosimetric materials are used for the determination of the irradiation dose received in the environment as well as in medical and technological activities. Natural dosimeters find application, e.g., in retrospective dosimetry and may be a lower-cost alternative to synthetic ones. Brazil is one of the largest producers of minerals in the world, including alexandrite (BeAl2O4: Cr3+). The chemical nature of the mineral alexandrite combines two binary oxides, BeO and Al2O3, both oxides being commercially used as dosimeters. So this suggests alexandrite an interesting candidate for investigation as a natural dosimetric material.
Methods and Materials: Alexandrite-polymer pellets, disc-shaped, homogenous and ductile were evaluated using OSL technique. OSL is the process by which a previously irradiated material emits light when illuminated. The OSL measurements were performed using a Riso equipment (beta source). OSL emission was stimulated using blue light emitting diodes (470 nm, FWHM = 20 nm) delivering 80 mW/cm2 at the sample position in CW mode. The characteristics studied were dose - response (0.1 up to 5 Gy), reproducibility and fading.
Results: The results showed that the OSL intensity signal varies linearly with the dose, a fast fading of 40% in the first half hour of storage, but with the signal remaining constant for at least five hours more. The reproducibility results showed a variation smaller than 5%, within the 95% confidence interval. Results obtained with these pellets showed sensitivity in a large range of doses. In addition, it was also noted that the shape of the OSL decay curve was independent of the radiation dose, an important feature for an OSL dosimetric material.
Conclusion: Composites based on alexandrite powder were successfully fabricated. Our results showed alexandrite mineral is a promising natural material for OSL dosimetry.

P-045

DOSIMETRY VERIFICATION OF HIGH DOSE RATE BRACHYTHERAPY FOR CERVICAL CANCER USING COBALT-60 SOURCE

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Radiation Oncology – Brachytherapy

Introduction: Transition from the low dose rate brachytherapy to high dose rate brachytherapy at our department necessitated the performance of dose verification test, which served as an end-to-end quality assurance procedure to verify and validate dose delivery in intracavitary brachytherapy of the cervix and the vaginal walls based on the Manchester system.
Materials: One dimensional manual water phantom, Gafchromic EBT3 film (Lot number: 04201601), in-house cervix phantom.
Methodology: An in-house water phantom was designed and constructed from perspex sheets to represent the cervix region of a standard adult patient. The phantom was used to verify whole dose delivery chain such as calibration of the cobalt-60 source in use, applicator and source localization method, output of treatment planning with dedicated treatment planning system and actual dose delivery process. Doses were measured with calibrated gafchromic EBT3 films at various points within in-house phantom for a number of clinical implants that were likely to be used to treat patient based on departmental protocol.
Results and Conclusion: The measured doses were compared to those of the treatment planning system. The discrepancies between measured doses and their corresponding calculated doses obtained with the treatment planning system ranged from - 28.75% to 42.19% (mean of plus or minus 12.50%). The results of this study provide a good evidence for agreement in dose distribution in a definite clinical condition regarding doses to the specific points in the phantom with a non-significant difference in accuracy. The study can therefore be used as a quality assurance tool to evaluate the entire procedures involved with brachytherapy treatment.

P-046

PRODUCTION AND STUDY OF THERMOLUMINESCENT MATERIALS FOR LOW DOSE DOSIMETRY

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Radiation Protection

Introduction
Thermoluminescent dosimeters (TLDs) are widely used for the quantification of radiation doses in different applications. Calcium sulfate doped with dysprosium (CaSO4:Dy) is the only TLD commercially produced in Brazil and is largely used on individual dosimetry.
The goal of this work was to produce TLD pellets with CaSO4 dopped with different rare earths and study its response parameters, such as the emission curve, sensitivity, energetic and dose dependence and fading.
Methods and Materials
TLDs were produce using the Yamashita method, in that crystals are formed in a CaCO3 solution of H2SO4. Pellets of CaSO4 doped with Dy;Tm, Tm, Dy;Tb, Tb, Eu and Dy;Eu were produced. Pellets of CaSO4:Dy, produced and marketed by MRA Indústria Ltda, Brazil, were used for comparison.
Beams ranging from 30 to 120 kVp from an X-ray unit (model ISOVOL TITAN 160-EG) were used for the energy dependence study. All the other tests were performed using Cs137. The calibration dose was 2.02 mGy. The pre-irradiation thermal treatment was at 300°C for 20 min, and the pre-reading thermal treatment was at 100°C for 30 min. The readings were performed with a Thermo Scientific TL reader (model Harshaw TLD 3500).
Results
The produced tablets of CaSO4:Tm presented the largest response (153 ± 14 nC/mGy), 17% higher than the commercial pellets in average. The pellets of CaSO4:Tb and CaSO4:Eu presented the smallest responses (88% and 42% of the commercial pellets). After 21 days, there was 5% fading for the CaSO4:Tm pellets, 9% for CaSO 4:Dy,Tm and 13% for CaSO4:Dy. Moreover, the pellets of CaSO4:Tm presented the higher homogeneity coefficient (36%). All the pellets presented energy dependence in agreement with the literature, being maximum for beam N40 (ISO 4037-1).
Conclusions
The TL materials produced, especially CaSO4:Tm, presented suitable dosimetric characteristics for diverse applications, and sensitivity for applications in individual dosimetry.

P-048

VARIOUS APPROACHES FOR BREAST 3DCRT PLANNING

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Radiation Oncology –Treatment Planning

Introduction:
Two parallel oppose and single direct supraclav field is standard conventional planning technique in breast planning. However, while doing 3DCRT the new technique needs to be used to address the hot spots, cold spots and under coverage. Each case is different, and the same method of planning does not work in breast planning.
Material and methods:
We have been using varian Clinac IX machine with 120 leaves Millennium MLC, Eclipse TPS version 15.5 and ARIA R& V system, version 15.5.
The following techniques are practiced for breast planning. All plan uses the hit and trail for mixed energy 6 and 15 Mv x-rays, MLC, wedge and Bolus.
1. Parallel oppose field to cover both chest wall and supraclave
2. Two parallel oppose field for chest wall and single direct field for supraclav
3. Multiple field technique.
4. SSD plan
Result:
Our experience shows that the cosmesis of breast surgery greatly affects the dose distribution and optimization of the plan. Generally hot spot is found near the entrance of lateral tangential field. This can be removed using 15 Mv x-rays. Sometime bolus is found to be useful to address the underdose on chest wall. Multiple field increases dose to the organ at risk but can be used carefully to get better coverage
Conclusion:
The mixed energy method is very useful to reduce hot spot. Generally hot spot is found near the entrance of lateral tangential field. This can be removed using 15 Mv x-rays while the medio tangential field has 6 Mv x-rays. Bolus is found to be useful to address the underdose on chest wall. SSD technique is not very useful as it needs to set patient every day. If distribution is not good a multiple field approach can be used.

P-049

STUDY OF DOSE DISTRIBUTION IN RADIOPHARMACEUTICALS AND THEIR INTERCOMPARING WITH 3D HAND ARTICULATED SIMULATOR IN A NUCLEAR MEDICINE SERVICE USING TLD-100H

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Nuclear Medicine

In occupational nuclear medicine procedures, care should be taken to protect workers in order to keep doses as low as reasonably practicable, thereby minimizing the risks associated with the occurrence of stochastic effects.
In Brazil, the evaluation of the doses received by the IOE must be part of an occupational dosimetry program. In a nuclear medicine service, the occupational dosimetry program must comply with CNEN-NN-3.01 and CNEN-NN-3.05 of the National Nuclear Energy Commission.
Thus, this study aims to determine the equivalent dose in the lens and the distribution of doses at the ends of the IOE of a Nuclear Medicine Service, in addition to the use of physical simulation through 3D printing technology to aid in this search and obtain the relation between the most exposed point and the most operationally adequate region for its monitoring. We evaluated four radiopharmaceuticals directly involved in the routine manipulation of 99mTc-labeled radiopharmaceuticals. For each measurement point, dosimetric assemblies containing four TLD-100H (LiF: Mg, Cu, P) were used. Termoluminescent Dosimetry Laboratory (LDT) of the Division of Dosimetry of the Institute of Radioprotection and Dosimetry of the National Commission of Nuclear Energy. The dose result obtained in each region was calculated as the mean of the doses obtained in four TLDs present in the dosimetric set. The characterization and calibration of the TLDs was done in the LDT according to ISO 4037-3.
From the results, it can be concluded that the occupational monitoring for the endpoint can be underestimated 2 to 12 times in relation to the dose received by the radiopharmaceuticals, this underestimation is directly related to the differences attributed to the monitoring model adopted by the service. The estimation of the equivalent dose of crystalline from the value obtained by the effective dose shows a good method for the estimation of the same.

P-051

FINITE ELEMENT MODEL OF THE HUMAN EYE

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Biomedical Engineering

The deformation of the eyeball is a topic of interest for the study of ocular traumas caused by blunt objects. Hence in this work, two computational models of the ocular globe of the human eye were implemented in a finite element modeling system in order to analyze such traumas.

The first geometric model of the eyes included the cornea, sclera, limbus, the optical nerve head and the adipose tissue. Lineal elastic and hyperplastic material models were selected to represent the behavior of the tissues. Using this globe model, the influence of the variation of intraocular pressure was considered in the zone of the optical nerve; when the values of the maximum shear stress obtained were comparable with those reported in the modern literature. This model was also employed to study traumas caused by the impact of blunt objects, evaluating stresses and strains in the lamina cribrosa and the retina.

The rectus extraocular muscles were incorporated into in a second model, which included the cornea, limbus and sclera. The action of a blunt object at different impact velocities was simulated to study the influence of muscles on the deformation of ocular structures. An optimal meshing was obtained for which the numerical simulation results are independent of the number of volumes in the computational domain. The apical displacements of the cornea were compared in the model with and without taking into account the presence of the rectus muscles. From this comparison, the minor apical displacement was obtained in the model with muscles; this result may be due to a greater distribution of the loads in the system. However, the behavior of the apical displacement when varying the impact velocity of the projectile is very similar in both cases, which shows a stability in the response of the system.

P-052

DOSE OPTIMIZATION IN PEDIATRICS CARDIAC X-RAY IMAGING

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Diagnostic Radiology –Dosimetry

Objective: To quantify the patient radiation dose reduction after the introduction of an X-ray imaging technology using advanced real time image noise reduction and optimized acquisition chain for fluoroscopy in pediatric and adult population with congenital heart disease

Background: Pediatric catheterization exposes patients to varying radiation doses. Dose optimization was assessed by obtained radiation data collection. Biplane X-ray angiography Siemens Artis zee equipment was used for clinical procedures. It is equipped with two flat detectors - a frontal detector measuring 30x38cm (48 cm diagonal) and lateral detector measuring 20x20cm (25cm diagonal). The flat detectors are mounted on C-arm of the angiography system and move through a 360 degrees range around the patients.

Methodology: Patients and radiation doses were retrospectively collected August 2014 - August 2015 for 100 consecutive patients treated with a system using state of the art image processing and reference acquisition chain. Radiation dose was quantified using dose area product (DAP), while procedure complexity using fluoroscopy time, procedure duration and volume of contrast medium. Patients were divided into three weight groups: A) below 10kg B) 10-40 kg and c) over 40kg. Results: For below 10kg, 10-40kg, over 40kg mean DAP values were 63.7cGycm2, 200 cGycm2, and 1900cGycm2 with quantification at 50%, 70% and 60% respectively.

Conclusion: The new system provides significant patient dose reduction compared to the reference system. Despite no other changes in the procedural approach, X-ray imaging technology provides a substantial radiation dose reduction.

P-053

DETERMINATION OF DOSIMETRIC LEAF GAP FACTOR WITH ROUNDED UNIT MONITOR METHOD AND STUDY OF THE DOSIMETRIC EFFECT OF VARIATION OF THIS FACTOR FOR PATIENTS TREATED IN IMRT WITH LINAC 80 LEAVES

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Radiation Oncology – Dosimetry

Materials and Methods:
6MV beam energies and the Eclipse V.13.7 TPS are used in this study.
1- First Objective:
For the Rounded Monitor Unit method (RMUM), we use sweeping dynamic MLC leaf gap fields created by Varian MLC shaper software with gaps: 4 mm, 10 mm and 20 mm.
The RMUM is based on this formula:
Vmax=VMmax/(D/60)
Vmax = Maximum value of speed of leaves deplacement = X jaw dimension / Monitor Unit = X / UM
V M max = Maximum value of mechanical speed of laves = 2.5 cm / s for our linac D = Dose rate used for treatment : 300 UM/min
DLG values are measured with both 0.13 cc semi-flex ionization chamber and 0.6 cc Farmer Chamber, for 2 fields 10 cm x10 cm and 10 cm x 40 cm, for Water phantom and slides phantom, for different SSD (Skin Source distance) and 2 rotation collimator angles 0 and 90 degrees and for different rotation bras angles.
For each method, the final DLG Value is the mean of the all values.
2- Second Objective:
On TPS, for ten Patients, we change the value of DLG. With the verification plans created on TPS, we measure the absolute dose with 0.13 cc semiflex chamber and the 2D dose distribution with 2D
Array Matrix and Portal Imaging.
Results:
The difference between the DLG Values measured by Constructor Method and Rounded Unit Monitor Method is around 0.5 mm. For ten patients, The DLG value determined by Rounded Unit Monitor Method gives us results more than 95% for all fields. Those results are not found for the constructor method for some fields.

P-054

DOSIMETRIC COMPARISON OF CERVICAL CANCER TREATMENTS BETWEEN ELECTRONIC BRACHYTHERAPY AND IR 192

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Radiation Oncology – Brachytherapy

Purpose:
We report the first cervical cancer cases treated with interstitial electronic brachytherapy (eBT) at our hospital and compare them with plans made with high dose rate interstitial brachytherapy based on Ir192 (HDR-BT).
Materials and methods:
Eight patients with cervical cancer were treated with the Axxent eBT device (Xoft, Inc.). Planning was with magnetic resonance imaging and computed tomography following the recommendations of the EMBRACE protocol.
The dosimetry parameters of organs at risk (OAR) were evaluated for the bladder, rectum, and sigmoid colon (D2cc, D1cc, D0.1cc). In addition, the V150 and V200 of irradiated tissue were compared for both eBT and HDR-BT.
All patients received intensity-modulated external beam radiation therapy with a regimen of 23 sessions of 2 Gy followed by 4 sessions of 7 Gy of eBT performed over 2 weeks (2 sessions followed by another 2 sessions a week later) following the EMBRACE recommendations. Each of the 8 patients was followed to assess acute toxicity associated with treatment.
Results:
The doses reaching OAR for eBT plans were lower than for HDR-BT plans. As for acute toxicity associated with eBT, very few cases of mucositis were detected. No cases of rectal toxicity and 1 case with grade 1 urinary toxicity were detected. The results at 1 month are equally good, and no relapses have occurred to date.
Conclusions:
The first results of treatment with the Axxent eBT device are promising, as no recurrences have been observed and toxicity is very low. eBT is a good alternative for treating cervical cancer in centers without access to conventional HDR.

P-055

GENERALIZATION OF AN ANALYTICAL MODEL FOR PHOTON PERIPHERAL DOSE CALCULATION

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Radiation Oncology – Dosimetry

Introduction: A simple analytical model that allows estimation of photon peripheral dose to organs in adult patients, valid for any isocentric technique, has been proposed by Sánchez-Nieto et al. (Biomed.Phys.Eng.Express 1,2015). This model fails in predicting a) dose to peripheral organ in paediatric patients and b) peripheral dose to skin (for both, adults and children). The aim is to provide model parameters for these two specific cases.
Method: The original peripheral photon dose-to-points model was fitted to the midline dose profile measured with an EBT3 film sandwiched along a polyethylene block of 15×14×60 cm3, simulating the volume of a child. An isocentric 6MV irradiation with 8 coplanar 6x6cm2 open beam was carried out. Afterwards, validation was done using data from a clinical head treatment by EURADOS-WG9 (Rad.Prot.Dosim. 176:331-340,2017).
To generate the model for calculation of peripheral skin dose, the same humanoid phantom and irradiation setting (but 6MV) as in (Sánchez-Nieto, 2015) was used to measure peripheral surface dose with EBT3-films. A modified version of the model (avoiding the term related to depth in tissue) was then fitted to these surface doses. Model validation was done with TLD-100 and EBT3-films placed on the surface of the adult and child geometries, respectively.
Result: Parameters for the paediatric and skin dose models were A=0.0020 ±0.0001mSv/UM and B=10.769±0.021mSv.cm2/UM and A=0.008±0.001mSv/UM and B=18.045±0.097mSv.cm2/UM, respectively. Agreement between predictions and measurements were within 17%, except for the peripheral skin dose model in the paediatric case. The resulting dose-at-points models were integrated between cranial-caudal organ limits for peripheral dose-to-organ calculations.
Conclusion: Generalization of a peripheral dose model has been carried out to consider superficial dose and paediatric cases. Validation of the model with the ATOM adult phantom and improvement of the surface dose model for the paediatric case are in progress.
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P-058

EFFECTS OF NON-CONFORMAL RADIOTHERAPY TECHNIQUES IN BREAST CANCER PATIENTS

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Radiation Oncology –Treatment Planning

Introduction: Breast cancer is the most prevalent cancer type in women and global best practice in radiation treatment of cancer requires the use of conformal techniques. Unavailability of required equipment in some developing countries result in a deviation from standard practice. This study set out to estimate the ensuing risk.

Methods and Materials: Twenty (20) breast cancer patients (stages I – III) were planned on a Prowess Panther TPS using a 1.25 MeV cobalt beam of 80 cm SSD. The patients were simulated using both the standard 3D two laterally opposed tangential fields with appropriate wedge angles and a 2D technique in which the field borders were determined using bony landmarks on the Digitally Reconstructed Radiographs (DRR) images mimicking the scenario in a typical low resource radiotherapy center. The beam was conformed to the target using Cerrobend blocks for the standard 3D technique only. The two techniques were compared in terms of the doses to the Planning Target Volume (PTV) and the Organs at Risk (OAR); the lungs and the heart. The Lyman Kutcher Burman (LKB) Normal Tissue Complication Probability (NTCP) model was used to assess the possibility of developing radiation pneumonitis and pericarditis in the OARs respectively.

Results: The mean and maximum doses to the PTVs and OARs were significantly higher in the 3D technique for all patients. The NTCP values showed that there was no risk of pericarditis while the risk for pneumonitis was higher in the 3D technique. Conclusion: The doses to the OARs were lower in the 2D technique than the 3D technique however at the expense of the coverage to the PTV.

P-059

THE NEW IAEA PUBLICATION AND E-LEARNING MATERIAL ON IMAGE GUIDED RADIOTHERAPY (IGRT)

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Education and Professional Issues

Introduction
In February 2019, the IAEA published new guidelines highlighting the milestones to be achieved by radiotherapy departments in the safe and effective introduction of image guided radiotherapy (IGRT). The publication, titled “Introduction of Image Guided Radiotherapy into Clinical Practice”, is available for free download on the IAEA website and is accompanied by an e- learning module available on the open IAEA e-learning platform CLP4NET. Part of the material of the e-learning was produced during a joint International Centre for Theoretical Physics (ICTP) - International Atomic Energy Agency (IAEA) workshop held in Miramare, Trieste in 2017. During this course, the lectures were video recorded with the aim of creating virtual classes that would be included in an e-learning module.
Methods and Materials
The interest in the published educational material is analyzed from the number of downloads of the publication and accesses to the online e-learning module. Correlations of regional distribution and other users' data collected through the e-learning module are explored.
Results and Conclusions
The users accessed the material from all regions and the e-learning module, which included a self-assessment in between each sub-module, showed a systematic progression of the users through the sub-modules. This confirms the importance of self- assessment in pacing e-learning activities and ensuring that key concepts are absorbed before e-students are allowed to access a module at a higher level of difficulty.

P-064

PARTICULARITIES OF THE CONVERSION OF FMEA TO RISK MATRIX

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Education and Professional Issues

Introduction: Currently two approaches are used for risk assessment in radiation medicine, namely, the risk matrix (RM) and the Failure Mode and Effect Analysis (FMEA) methods. Methods and Materials: A general description of RM and FMEA is shown, revealing each method's pros & cons, and the advantages of a coupled approach. The methodology for the conversion from one method to the other is described. Results: The analysis of their similarities and differences between them is presented. The rationality for coupling both methods is discussed, arguing on their positive and negative features. Conclusions: The article demonstrates the feasibility of deducing a RM from a previous FMEA study.
Keywords: risk matrix, FMEA, defense measures, quality assurance.

P-068

CLINICAL INDICATION BASED DIAGNOSTIC REFERENCE LEVELS (DRLs) FOR CONTRAST RADIOGRAPHY EXAMINATIONS: A GUIDE FOR MEDICAL PHYSICIST WITH EXCERPTS FROM ICRP PUBLICATION 135

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Diagnostic Radiology –Dosimetry

Background: The study is an excerpt of a comprehensive project to establish clinically based DRLs for contrast radiography procedures in Nigeria and to guide medical physicist in achieving the international recommendations and current trends in dose optimization steps using ICRP Publication 135 as a guide.
Methods and Materials: Prospective cross - sectional study conducted in two major University Teaching Hospitals. Three hundred and Sixty (360) patients were recruited for the study. Doses were recorded using thermo-luminescent dosimeter (TLD) chips and dose area product (DAP) meter. Student T-test was used to determine the relationship between the mean entrance skin dose (ESD) obtained in the two centers while Pearson's correlation was used to determine the relationship between the dose and anthropo-technical parameters. Statistical significance was set at $p < 0.05$.
Results: Clinical DRLs for this study were 6.68 mGy and 10.66 mGy.cm2 (IVU), 2.31 mGy and 3.67 mGy.cm2 (HSG), 2.66 mGy and 8.98 mGy.cm2 (barium meal), 12.78 mGy and 20.64 mGy.cm2 (barium enema), 2.73 mGy and 6.56 mGy.cm2 (barium swallow), and 2.05 mGy and 7.77 mGy.cm2 (RUG), respectively. The ESD and DAP showed statistically significant relationship with technical parameters for barium enema. The remaining studies showed no statistical significance ($p > 0.05$). Conclusion: Clinical DRLs in this work recorded lower values. However, regular dose optimization technique and etiquettes are required to ensure good practice.
Key words: Barium Meal, Barium Enema, Barium Swallow, Hysterosalpingography (HSG), Intravenous Urography (IVU).

P-069

RADIOLOGICAL IMPORTANCE OF THE COMPUTER RADIOGRAPHY SYSTEM FOR TOTAL BODY IRRADIATION TREATMENTS

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Radiation Oncology – Treatment Delivery

Introduction: The Computer Radiography system, installed in the Ameijeiras Hospital, is only used as an image basis for the design of the pulmonary blocks in Total Body Irradiation treatments. Taking into account that the positioning should be supported by images, it would be important to assess the advantages of this system over films such as EDR2 type for the correct position of blockages lungs and how this affects the absorption doses in this organ. Materials and Methods: The doses absorbed in the lung were calculated for the treatments that were not corrected with images. For this, we made measurements with the block in different positions and plot how the dose varies with the movement of the blocks. The image quality tests were carried out and verified, reporting the dose and the minimum time to obtain a good image quality for each system. Results: In the comparison of the two systems, it was demonstrated that the CR presents better resolution of high and low contrast. In addition, this quality is obtained with much less exposure time, which represents a dose reduction of 97% of dose that is necessary to obtain an adequate image with the other system. Also, it was demonstrated that without images for the positioning of the lung blockages, this organ can receive doses more than 9.2 Gy. Conclusions: The use of CR was validated as an image portal system for the individual positioning of each patient by direct influence on the quality of treatment by absorbing doses in lungs at different displacements, verifying that in the correct positions of the block, the lung dose is maximum 7 Gy. The optimal image quality parameters for each system and their dosimetry contribution were determined and compared, demonstrating the advantages of CR over the films in each of the selected aspects.

P-071

CHALLENGES ON PROCESS VALIDATION IN BRACHYTHERAPY SOURCES PRODUCTION

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Radiation Oncology – Brachytherapy

Cancer is a devastating disease not only Brazil but in whole world. New brachytherapy sources production laboratories are being implemented in several countries, including in our facility. A great challenge when implementing a production laboratory is to follow the Good Manufacturing Practices (GMPs), which involves process validation and all supporting activities such as cleaning and sanitization. Much more than compliance with regulatory guidelines, required for certification and inspections, a validation builds large process knowledge, provides possibilities for optimization and improvement, increasing the degree of maturity of all people involved and also the quality system as a whole. The process validation results in a document that certifies that any procedure, process, equipment, material, operation or system actually leads to the expected results. In theory, it is a simple and objective definition. In practice, it brings a series of issues and challenges.
The purpose of this work was to execute a process validation in the Brachytherapy sources production laboratory on Radiation Technology Center located at IPEN- Brazil.
Materials and Methods: The fabrication process was performed three times for evaluation. The parameters evaluated in this study were: the source welding efficiency and the leakage tests results (immersion test). The welding efficiency doesn't have an established parameter, since is visually evaluated by the operator, and the leakage detection has to be under 5 nCi / 185 Bq, accordingly ISO 9978.
Results: The observed values were: 70% welding efficiency and 32% leakage detection. Although established values for the global efficiency aren't available in the literature, the results showed high consistency and acceptable percentages, especially when other similar manufacturing processes are used in comparison (average 85-70% found in the literature for other similar metallic structures).
Conclusions: Those values will be important data when drafting the validation document and to follow the Good Manufacturing Practices (GMPs).

P-072

KNOWLEDGE-BASED RAPIDPLAN MODEL FOR PROSTATE SBRT WITH AND WITHOUT LYMPH NODES

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Radiation Oncology –Treatment Planning

Purpose: The use of Knowledge-Based Planning (KBP) in radiotherapy it is becoming increasingly common. The objective of this work was to create and validate a KBP RapidPlan model for prostate SBRT with and without lymph nodes.
Methods: Forty SBRT prostate patients' clinical plans (CP) with a total dose of 36.25Gy/5 fractions and a second group of 40 SBRT prostate/lymph node CP with a total dose of 40Gy/25Gy/ 5 fractions were selected. OARs and PTVs structures and constraints were added to the Model Structure and Objectives. Dosimetric and geometric data were extracted from the selected patient plans and added to the DVH estimation model. Two KBP models were generated (Model1: SBRT prostate and Model2: prostate/lymph node) and verified using RapidPlan of Eclipse v15.1 (Varian). The quality of the models was evaluated using R2 and x2 value. The models were validated for 10 patients in each SBRT protocol, comparing the RapidPlan with the CP for PTVs, rectum and bladder.
Results: During the verification process some structures were excluded if it did not well represent the model estimation using in field DVH plots. For Model1 the R2>0.46 and x2 <1.61 and for Model2 R2>0.41 and x2<1.3. For Model1 the differences between RapidPlan and CP was: PTV_High_3625, 0.19±0.10 [Gy] for D98% and 0.77±0.92 [Gy] for D2%; bladder, maximum difference (MD) 0.82±0.63 [%] for V18Gy; rectum, MD 2.33±1.5[%] for V18Gy. For Model2 the results were: PTV_High_4000, 0.55±0.36 [Gy] for D98% and 1.83±1.14 [Gy] for D2%; PTV_Low_2500, 0.40±0.25 [Gy] for D98%; bladder, MD 12.55±9.42 [cc] for V25Gy; rectum MD 3.09±2.63 [%] for V20Gy.
Conclusion: We successfully implemented two models with RapidPlan for prostate SBRT with and without lymph nodes. Small adjustments are required in the optimization process to achieve clinical protocol restrictions and obtain high quality plans. More plans are required to improve statistics.

P-074

FEASIBILITY STUDY OF BORON NEUTRON CAPTURE THERAPY CONCOMITANT WITH INTERSTITIAL BRACHYTHERAPY

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Radiation Oncology – Treatment Delivery

Cancer recurrence represents a great challenge when evaluating possible treatments. Thus, clinical trials based on advanced radiotherapies such as Boron Neutron Capture Therapy (BNCT) are being performed. BNCT is an extremely hypofractionated technique that involves an intravenous injection of a selective borated compound to tumor cells, follow by an external irradiation of the target using a suitable neutron beam. Boron-10 atoms cumulated into tumor have a high thermal neutron capture probability, giving rise to a nuclear reaction and high-LET products able to produce lethal cellular damage with great advantages in the treatment of radio-resistant and hypoxic tumors. BNCT has been applied mainly in glioblastomas, melanomas and head-and-neck tumors (HN), with varying results. A precisely control of the borated compound biodistribution is currently the most important challenge.
In this work, we study the feasibility of using “Beta Enhancers” in BNCT. We propose to complement the biochemical dependence of the dose distribution with a physical dependence of an interstitial brachytherapy, by implanting a non- radioactive material matrix that activates during irradiation with neutrons and become short life Beta emitters. This technique does not sensibly perturb the original procedure.
Feasibility studies were performed using the Monte Carlo code MCNP. Several implant distributions and materials within a water cube using the clinical BNCT beam available in Argentina were analyzed. Different figures-of-merit to assess the performance of the proposed technique were evaluated: suitable geometry and distance between implants, thicknesses and masses, flux perturbation, among others.
Using the most appropriate implant arrangement for a HN cancer patient treated with BNCT, a retrospective treatment planning was carried out concomitantly with Interstitial Brachytherapy. The advantages obtained in terms of dose-volume histograms and dose distributions were analyzed.
We concluded that it is possible to obtain relevant additional doses due to the implants. Further research for clinical development is in progress.

P-075

CLINICAL INDICATION BASED DIAGNOSTIC REFERENCE LEVELS (DRLs) FOR CONTRAST RADIOGRAPHY EXAMINATIONS: A GUIDE FOR MEDICAL PHYSICIST WITH EXCERPTS FROM ICRP PUBLICATION 135

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Radiology – Radiation Protection.

Background: The study is an excerpt of a comprehensive project to establish clinically based DRLs for contrast radiography procedures in Nigeria and to guide medical physicist in achieving the international recommendations and current trends in dose optimization steps using ICRP Publication 135 as a guide.
Methods and Materials: Prospective cross - sectional study conducted in two major University Teaching Hospitals. Three hundred and Sixty (360) patients were recruited for the study. Doses were recorded using thermo-luminescent dosimeter (TLD) chips and dose area product (DAP) meter. Student T-test was used to determine the relationship between the mean entrance skin dose (ESD) obtained in the two centers while Pearson's correlation was used to determine the relationship between the dose and anthropo-technical parameters. Statistical significance was set at $p < 0.05$.
Results: Clinical DRLs for this study were 6.68 mGy and 10.66 mGy.cm2 (IVU), 2.31 mGy and 3.67 mGy.cm2 (HSG), 2.66 mGy and 8.98 mGy.cm2 (barium meal), 12.78 mGy and 20.64 mGy.cm2 (barium enema), 2.73 mGy and 6.56 mGy.cm2 (barium swallow), and 2.05 mGy and 7.77 mGy.cm2 (RUG), respectively. The ESD and DAP showed statistically significant relationship with technical parameters for barium enema. The remaining studies showed no statistical significance ($p > 0.05$). Conclusion: Clinical DRLs in this work recorded lower values. However, regular dose optimization technique and etiquettes are required to ensure good practice.
Key words: Barium Meal, Barium Enema, Barium Swallow, Hysterosalpingography (HSG), Intravenous Urography (IVU).

P-077

ASSOCIATION BETWEEN STOCHASTIC NOISE IN CT IMAGES AND THE AREA UNDER THE ROC CURVE

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Diagnostic and Interventional Radiology – General

One hundred Images of head studies in adults were obtained with a Siemens Sensation 64 CT unit in a previously performed ROC study. The images corresponded to five levels of the dose index Cvol (22.9, 32.9, 42.7, 52.8 and 59.3 mGy), with five levels of the tube current per exposure time (145, 209, 272, 336 and 380 mAs). The images obtained for Cvol < 59.3 mGy were simulated by adding stochastic noise proportional to the mAs levels. Regions of Interest (ROIs) were placed in homogeneous areas of the resulting image from the difference between two adjacent images. The stochastic noise was estimated as the average of the standard deviations of the ROIs in each image. The standard deviation was divided by the square root of two to consider the added noise due to the subtraction. The association between the Area Under the ROC Curve (ABCROC) and the stochastic noise was analyzed. The minimum stochastic noise level for which the ABCROC = 80% was set as a reference to identify feasible protocols with Cvol lower than for default protocol but preserving an acceptable diagnostic quality. A fit was made between the ABCROC and stochastic noise for a hyperbolic secant function whose argument is a potential function of stochastic noise, where the 80% point of the AUCROC corresponded to 6 HU. This minimum value of stochastic noise corresponds to a minimum value of Cvol = 33.53 mGy, below which the diagnostic accuracy would be reduced to less than 80% for the sample of cases studied. The association of noise, with measures of image quality based on observer models, compensates the limitations of using stochastic noise as a unique measure of image quality and allows to define reasonable restrictions for the optimization of clinical head protocols.

P-078

RESPONSE OF A MINIATURE SPHERICAL DIODE AS A DOSIMETER FOR THERAPEUTIC CARBON-ION BEAM

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Radiation Oncology – Dosimetry

Introduction:
As the best use of the Bragg curve nature, hypofractionated ion-beam therapy has been promoted on various tumor site. In carbon-ion therapy for prostate cancer treatment at the Heavy Ion Medical Accelerator in Chiba (HIMAC), radical hypofractionation has been performed by selectively reducing the urethral dose located at the center of the prostate tumor. It is needed there to establish an in-vivo dosimeter to confirm if the dose to urethra is surely reduced as planned during the therapeutic irradiation. This study investigated a response of a miniature sphere diode as a candidate for the in-vivo dosimeter for therapeutic carbon-ion beam.
Material and Methods:
Sphere diode of 1.2 and 1.8mm in diameter made by Sphelar Power Co., Ltd. (Kyoto, Japan) was tested. The measurement was carried out at the therapeutic port of HIMAC with pristine 290 MeV/n of carbon beam as well as therapeutic 350 MeV/n spread-out Bragg peak (SOBP) beams. Output current from the diode during the irradiation was measured with an electrometer as integral charge. A pinpoint ionization chamber was also used for the sake of comparison.
Result and Discussion:
The spherical geometry of silicon caused slight broadening or pristine Bragg peak of the carbon-ion beam, however, for SOBP beam it showed superior dosimetric response free from LET dependency as almost comparable as those measured with an ionization chamber. The measurement with the smaller diode successfully reproduced the decrease in dose at the middle of the SOBP intentionally designed to simulate the therapeutic irradiation reducing urethral dose. The diode showed decrease in sensitivity of about 1% / Gy as a function of integral dose, however, the output linearity on dose and subtle incident angular dependence together with the smallness and safeness make the silicon diode as a good candidate for the in-vivo dosimeter in ion-beam therapy.

P-079

EFFECT OF LONGITUDINAL AND PERPENDICULAR MAGNETIC FIELDS ON RADIOCHROMIC EBT3 FILM RESPONSE TO CARBON-ION BEAMS

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Radiation Oncology – Dosimetry

Introduction: Merging MR imaging and charged-particle therapy (MRiPT) has gained interest to increase the targeting accuracy of radiations. The radiochromic films are suited to measure the 2D dose distribution of charged particle beams with high special resolution. However, the dose response of the films under magnetic fields to the charged-particle beams has never been studied intensively. The purpose of this study is to investigate the effect of longitudinal and perpendicular magnetic fields, BL and BP, on radiochromic EBT3 file response to therapeutic carbon-ion beams.
Methods and Materials: A water-cooled solenoid (dipole) magnet was used to produce a magnetic field longitudinal (perpendicular) to the carbon-ion beams. The radiochromic EBT3 films placed within the bore (gap) of the magnet were exposed to low (12 keV/μm) and high (50 keV/μm) linear energy transfer (LET) carbon-ion beams of 5 Gy dose under BL (BP) of 0, 0.3, and 0.6 T. The dose-monitor output was calibrated with the ionization chamber for each LET beams without the magnetic field. The optical density (OD) of the films was measured in red color channels of a scanner. The change in ODs by the orientation and the strength of magnetic fields were investigated for each LET beams based on t-test.
Results: Under BL of 0.3 and 0.6 T, the ODs decreased significantly by 1.0% and 0.6% for low LET beams and by 1.4% and 1.3% for high LET beams from the ODs without BL. Similarly, under BP of 0.3 and 0.6 T, the ODs decreased significantly by 1.0% and 0.8% for low LET beams and by 1.3% and 1.1% for high LET beams from the ODs without BP.
Conclusion: We observed small (~ 1%) but significant reductions in ODs of radiochromic EBT3 films exposed to low and high LET carbon-ion beams by the longitudinal and perpendicular magnetic fields.

P-081

SAFETY ASSESSMENT FOR THERAPEUTIC NUCLEAR MEDICINE IN CUBA

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Nuclear Medicine

Introduction: The most useful prospective methods to risk analysis in medical practices with ionizing radiation are the risk matrix (RM) and the failure mode and effect analysis (FMEA). In another hand, at the world level developed various systems for reactive risk analysis, for example ROSIS and SAFRON. In the state of the art the tools for these two approaches (prospective and reactive) are not matching. This study is aimed to identify the most contributors to the radiological risk for radionuclide therapy in Cuba.
Methods and Materials: Generic models for nuclide therapy were adapted to five nuclear medicine services. This includes the radiosynoviorthesis and the myelosupressor treatment with Phosphorous 32 of polycythemia Vera. For safety assessment are used RM, FMEA and the reactive method of the incident learning system. The use of Cuban code SECURE-MR-FMEA version 3.0 allows increasing the efficacy and efficiency in this study.
Results: The application of generic models shows a 63% of the total accidental sequences, 76% of barriers, 58% of frequency reducers and 50% of consequence reducers, as minimum. For patient specific treatment these were higher than 91%. For the first, the clinical prescription of the treatment is most important. The stages of pre and post treatment image acquisition and the preparation of radiopharmaceuticals are the most risk contributors in the last case. The main elements for decision makers are obtained. Most important identified steps, control elements and root causes for the risk are showed as integrators of the improvement quality and safety plan.
Conclusions: This study focused on analyzing of all possible radiological events in representative nuclear services in Cuba with a holistic approach. The human errors are the most contributors and the fatigue of staff as the main cause. This research allowed identifying priority measures to keep exposure optimization for patients, workers, and public.

P-084

EVALUACIÓN DEL RENDIMIENTO DEL CICLOTRÓN PETTRACE 800

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Hancco, Peru

Nuclear Medicine

El estudio con Pet ct y el usos de radiofármacos en la actualidad ya es casi común a nivel mundial para detectar el cáncer en estadio temprano y en problemas cardiológicos y neurolépticos y mi principal motivo para realizar este estudio fue siempre conocer la producción de 18F-FDG y la aplicación de la detección de cáncer en pacientes en el Hospital Nacional Alberto Sabogal Sologuren y en el Hospital Edgardo Rebagliatti Martins y escoge como tema la capacidad de producción de 18FFDG y espero que se sigan abriendo más ciclotrones en Perú y se produzca más radiofármacos para uso clínico en la evaluación de diferentes enfermedades. Este radiofármaco 18 F-Fluorodesoxiglucosa es el que más aplicaciones tiene en oncológicos, neurológicos y cardiológicos. 18F-fluorurotimidina, 18F-fluorodopa
Se conoce que el incremento del índice de mortalidad debido al cáncer ha crecido en el Perú, de acuerdo a lo que se conoce el Instituto Nacional de Enfermedades Neoplásicas (INEN). El organismo especializado atiende nada más que a 12 mil 500 nuevos pacientes por año. Es decir, al 18 por ciento. Al resto, a los otros 54 mil enfermos de cáncer (el 82 por ciento), son recibidos por otro hospital ESSALUD o simplemente no se atienden.
Detrás de las cifras hay personas. Seres humanos atrapados por una espantosa enfermedad.

P-087

EFFECTIVE POINT OF CYLINDRICAL IONIZATION CHAMBER IN ABSORBED DOSE MEASUREMENT OF CARBON BEAMS

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Radiation Oncology – Dosimetry

Introduction:
Using a cylindrical ionization chamber is recommended by the protocols (TRS-398) for measurement of water absorbed dose with carbon beams because of its small uncertainty compared to that of parallel plate ionizing chambers. It is very important, therefore, to evaluate the effective point of the cylindrical ionization chamber. The value of the effective point is defined in the protocol. In the case of carbon beams, the point is displaced by 0.75 times the cavity radius from the geometric center to the incident side. Because this is a value obtained from the material and geometric shape of the cylindrical ionization chamber, we examined whether it depends on the energy of the incident beam and the SOBP width.
Methods and Materials:
We decided the value of the effective point by measuring the displacement of depth dose distribution in combination with the parallel plate ionization chambers (PTW23343 and PTW34045) and the cylindrical ionization chambers (PTW30001. PTW30013) And we used the optical theodolite to measure the position of the reference point of each ionization chamber in the water phantom with high accuracy.
Results and Conclusions:
The measured values of the effective point were slightly larger than the value of 0.75 defined in the protocol. They did not depend on the energy and SOBP width of carbon beams and also did not depend on the ionization chamber combinations. We will examine the reason for the slightly large effective point of the cylindrical ionization chamber.

P-088

3D CONFORMAL RADIOTHERAPY END-TO-END TEST WITH CUSTOMIZED ANTHROPOMORPHIC PHANTOM CHEST CONSIDERING HIGH HETEROGENEITY CORRECTION

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Radiation Oncology – Quality Assurance

Introduction: 3D conformal radiation therapy is the standard method of treatment in many places in Brazil. AAPM TG40 states that it is recommended that dose measurents deviations lies under 5%, as well as geometric deviations don't go further than 5 mm. A method to test the overall treatment delivery precision consists in performing the so-called ""end-to-end test"", which can make use of an anthropomorphic phantom and considering heterogeneity corrections for different relative electronic densities just like tissues in a real human body.
Methods and Materials: An anthropomorphic phantom torso was made using a hollow plastic dummy chest filled with paraffin. Inside this phantom, there is a tissue like lung, made of cork slabs piled up one above the other, so this phantom could test the overall precision of the treatment planning system when high heterogeneities are present. A hole was drilled for an ionization chamber to be placed inside this lung. A simple 3DCRT plan was planned in Varian Eclipse Version 13.6 treatment planning system and dose distribution was calculated with AAA considering heterogeneity corrections. Measured mean dose delivered to the ionization chamber sensitive volume was used as reference to assess the percentage deviation from treatment planning system calculated mean dose.
Results: The construction method applied in the phantom chest produced a consistent external anatomy shape. Heterogeneities inside the phantom helped exploring the treatment planning system dose calculation capabilities while also not compromising dosimetric accuracy due to lack of ion chamber electronic equilibrium. The percentage dose deviation obtained was 4,60±(0,14)% and it's geometric deviation was 3,16±(0,10) mm.
Conclusion: Since our dosimetric and geometric measurements showed a deviation bellow the AAPM TG40 recommended threshold, we could assume our institution overall treatment delivery precision to be in accordance to the highest international protocols, such as AAPM TG40 and the IAEA ICRU No. 24.

P-090

IMPLEMENTATION OF DIBH TECHNIQUE USING RAPIDARC IN TRUEBEAM STX

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Radiation Oncology – Treatment Delivery

Purpose: Implementation of DIBH technique using RapidArc in Truebeam STx for its clinical use in left sided breast cancer. Methods: A Truebeam STx equipped with real time position management system (RPM, Varian) was used. The breathing signal was obtained by the optical camera, tracking the movement of the reflector block. A respiratory phantom (Brainlab) with three movement modalities: static position, free breathing (amplitude 1.6cm, sinusoidal wave and breathing period of 5 seconds) and DIBH (gated limits 20% of maximum amplitude, breath hold 10 seconds) was used. A Rapidarc plan with a recognizable form with angles and borders (letter S) was planned on Eclipse TPS. Phantom positioning was achieved using gated MV-KV orthogonal images, using markers fusion and 2D-3D comparison. Static versus gated DIBH CBCT was compared using distances between phantom internal markers. The accuracy of the dose delivery was verified comparing static, free breathing (FB) and gated treatments using EBT3 film dosimetry on a coronal plane ($\gamma<1$, 3%-2mm-Th30%) and absolute dose variation using ion chamber measurement.
Results: Plan delivery time without interruption was 2:51min and its increased 50% (30%) with 10s (20s) breath hold. The differences between static and DIBH CBCT was less than 0.1cm. The difference between phantom positioning using gated orthogonal MV-KV and DIBH CBCT was less than 0.1cm. Dose distribution comparison between static and FB plans showed less than 60% of the pixels with $\gamma<1$ and absolute dose variation higher than 40%. Dose distribution comparison between static and gated DIBH plans showed 99.8% of the pixels with $\gamma<1$ and absolute dose variation less than 1%
Conclusion: Truebeam STx equipped with RPM system is capable to delivery gated DIBH Rapidarc plans for left sided breast cancer. Gated DIBH CBCT and MV-kV images can be used for patient positioning.

P-092

PERFORMANCE OF MONACO TREATMENT PLANNING SYSTEM

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Radiation Oncology –Treatment Planning

Background: Monaco commercial treatment planning system (Version 2.03.00) was recently introduced in our clinic for making IMRT and VMAT treatment planning. As we all know when a TPS is newly introduced like this, it's important to verify its performance as part of commissioning procedure.
The Aim and Objectives: To investigate the performance of Monaco TPS by manipulating some optional and required parameters to see how We can achieve better dose distribution to target volume and sparing of organs at risk in a short calculation time and good plan efficiency.
Materials and Method: Materials used are Monaco software version 2.03.00(Elekta CMS software), Microsoft windows XP professional x64 Edition, Version 2003; Mat Lab (imaging processing software), computer system, Hewlett-Packard (CPU Intel®Xeon®,X5550@2.67GHz; Ram of 2.67GHz,15.9GB).Six patients CT slices set of following entities: stomach, head& neck, prostate, brain, breast and lungs were transferred to Monaco treatment planning software version 2.00.03. The necessary clinical structures were outlined (Target volume and the OARS). And IMRT and VMAT reference plan were generated with Centre of the target structure as the isocenter for all plans. (6mv) energy was used for the plans with 0.0cm couch angles and collimator angles. All plans were also generated with factor (1) for maximum number shape changes.
Result: Comparing reference plan of fixed parameters: Maximum number shape changes, Multicriterial and Grid size spacing with the manipulated plan of different values of the same parameters.
Conclusion: It was obvious that reference plan forboth in IMRT and VMAT, there is little or no significant differences in the result of dose distribution to the target volume and sparing of OARs when compared with the manipulated plans despite the difference in calculation time. In choosing value in maximum number of shape changes parameter, it is advisable to save time with factor (1).

P-094

MONTE CARLO STUDY ON OPTIMAL BREAST VOXEL RESOLUTION FOR DOSIMETRY ESTIMATES IN DIGITAL BREAST TOMOSYNTHESIS

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Diagnostic Radiology – Dosimetry

Introduction: Digital Breast Tomosynthesis (DBT) is currently used as an adjunct technique to Mammography for breast cancer imaging. Being a quasi-3D image, DBT is capable of providing depth information on the internal breast glandular tissue distribution, which may be enough to obtain an accurate patient-specific radiation dose estimate. However, for this, information regarding the location of the glandular tissue, especially in the vertical direction, is needed. Therefore, a dedicated reconstruction algorithm designed to localize the amount of glandular tissue, rather than for optimal diagnostic value, could be desirable. Such a reconstruction algorithm could benefit from the use of larger voxels, rather than the small sizes typically used for the diagnostic task. In addition, the Monte Carlo (MC) based dose estimates would be accelerated by the representation of the breast tissue with fewer and larger voxels.
Methods: In this study we investigate the optimal DBT reconstructed voxel size that allows accurate dose evaluations using a validated Geant4-based MC code. Two re-binning approaches were applied, leading to isotropic and anisotropic voxels of different volumes.
Results: Isotropic cubic voxels of 2.73 mm size provide a dose estimate accurate to within 5%, while a comparable accuracy is obtained with anisotropic voxels of dimension 5.46 x 5.46 x 2.73 mm3. In addition, the MC simulation time is reduced by more than half, in respect with the original voxel dimension, when either of the proposed re-binning approaches is used. Conclusions: we have determined the optimal voxel size for dose estimate in DBT by MC simulation, reducing the computation time by half.

P-095

CURRENT STATUS OF ABSORBED DOSE RATE IN AIR IN KANTO DISTRICT AFTER THE FUKUSHIMA DAIICHI NUCLEAR POWER PLANT ACCIDENT

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Radiation Protection

The distribution of environmental radiation in eastern Japan was dramatically changed after the Fukushima Daiichi Nuclear Power Plant accident of March 2011. While the relevant ministries and local government authorities have been measuring absorbed dose rates in air with car-borne surveys or fixed-point observations, simple comparisons of these results are not possible because the dosimeters used, and the measurement conditions differ among the groups doing the measurements. In this study, the absorbed dose rates in air in the Kanto district (Tokyo and six surrounding prefectures; 32,423 km2) were extensively measured with the car-borne survey technique and fixed-point observations using the same NaI(Tl) scintillation spectrometers and same measurement conditions. The measurements were done in 2015, 2016 and 2017 (n = 31,147). The average and range of absorbed dose rates in air from all radionuclides (i.e., natural and artificial radionuclides) were: 59 nGy h- 1 (28 – 106 nGy h-1) for Tokyo; 45 nGy h-1 (14 – 243 nGy h-1) for Saitama Prefecture; 55 nGy h-1 (18 - 197 nGy h-1) for Chiba Prefecture; 66 nGy h-1 (29 - 289 nGy h-1) for Tochigi Prefecture; 44 nGy h-1 (18 – 99 nGy h-1) for Gunma Prefecture; 67 nGy h-1 (31 - 223 nGy h-1) for Ibaraki Prefecture; and 45 nGy h-1 (13 – 80 nGy h-1) for Kanagawa Prefecture. The maximum combined standard uncertainty in these surveys ranged from 3.5 to 6.7%. The maximum contribution ratio of long half-live artificial radionuclides (134Cs + 137Cs) measured for all absorbed dose rates in air (22%) was observed for Chiba and Tochigi Prefectures. These findings will be useful to estimate impact of nuclear disaster.

P-096

EFFECTS OF IMMOBILIZATION DEVICES ON SKIN DOSES AND DOSES IN THE BUILD-UP REGIONS FOR HIGH ENERGY PHOTON BEAMS

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Radiation Oncology – Dosimetry

This study presents the significant increase in skin dose caused by the presence of thermoplastic masks used for positioning and immobilization of cancer patients during treatments in the head-and-neck region. The use of the mask in treatment plays a key role in achieving the therapeutic aim in head-and-neck treatments but can as well lead to a rise in patient surface dose. Measurements in the PMMA coupled with an electrometer and an ionization chamber at the surface, dmax and a specified depth of 10cm for the 6MV photon beam were made and recorded employing the isocentric technique for varying field sizes with 100MU. Measurements were also made on the phantom with and without the mask. GafChromic films were also used to assess the skin dose and dmax and compared to the measured values.

Surface dose increased significantly due to the presence of the thermoplastic masks. It was observed that the estimated surface doses with the mask were consistently higher than those without the mask. The mask increased the dose to the build-up region, subsequently shifting the dmax to shallower depths to the skin surface. The skin-sparing effect which is an advantage for megavoltage beams was not achieved due to the presence of the masks.

The skin and build-up region doses increased significantly with increasing; field size and thermoplastic mask thickness. For high energy photon beams, the surface dose depends on the energy and field size, hence, the higher the energy, the lower the surface dose and the deeper the penetration. For the given beam energy, the surface and build-up region dose increased with the presence of the thermoplastic mask and increasing field size.

P-097

QUALITY ASSURANCE OF DYNAMIC WEDGES IN A LINEAR ELECTRON ACCELERATOR WITH A DAILY VERIFICATION EQUIPMENT

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Radiation Oncology – Quality Assurance

Introduction:
The QuickCheck device (PTW) has a software tool to verify the wedge angle. The objective of this work is to verify the capacity of detectability of errors in dynamic wedges beams using the QuickCheck in a LINAC.
Methods and Materials:
The LINAC used is a CLINAC 2100 with Millenium MLC. The energy and field size used are 6 MV and 20x20 cm2.
The QuickCheck device is used for daily dosimetric checks of a LINAC, consisting of 9 ionization chambers (IC) on the main axes (one central and eight peripheral), in addition to 4 more IC used to measure the quality of the beam.
In order to evaluate de capacity of the device to check dynamic wedges, irradiations are made for several wedge angles and both wedge directions. Two methods are used for checking the wedge angle:
1) Using the QuickCheck software tool, which provides a wedge angle parameter.
2) Calculating the ratio of the reading of two IC (accessible from the software), placed 5 cm from the beam center in the wedge direction.
Results and Discussion:
1) Applying a 5o change in nominal wedge angle, the QuickChec software provides a change in the ""wedge"" parameter of 4- 5o. With a change in wedge direction, the software provides the same wedge angle.
2) Using the data from the two IC: a nominal change of 5o in wedge angle, provides a change > 3 % in the ratio between the two peripheral IC. Changing wedge direction, the differences in the ratio are bigger than 30%.
Conclusions:
The ""wedge"" parameter of the QuickCheck software doesn't allow to discriminate wedge direction. However, the QuickCheck is a device capable to discriminate small angle changes and wedge direction using the measurements from peripheral cameras.

P-098

QUALITY ASSURANCE OF MULTILEAF COLLIMATOR IN A LINEAR ELECTRON ACCELERATOR USING A 2D ARRAY

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Radiation Oncology – Quality Assurance

Introduction:
The Starcheck device (PTW) includes a MLC positioning verification module. The objective of this work is to check the capacity for detecting leaf position errors though Starcheck.
Methods and materials:
The LINAC is an Elekta Synergy with Agility MLC. The energy and field used are 6 MV and 26x26 cm2. The Starcheck measuring device consist of detectors on the main and diagonal axes. In addition, at 13 cm from the field center it has detectors on the left and right sides of the field, separated 5 mm one from the other. This allows the software to detect the position of the leaves in a 26x26 cm2 radiation field.
First, a measurement of a rectangular field (reference) is made. Secondly, a field with some mispositioned leaves is created and irradiated. The displacement errors are 0.5 and 1 mm, both opening and closing leaves. Errors are made for individual and pairs of adjacent leaves.
Finally, leaves position from the field with errors are compared with those of reference field. The displacements between leaves (with and without errors) are measured.
Results:
The Starcheck software detects the displacement errors of 0.5 and 1.0 mm in both directions.
The displacement accuracy is 0,2 mm greater when two adjacent leaves are displaced instead of one.
Conclusions:
The accuracy of the measured displacement is greater when two adjacent leaves are displaced instead of one (because leaves width is the same than distance between consecutive detectors). Despite this difference, it can be concluded that StarCheck is a valid device to verify leaves positioning errors as low as 0.5 mm for a field 26 cm wide.

P-099

ACCURACY AND REPEATABILITY OF AGILITY MLC IN STATIC FIELDS USING THE PORTAL IMAGING DEVICE

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Radiation Oncology – Quality Assurance

Introduction:
The purpose of this work is to investigate the accuracy and repeatability of the positioning of the Agility multileaf collimator (MLC) in static fields, using the Electronic Portal Imaging Device (EPID). An in-house software is used for this purpose. Methods and materials:
The Electron Linear Accelerator (LINAC) is an Elekta Synergy with Agility MLC.
To perform this study is used a strip-test, consisting of 10 step-and-shoot segments with 4 mm gap between them. The images are acquired with the EPID. For image analysis is used our own software made in Matlab.
Analysis algorithm:
A horizontal profile is acquired in the middle of each leaf. The profile of every gap is adjusted to a Gaussian curve. The maximum PV (pixel value) of every curve is obtained. A calibration of the strip-test with gap width from 1 to 10 mm is performed, relating the nominal gap width to the maximum PV.
The software developed is validated using film.
Measurements:
6 strip-test are made without displacing the EPID. The leaf positions in every gap are exported to a Excel workbook. Average positions and standard deviations are calculated for each leaf.
Results:
The average position error for the whole set of leaves is -0,01 mm and its standard deviation is 0.27 mm, then position accuracy for MLC system is 0,54 mm (when K=2 is considered). The average standard deviation for leaves positions is 0,14 mm, the mean repeatability for all the leaves is 0,28 mm.
Conclusions:
The developed software is able to check the MLC in static fields. Position accuracy and repeatability of the MLC agility is within tolerance for all the leaves (< 1mm).

P-100

QUANTITATIVE BREAST ELASTOGRAPHY FROM B-MODE IMAGES

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Non-ionizing applications

Purpose: In this work we investigate, from a physics point of view, the feasibility of quantifying the Young's modulus of breast tissue from the auto-correlation of a diffuse field computed from a sequence of B-mode images acquired through conventional ultrasound scanners.
Methods: Inspired in the seismological approach of retrieving the Green's function by cross-correlation, we obtained a quantitative expression that relates the shear modulus of soft tissue to the auto-correlation of the displacement field. We designed a mechanical prototype device adaptable to the breast anatomy, in order to create the necessary conditions in terms of diffuse field generation. The device is easy to handle, and its positioning does not interfere with the ultrasonic probe, being friendly to use within the clinical environment. The displacement field was measured from a sequence of B-mode images acquired with conventional ultrasound equipment. This method was tested in a breast tissue mimicking phantom using standard ultrasound scanners. We also performed an in-vivo measurement as a preliminary validation. Results: In the reconstructed elasticity maps the inclusions were identified and the obtained quantitative results of the phantom are in good agreement with the values reported by the phantom's manufacturer. In the case of the in-vivo measurement, the obtained images are in accordance with the patient known pathology (BI-RADS 5, Infiltrating Ductal Carcinoma, Score 6). The pathological breast showed a heterogeneous elasticity map with a mean Young's modulus of 98 KPa, while the normal breast displayed a homogeneous map with a mean Young's modulus of 25 KPa.
Conclusions: We successfully reconstructed the Young's modulus map of the breast tissue mimicking phantom and of a real breast tumor using B-mode images acquired with conventional ultrasound scanners. The results support that our technique can be developed as a medical tool to obtain quantitative breast tissue elasticity maps.

P-103

ANALYSIS OF NTCP BASED RADIOBIOLOGICAL MODELS: A SYSTEMATIC REVIEW OF LITERATURES

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Radiobiology

Background and purpose: To achieve the optimal treatment goal, radiobiological parameters have to evaluate and predict the outcome of this treatment plan in terms of both TCP and NTCP. Different types of radiobiological model were used to achieve prescribed treatment dose of radiation during the tumor control. Where TCP models play a important role in order to achieve desired dose to the tumor. A suitable NTCP model was theoretically found among different models that can be used in treatment plan evaluation.
Materials and Methods: Theoretically, six different radiobiological dose response models were analyzed in this project. Lyman–Kutcher–Burman, Critical element, critical volume, Relative Seriality, Parallel architecture, Weibull distribution models were analyzed from the derivation. All models were discussed elaborately with its various parameters and were used in the calculation of normal tissue complication probability during the treatment in radiotherapy. Further, all models were compared with each other.
Results: The models denote the dose for 50% complication probability (D50) parameters is the most commonly used radiobiological models for the normal tissues. The functional subunit response models (critical element & Relative seriality, Critical Volume, parallel architecture) are used in the derivation of the formulae for the normal tissue.
Since all complicated NTCP model predict same as the simple NTCP model that is Lyman–Kutcher–Burman model as well as it is computationally efficient. Also, Lyman–Kutcher–Burman model can be used in different treatment planning system incorporating with another model. For this reason, our suggested model is Lyman–Kutcher–Burman NTCP model which can be used in treatment plan evaluation.
Conclusion: After analyzing six different model of NTCP, finding of the study is the treatment plan evaluation in where Lyman–Kutcher–Burman model is the best model for biological plan evaluation.
Keywords: TCP, NTCP.

P-104

STUDY OF BIOLOGICAL-BASED OPTIMIZATION FOR INTENSITY MODULATED RADIATION THERAPY (IMRT) PROSTATE AND HEAD AND NECK CASES

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Radiation Oncology –Treatment Planning

Introduction:
Although present treatment planning systems apply biological-based optimization, its cost functions are not always entirely understood by users, thus limiting the adequate implementation of that method. In this work, we aimed to gain a deeper comprehension on how biological optimization is carried out in Monaco 5.1, apply it in order to find the best possible plan, and compare these results with those obtained with physical optimization for VMAT prostate and head and neck cases.
Materials and Methods:
Biological and physical optimization for various prostate and head and neck cases was implemented using Monaco 5.1 for VMAT. An in-depth exploration of Monaco's biological cost functions was performed, particularly of the influence of the various function parameters on target coverage and OAR sparing. We also assessed the need to include further physical cost functions. Treatment plans were evaluated by DVH analysis and calculating TCP and NTCP using DVH reduction methods. Results:
Both in prostate and head and neck cases, high-quality treatment plans were achieved by using biological optimization in combination with some physical cost functions, which we found to be necessary to shape the DVH and limit high dose points in targets and OARs. We found that the use of biological cost functions facilitates the tailoring of the DVH, avoiding the use of multiple physical cost functions to obtain the same result. As opposed to physical optimization, biological optimization provided better OAR sparing, without sacrifice of conformality and homogeneity.
Conclusions:
Biological optimization provides an efficient optimization method for treatment planning, with the advantage of being associated to radiobiological concepts necessary for the evaluation of IMRT plans. By applying these functions in combination with physical cost functions, high-quality plans were achieved for prostate and head and neck cases.

P-105

DEVELOPMENT OF SECOND-CHECK 3D DOSE CALCULATION SOFTWARE FOR HIGH-DOSE-RATE BRACHYTHERAPY

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Radiation Oncology –Treatment Planning

Purpose: To implement fast and comprehensive dose evaluation beyond a point-based plan decision in high-dose-rate brachytherapy (BTHDR), volumetric independent dose calculation (vIDC) software was developed. The feasibility and clinical practicality of the calculation module were evaluated for patient cases.

Methods: As a fractional dose of 550 cGy was prescribed to 90% of the high-risk critical target volume (HR-CTV), five patients with cervix carcinoma were selected to evaluate dose distributions in BTHDR using a tandem and ring applicator. The vIDC adopts an updated version of the TG-43 formalism and the same air-kerma rate for iridium-192 with a clinical treatment planning system (TPS). Volumetric dose evaluation using the vIDC was preceded by an accuracy test at the ICRU reference points, namely point A and B, and rectal points. Dose differences were presented with dose-volume histograms (DVHs) and primary dose-volume parameters such as D2cc for organs-at-risk (OAR). A grid size of 1.0 x 1.0 mm2 (G-1.0) was chosen for elaborate dose calculation. However, a sparse and a fine grid resolution of 2.5 x 2.5 mm2 (G-2.5) and 0.5 x 0.5 mm2 (G-0.5) were used to evaluate effect of grid size, especially at the high-dose gradient.

Results: The averaged difference throughout an entire volume of dose points was less than -1.79%. When the 1-mm grid resolution was used, the DVHs for the CTV and OAR showed the insignificant difference between the vIDC and the TPS. While D2cc of OAR showed averaged dose deviation less than 10 cGy, D90 of CTV showed the averaged difference of - 12.90%, -8.26%, and -6.18% in G-2.5, G-1.0, and G-0.5, respectively.

Conclusion: The vIDC was usefully used for efficient second-check 3D dose evaluation for BTHDR using iridium-192. Volumetric dose calculation using the sparse grid size can affect delivered dose distributions using volume-based dose prescription.

P-106

MONITORING RADIOACTIVE AIRBORNE CONTAMINATION DURING F18-FDG PRODUCTION

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Radiation Protection

Airborne contamination monitoring is part of the Radiation Surveillance Program at PET radiopharmaceuticals production centers in Argentina. This work presents the design and validation of a quantitative airborne radioactivity monitoring methodology, associated to the production of FDG in the Cyclotron-Radiopharmacy division at FUESMEN. As a significant improvement, the system was optimized through the design and installation of an activated carbon filter. At present, our division has two FDG synthesizers: a cGMP IBA Synthera, and non-cGMP Nuclear Interface, each installed inside a TAEN Hotcell. First, the F-18 net activity from ventilation stack is evaluated. Second, the activity concentration of F-18 in air, in DAC, is evaluated in workplaces. In both cases, an air sampling system based on a portable pump with an air flow meter was used, with a two-filter set: fiberglass paper and carbon impregnated with TEDA. In addition, an appropriate isokinetic probe was created and installed for in-line air sampling from ventilation stack. In order to estimate activity levels in air, a method based on the use of a PET-CT scanner was developed to measure the activity of F18 retained in sampling filters. For the detection system, a Minimum Detectable Activity (MDA) of 3.18 KBq and a sensitivity of 0.0624 Kc/KBq have been determined. When measured in workplaces, F-18 DAC values fell within regulatory limits. Regarding the discharge ventilation stack measurements, activity values showed room for improvement, particularly for FDG production using the non-cGMP synthetizer Nuclear Interface. In response, a modernization on the two FDG TAEN hotcells was performed, adding a mixed bed activated carbon filter in hotcells exhaust air duct, downstream the existing HEPA exhaust filter. As a result, F-18 emissions in the venting stack remained below the MDA of the developed measurement method.

P-107

GAMMA-CAMERA CALIBRATION TO DETERMINE UPTAKE ACTIVITY ON THYROID SCINTIGRAPHY WITH Tc-99m

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Nuclear Medicine

Introduction:
Thyroid scintigraphy with technetium 99 metastable (Tc-99m) allows the physiological and functional evaluation of the thyroid gland and thus to determine some disease, the advantage of using Tc-99m is its short half-life and rapid uptake in the patient. This image is common in the clinical routine of diagnosis in the thyroid, but the activity collected and cumulated as well as the dose in the thyroid and organs around are not known, so it is necessary to have the calibration factor that allows to determine the activity captured due to the number of thyroid counts in the obtained image.
Materials and methods:
The scintigraphy images of two groups of three Petri dishes were acquired and studied, in two Gamma-Chamber General Electric Models Discovery NM 630 and NM/CT 670. For each acquisition, Petri dishes filled with 93, 64 and 19 MBq of Tc- 99m in a volume of 20 ml each and placed on 8 PMMA plates each one 1 cm thick, then two more PMMA plates were placed on the Petri dish. The acquisition of each image was performed 5 cm from the detector, image size 15x15 cm2, matrix 256x256 pixels and 360 seconds time in all cases. The study of the images was done by determining the number of counts within an ROI delimiting the main region, and four smaller ROIs to determine the background counts in the thyroid image.
Results and Conclusions:
The calibration factors of the two Gamma-Chambers were calculated, obtaining values of 1.71x10-2 and 1.95x10-2 MBq.s/cts for the models Discovery NM 630 and NM/CT 670, respectively. These factors will allow to determine the activity uptake in the thyroid using imaging thus being able to perform dosimetry both in the thyroid and in the adjacent organs as well.

P-109

CORNEA INFLATION TESTS TO COMPLEMENT A BIOMECHANICAL MODEL OF THE HUMAN CORNEA

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Biomedical Engineering

Numerical modeling of human cornea has paramount importance to test in silica surgical procedures and to understand the effect on human eyes of injuries and other external aggressions. To prepare a numerical model that could reproduce correctly the corneal behavior, it is necessary firstly to select a type of elastic material and its mechanical model of response. Then a numerical procedure must be implemented; normally FEM is used for calculations. It is then necessary to select geometry, create a mesh and calculate the elastic constants of the model. It was created a mesh consisting in three layers and eleven elements per meridian from the apex to limbus. Two geometries were tested: cornea fixed by limbus and a second one formed by cornea, corneal limbus and part of sclera. It was prepared and tested the numerical procedure for establishing the stress-free configuration. In the present contribution, it is shown an experimental installation that is being employed in inflation tests. Due to their similarity to human corneas, porcine corneas were used to help in developing a methodology in order to get stress- strain relations from inflation tests. From these relations the numerical parameters of a Mooney Rivlin hyperelastic material model are obtained.

P-110

DOSIMETRIC COMMISSIONING OF AN UPGRADED EQUINOX-100 COBALT-60 UNIT IN THE VARIAN ECLIPSE TREATMENT PLANNING SYSTEM

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Radiation Oncology – Quality Assurance

Introduction: An existing clinical Theratron 780C (T780C) (Best Theratronics, Kanata, CA) Cobalt 60 unit with 80 cm source to axis (SAD) was upgraded to an Equinox-100 Cobalt-60 unit with 100 cm SAD. The upgraded Equinox-100 has increased clearance to accommodate a removable multi-leaf collimator enabling conformal radiation therapy, and potential intensity modulation capabilities. The upgrade also included installation of a computer-controlled collimator system with a motorized 60° wedge, and a new Avanza patient support system to enable patient positioning with improved motion accuracy and stability. This was the first upgrade of a T780C unit worldwide and represents an exciting opportunity to advance conventional Cobalt 60 technology.
Methods: In this work we present mechanical commissioning of the upgraded unit following Task Group 45 report (AAPM) recommendations, and commissioning of the Cobalt-60 source in the Eclipse treatment planning system (TPS) (Varian Medical Systems, Palo Alto, CA) for dose calculations. Dosimetric measurements required for configuration of the Eclipse AAA algorithm were acquired, and various source modeling parameters were adapted and optimized in the Eclipse TPS to model the Cobalt 60 source. The Eclipse TPS was validated by comparing the treatment plan calculations with ion chamber, and radiochromic film dosimetry measurements in water phantom.
Results: The mechanical test results were mostly comparable to typical tolerances acceptable for clinical linear accelerator as recommended in TG 45 report. This suggests that upgrading a conventional Cobalt 60 unit improves treatments without compromising the mechanical accuracy. Treatment plan calculations in the Eclipse TPS showed excellent agreement with measurements for 5×5 cm2 or larger radiation fields. Our results show that the Eclipse TPS can be appropriately commissioned for forward treatment planning with Cobalt-60 beams for 3D conformal radiation therapy for large fields. We continue investigating the accuracy of the Eclipse calculations for Cobalt 60 small fields.

P-113

A WAY TO PRESENT THE INSTITUTIONAL DOSIMETRY

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Radiation Protection

Introduction:
Currently, dosimetry focuses on the worker through records between annual, quarterly or monthly periods, but at the institutional level is not analyzed. To guarantee a radiological protection program that is sustained over time, it is necessary to know in which area of the institution a greater resource of the estimated ones is required due to the risk that the practice merits. Methods:
The last 5 years of registration were taken. The data were analyzed by means of a normal distribution and plotted by means of box and whisker diagrams. You can compare the classic method of representing the data plotted month by month to a global graph of box and whiskers where all the data of a worker in a same year is synthesized.
Results:
The maximum and minimum values are differentiated, while the median and with them comparing them with the reference levels, can determine the dosimetric range as the difference between 75% percentile and 25%. With this, the dosimetric range of the practice is estimated
Conclusions:
The box and mustache diagram allow to visualize in a practical way the personal occupational dosimetry better than the classical form. This type of graphs also allows us to observe where most of the data are concentrated and to estimate in what level of dose the worker is with respect to its last 5 years of records, with respect to the group or department that belongs and at the same time compare the different Services to estimate where the highest dosimetric risk is obtained. Finally, the values of the institutional dosimetric range, the confidence interval, the standard deviation can be obtained since the dosimetric data of the institution behave in a normal way and allow to synthesize the institutional dose in statistical values traceable in time.

P-115

DEVELOPMENT OF CALCULATION APPROACH FOR THE DETERMINATION OF CENTRAL AXIS DEPTH DOSES IN WATER FOR COBALT 60 BEAM

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Radiation Oncology – Dosimetry

One of the dosimetric functions, which is of great importance, is central axis percentage depth dose, which are usually measured with automated systems. The aim of the study was to develop and propose a semi-empirical formula that can be used to determined central axis percentage depth doses through manual calculations and also be used as a quality assurance tool to check uncertainties associated with measured central axis depth doses. Linear attenuation coefficients of water were measured for water with beams from a Theratron Equinox 100 cobalt 60 teletherapy unit using field sizes ranging from 4 cm x 4 cm to 30 cm x 30 cm. The linear attenuation coefficient measurements were done in air with a 0.125cc Semiflex ionization chamber with its build-up cap on. With the expression for the primary component of the PDD and the measured PDD data obtained during commissioning of the telecobalt machine, a semi-empirical formula was developed and proposed for the determination of PDD, which considered both the primary and the scatter components of the PDD. The PDDs calculated with the proposed semi-empirical formula compared well with their measured counterpart with percentage differences between measured and calculated PDDs ranging from 0.10% to 2.01% (mean of 1.24±0.88%), which is within the 2% acceptable limit for central axis parameter constancy (PDD, TAR) as recommended in the report of the TG-40. The use of the proposed formula for calculating PDD is recommended for clinical application, but one needs to be circumspective in the use of the formula as some few PDDs (2%) calculated with the formula compared to their measured counterparts were found to have discrepancies beyond the tolerance of 2% recommended for the determination of central axis depth doses.

P-117

OCCUPATIONAL RADIATION DOSE TO OPERATOR BY HANDHELD DENTAL INTRAORAL EQUIPMENT VERSUS A FIXED INTRAORAL X-RAY SYSTEM

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Radiology – Radiation Protection.

Medical and dental exposures are the main contribution of radiation dose to the population due to artificial sources. Then, operator and staff must be aware of safe use of ionizing radiation. The intraoral X-ray equipment is designed to be fixed or arranged on a mobile support. A new X-ray equipment has been introduced, which can be held by operator`s hands during exposure. The aim of this study was to estimate radiation dose to operator when using a handheld dental intraoral X-ray system without a backscatter shield during intraoral radiography and to compare the measurements with fixed dental equipment with and without protection barrier. Measurements were taken at a maxillofacial radiological clinic. A Planmeca Intra fixed intraoral equipment and DX 3000 Dexcowin handheld intraoral equipment were used. A dental simulator to calibrate the radiographic technique was used, together with the Kodak film and Sirona digital system. The diagnostic images were obtained with 0.3 and 0.15 s for film and digital system, respectively. Then, an exposure time scale for each tooth piece was made. Scattered radiation was measured using a Thermo Scientific Mini-ION ionization chamber. The chamber was positioned at 30 cm to skull simulator, simulating working conditions. The method to calculate occupational radiation dose is based on the protocol of Public Health Institute of Chile. This study shows the first results for Chile estimating radiation dose to operator when using a handheld intraoral X-ray system. The operator radiation dose using handheld intraoral equipment with digital system and fixed dental equipment with film was 12 and 14 μSv, respectively. When handheld intraoral equipment is used with film system, the dose was 28 μSv, significantly higher than fixed intraoral equipment. Consequently, the limit of 20 mSv / year can be easily exceeded. Therefore, precautions must be taken to avoid unnecessary exposures to operator.

P-118

METHOD FOR NOISE REDUCTION IN COMPUTED TOMOGRAPHY IMAGES WITH AN APPROXIMATED BILATERAL FILTER

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Diagnostic and Interventional Radiology – General

Despite the clear evidence that computed tomography provides very valuable information for diagnosis, there is a potential risk for the use of ionizing radiation. In CT, decreasing the dose of radiation increases the amount of noise in the images; therefore, the noise can hide anatomical details and decrease the detection of injuries. The Bilateral filter, proposed by Tomasi and Manduchi, is able to preserve the edges of the image and to reduce noise in uniform regions. The ability of the BF to reduce noise depends on the function of two sub-factors including spatial distance and intensity weights. In the BF the functions of these weights are exponential. This function has the advantage of reducing the greater amount of noise and better preserving the structural details. The disadvantage is that this noise reduction and detail preservation capability decreases after a certain noise value by reducing filter performance. The advantages of this feature have a very narrow margin and can easily be lost in practical applications where noise variability increases. This affects the performance of the BF causing blurring in the details of the image and a decrease in the ability to reduce noise in the image. In order to be more effective, the filtering process in our work, we made a reformulation of the sub-factors of spatial distance and intensity. The function exponential of these sub-factors was approximated to fractional through the MacLaurin serial development. The reformulation guarantees a better stability in the noise reduction capacity, a better preservation of details in the image when there is an increase in noise variability as well as a reduction in the execution time.

P-119

DETERMINATION OF ABSORBED DOSE TO WATER FOR MEDIUM AND HIGH ENERGY X-RAY BEAMS USING FRICKE DOSIMETRY

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Dosimetry – Reference quality

Introduction: Currently, the determination of absorbed dose to water for medium and high energy X-ray beams is done using water calorimetry or ionization chamber. However, these measurements need to be validated and the technique used is very restricted to a few standard primary metrology laboratories. This work presents the Fricke dosimetry as a solution for the measurement of the absolute absorbed dose to water for medium and high energy beams. Material and Methods: First, the chemical yield curve of the Fricke solution was determined as a function of photon energy. From the chemical yield curve, it was possible to determine the absorbed dose to water equivalent depth of 2 cm in X-ray beams, defined by the CCRI/BIPM, as well as the expanded uncertainties of the dose value. For the CCRI/BIPM qualities, the spectra were also simulated and the R2.5 parameter was evaluated experimentally to be used as a quality index for medium energy photon beams. In addition, the quality factor of three ionization chambers were determined experimentally for high energy beams. The expanded uncertainties of the quantities obtained were calculated. Results: The uncertainties obtained for the medium X-ray measurements were 2.3% (k=2), which is lower than the uncertainties obtained with the ionization chamber. For the high energy beams, the absolute dosimetry was done with ionization chamber and Fricke dosimetry. The results of absorbed dose to water shows a difference of 0.9% among them. Conclusion: Fricke dosimetry has shown good potential to be used as a primary standard for the absorbed dose to water measurement. Some important aspects should be observed, as this is a chemical dosimeter, any contamination at the Fricke solution can change the results. The prepare of the solution must be done carefully to avoid contamination.

P-120

AN UNCERTAINTY ANALYSIS FOR OPTIMIZATION OF COMPUTED TOMOGRAPHY PROTOCOLS

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Diagnostic Radiology –Dosimetry

The objective of this work was to identify the uncertainties with the greatest contribution into the optimization of Computed Tomography (CT) protocols and their possible reduction for measurements under clinical conditions. A continuous uniform distribution was assumed to estimate the relative uncertainty of kQ, equal to u(kQ) = 0.3% for k = 1. The ionization chamber used (CT chamber 30009, PTW-Freiburg) has a response variability in the energy range (80-140 keV) used =<4%. The expanded uncertainties of air kerma free-air (Ca,100) and Polymethyl Methacrylate phantom (Cpmma,c) indices were 11.1% and 12.7% for k = 2, respectively. The uncertainties >1% contributed 92% to the combined uncertainty. According to the results obtained and the recommendations of the Report TRS-457 of the International Atomic Energy Agency, when replacing the dosimeter used by a reference class dosimeter, such as a Farmer 30010 type camera (PTW, Freiburg), the uncertainty =<0.5% per year corresponds to a scenario 3. In addition, the Farmer 30010 type camera has a response in the energy range =<2%, and its directional response =<0.5% for an inclination range of the camera axis of ±5°, which belongs to a scenario 3 as well. Therefore, the uncertainty budget is reduced by 49.5% and 66.1% for Ca,100 and Cpmma,c respectively. We estimated the spectra that satisfy the calculation of Ca,100 and Cpmma,c with relative differences less than 2%, in addition to the primary and scattered spectra. The reduction of the expanded uncertainty for measurements in clinical conditions improves the accuracy of the dosimetry for the optimization of CT protocols. The determination of fitted spectra contributes to the knowledge of the influence quantities of uncertainty due to scattered radiation and beam hardening.

P-122

QUALITY CONTROL OF OPEN FIELDS WITH EPID IN AN ELEKTA SYNERGY

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Radiation Oncology – Dosimetry

Introduction:
The Electronic Portal Imaging Device (EPID) is sometimes used as quality control device for linear electron accelerators (LINACs). Due to the corrections applied to the image by the EPID software, the homogeneity of a square field obtained by the EPID is different from the one obtained by a conventional detector. In this work, the use of EPID as a tool for dosimetric quality control of open fields is analyzed.
Methods and Materials:
The LINAC is an Elekta Synergy with iViewGT EPID and 6 MV energy. The focus-detector distance is fixed, 160 cm.
Air profiles are acquired with the 2D Linear Array (PTW), for a 23x23 cm field (the largest field which allow to adquire the whole penumbra and part of the profile tail with EPID), dose rate 200 UM/min.
1) For the analysis of the images obtained with the EPID, a Matlab software developed by ourselves is used.
Using a 200 UM/min dose rate, the dose profiles along GT and LR axes are analyzed. The differences in homogeneity are evaluated for fluences of 10, 20, 50 and 100 MU.
2) The differences in symmetry between Linear Array and EPID are evaluated in both axes for 5 months.
Results and Discussion:
1) The maximum value of the homogeneity is reached at 50 MU, so this value is taken.
2) The differences in symmetry between Linear Array and the EPID along GT and LR axes are: -0.4 and +0.7, respectively. These differences can be attributed to the lack of homogeneity in the EPID dispersion.
Conclusions:
Despite the differences in symmetry between both devices, the EPID can detect changes in symmetry of open fields after establishing an initial reference.

P-123

PET/CT AND HYPO-FRACTIONATED RADIOTHERAPY OF PATIENTS WITH HEAD AND NECK CANCER

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Radiation Oncology –Treatment Planning

Positron emission tomography/Computer tomography (PET/CT) is a multimodality imaging diagnostic technique that analyzes the uptake and retention of different radiopharmaceuticals by cells providing metabolic information on biochemical processes. PET/CT has been used for radiotherapy planning, providing useful information to the Radio-oncologist about the localization, size and metabolic activity of tumor lesions. In this paper, we show advantages of the 18F-FDG PET/CT respect to simple CT imaging for target volume delineation in patients with diagnosis of Squamous Head and Neck Carcinoma that has been scheduled to undergo a hypofractionated radiotherapy treatment. On ten studied patients, the target volume defined from PET/CT images was less extensive than those defined from simple CT images. In six patients the target volume was significantly less extensive and in two of them a new lymph node disease was reported, re-staging and corresponding target volume was also delineated with less extensive margins from PET/CT images. A greater accuracy in delineating the volumes and improving the distribution of doses in the planning of the radiant treatment in these patients was possible, allowing a high precision in the delivery of the prescribed dose to the target volume diminishing the maximum dose to the adjacent healthy tissues. In conclusion we show that the use of 18F-FDG PET/CT was superior than the simple CT as the primary modality of imaging for hypofractioned radiotherapy treatment planning in patients with Squamous Head and Neck Carcinoma.

P-126

DETERMINATION OF THE DYNAMIC VISCOSITY IN SAMPLES OF BLOOD PLASMA AND HEMOGLOBIN SOLUTION BY NUCLEAR MAGNETIC RELAXATION

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Biomedical Engineering

A procedure based on proton magnetic resonance is presented for the evaluation of the dynamic viscosity in blood plasma and in hemoglobin solution from the determination of the transverse relaxation time (T2). To experimentally determine the T2 value, the impulse series Carr-Purcell-Meiboon-Gill was used in a MARAN DRX console (OXFORD INSTRUMENTS) and a homogeneous magnetic system (B0 = 0.095T). Values were obtained for blood plasma viscosity and hemoglobin of 1.68 ± 0.12 mPas and 12.78 ± 3.55 mPas respectively, which coincided with the determined, in the same samples, using an Ostwald viscometer (1.45 ± 0.06 mPas for the plasma and 12.82 ± 3.35 mPas for the dissolution of hemoglobin). The dynamic viscosity of the blood plasma was determined in 236 patients with multiple myeloma (2.19 ± 0.58 mPas), 142 with sickle cell anemia (2.20 ± 0.79 mPas) who showed statistically significant increases with respect to the characteristic values of the controls (1.68 ± 0.12mPas).

P-127

INTRAOPERATIVE RADIATION BEAM MODELING AND BREAST TREATMENT SIMULATION

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Radiation Oncology –Treatment Planning

Introduction: Intraoperative radiation therapy (IORT) delivers the treatment dose in a single fraction during the surgical procedure. IORT beams present different characteristics from conventional external therapy beams, and there is little information about the techniques's dose distribution. The goal of the present study is to assess IORT dedicated beams and simulate a breast treatment using the Monte Carlo method.
Methods: Monte Carlo simulation package PENELOPE was used to model IORT applicators and obtain the radiation beam spectra. The modeling geometry consisted in the applicator for NOVAC7 and the probe for Intrabeam, both inserted in a water filled phantom. The radiation spectra were validated through comparisons with literature. A breast treatment was simulated for both beams. A female thorax geometry was built into PENELOPE, using soft tissue and skin materials. Dose distributions were qualitatively evaluated.
Results: The beam modeling validation showed a maximum divergence between simulated and literature data of 7.8pp for NOVAC7 and 8.6pp for Intrabeam. For millimeter distances, the divergences in NOVAC7 are acceptable, while for Intrabeam both curves present the same behavior, and the biggest divergence occurs in close proximity to the probe tip, representing a small influence at the prescription depth. The Intrabeam dose distributions presented doses higher than 100% in the target volume, since the treatment is prescribed at 1 cm from the applicator. For NOVAC7, the dose distribution showed, for all the energies, a region of high doses in the intersection between air and soft tissue.
Conclusion: The high dose region observed for both IORT beams may compromise a large fraction of the target volume and must be carefully considered for treatment planning. The knowledge of the dose distribution can improve the treatment planning, allowing the study of target volume definition and improving treatment results.

P-129

STRUCTURING OF THE NATIONAL QUALITY CONTROL PROTOCOL FOR MAMMOGRAPHS CR

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Diagnostic and Interventional Radiology – General

This work makes available to the country, a protocol for computerized mammography; among other reasons, because this is the most abundant family of equipment in the national inventory. An important number of CR mammographs in the country were and will continue to be the product of a ""transformation"" of analogue equipment already in service, which have been converted into CR, by adding the module that allows the formation of the digital image, with all the implications that this brings; which is why it deserves to structure its specific protocol for quality control. The initial proposal is based on the existing protocols for both analogous and digital mammography, as relevant in each case; which is applied through a pilot, to 16 teams (14% of the country's total) of 14 hospitals (5.4% of the country), located 6 of them in a department of the Colombian Andes and the remaining 8 in a department of the Caribbean area. The relevant material used was: CR cassettes of each institution, Ray Safe System, mechanical weight, Free Software ""ImageJ"", blocks of PMMA and ACR mannequin. Once the pilot product information has been processed and analyzed, the final version of the protocol is structured, including the estimation of average glandular dose, as well as tools for the acquisition, processing and analysis of the information acquired in the application of the protocol, in such a way that it is ensured and facilitated, obtaining the results and conclusions of it. The most representative brands of mammographs and CR readers in the country were established, as well as the results of the application of the protocol tests, by type of test and by equipment. The protocol obtained will be harmonized with the participation of a group of medical physicists who work in hospitals that have mammography.

P-131

BIOSPECKLE LASER TO STUDY THE RED BLOOD CELL AGGREGATION IN ALTERED CONDITIONS

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Biomedical Engineering

Dynamics of human red blood cell aggregation was studied by means of biospeckle laser analysis. Red blood cells from healthy donors were suspended at 40% in autologous plasma with different concentrations of dextran 500 (0.2 g/mL, 0.4 g/mL y 0.8 g/mL) in order to modify the aggregation process. He-Ne laser light was used to obtain the biospeckle pattern from forward scattered light by the samples. Biospeckle parameters such as Correlation Coefficient and Inertia Moment, were calculated in order to assess their sensitivity and versatility. Results show variations of the calculated indexes related with the dextran concentration used. Consequently, the proposed biospeckle parameters could be used as a tool for assessing red blood cell aggregation and eventually diagnosis pathological conditions related the aggregation dynamics to prevent possible microvascular alterations.

P-132

PROTECTION OF CRYSTALLINE LENSES BY THE SEAT CONTAINING SHIELD MATERIAL

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Radiation Protection

Introduction: The absorbed dose of crystalline lenses in a computed tomography (CT) is decreased using the seat containing shield material. Influence on image quality by the shield material is estimated.
Methods and Materials: The bismuth containing seat and the barium containing seat were used for the shield material. An image evaluation of the CT in which the shielding seat was installed on the water phantom was done. A standard deviation of an obtained picture was measured using the Image J, and influence of image quality was estimated. The Image J is image analysis software. The absorbed dose of crystalline lenses was measured using the optically stimulated luminescence (OSL) dosimeter installed in head Phantom. The location of the OSL dosimeter was made the root of the nose, the eye socket center and an outer corner of the eye. The eye socket covered by the shielding seat did CT photography.
Results: A standard deviation was increased so that it increased in the thickness of the bismuth containing seat. However, the barium containing seat could get the same standard deviation irrespective of the thickness. Decrease of the absorbed dose of crystalline lenses showed by the shielding seat. The absorbed dose decreased so that it increased in the thickness of the shielding seat. The protective effect of the shielding seat of barium 15 mm and bismuth 3 mm was same.
Conclusions: The barium containing seat didn't influence diagnostic imaging, and it was possible to decrease radiation exposure of crystalline lenses. Influence on image quality of CT by the shielding seat was estimated using the Image J.

P-134

CHARACTERIZATION AND CALIBRATION OF RADIOCHROMIC FILMS EBT2 FOR USE IN PERIPHERAL DOSE MEASUREMENT

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Dosimetry – Reference quality

In radiotherapy treatments, there is an absorbed dose that is deposit outside the treatment field, this dose is known as ""Peripheral Dose"". The objective of this work was to characterize and calibrate the EBT2 radiochromic films in a range of lower doses with a beam of photons of 6 MV generated in a linear accelerator Clinac 2100C / D, in order that they can be used as dosimeters in the measurement of peripheral dose. The characterization of the radiochromic films, shows a reproducibility with uncertainty of ± 1.3 % (2μ), linearity for a range of low dose of up to 93 cGy with linearity coefficient of r2 = 0.9998, dependence of the dose rate of ± 4.7 % (2μ), energy dependence with linearity coefficient of r2 = 0.9412 and in the calibration a maximum uncertainty of 1.8 % (2μ). It is concluded that EBT2 radiochromic films can be used to measure peripheral dose, due to the characteristics they have, such as the low energy dependence (between 1% and 2% for the same dose) and in addition to being suitable for placing them on the surface of a patient

P-136

SCATTER RADIATION DOSE AT HEIGHT OF THE CARDIOLOGIST`S EYE: A MULTICENTRE STUDY

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Radiology – Radiation Protection.

Cases of radiation induced cataract among cardiologists have been reported in studies, estimates for the dose to eye lens ranged from 450 to 900 mSv per year (without ceiling suspended screen). Recent surveys regarding high prevalence of lens changes likely induced by radiation exposure suggest an urgent need for improved radiation safety and training, use of eye protection during catheterization procedures, and improved occupational dosimetry. The ICRP recommends limiting radiation dose to the lens of the eyes to 20 mSv per year for occupational exposure. The aim of this paper was to report scattered radiation doses at the height of the operator's eye at interventional cardiology facilities and correlate these values with different angiographic projections. Measurements were taken in three cardiac laboratories. Clinical working conditions were reproduced during the experiments for seven angiographic projections and three fluoroscopy modes and a cine mode were used. PMMA plates were used to simulate a standard patient and a cardiac protocol for patients between 70 to 90 kg was used. Measurements of ambient dose equivalent (H*(10)) were performed with Unfors Xi detector. The detector measuring scatter radiation was positioned at the usual distance of the cardiologist's eyes. A first entrance surface air kerma (Ka,e) rate reference proposal for the characterization of angiography for fluoroscopy low, normal, high and cine modes were 16; 35; 40 and 220 (mGy/min), respectively. An experimental correlation factor range 3.9 to 5.3 μSv/Gy*cm2 were calculated. Considering the typical PKA values to patient in interventional cardiology procedures, we have obtained that the dose at the height of the operator's eye lens ranged from 0.078 to 1.490 mSv per procedure when the radiological protection devices have not been used. Therefore, an operator could easily exceed the annual dose limit if the radiological protection devices are not used.

P-137

ALTERNATIVE FOR THE DESIGN OF THE CURRICULUM IN THE FORMATION OF MEDICAL PHYSICISTS

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Education and Professional Issues

The subject is inserted in the complex process of improvement of Cuban Higher Education and the formation of Bachelor in Physics (BP), with emphasis on Medical Physics (MP). The main destinations for the location of these professionals are in scientific research and health centers or other associated with medical applications. However, a significant number of graduates from BP enter the labor market of the MP without prior training in the subject, a limitation that has its genesis in the curricular design of the career. A research was developed in which theoretical methods such as analysis-synthesis,
ion, socialization workshops and theoretical exchange with professors were applied in order to analyze the curriculum in relation to the formation of BP, with emphasis on MP. The process of
ion carried out favored the proposal of an alternative for the design of the curriculum in which a proposal of the optional curriculum and the identification of the professional competences in FM have been taken into account. The first includes the subjects Biophysical Fundamentals of Morphophysiology, Radiological Protection, Radiobiology and Radiation Medical Physics, with which a greater level of essentiality is sought in the contents for performance as medical physicists. The second is aimed at the identification and contextualization of the specific competences that will allow the profession to be exercised according to the standards of the medical physicist in Cuba and internationally. The proposal of the alternative for the design of the BP curriculum allows an integral approach to the object of the profession from the initial stages of the career, from the implementation in the praxis of alternatives that respond to the totality of the social context related with the training of this professional.

P-139

GATED VMAT IMPLEMENTATION USING HOMEMADE 4D PHANTOM

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Radiation Oncology – Dosimetry

Introduction:
Radiotherapy treatment in lung cancer is a challenge due to intrafraction tumor motion. Additional margins added to the target volume trajectory can ensure treatment but also increase complications due to toxicity in adjacent tissues. Radiotherapy with respiratory gating reduces irradiated area to a specific window of the respiratory cycle. Gated technique implementation requires quality assurance tests that guarantee treatment accuracy for targets tracked by external references. For this purpose, we developed a phantom capable of mimicking the respiratory movement.
Methods and Materials:
An oval styrofoam cylinder reproduces a pulmonary lobe enclosed in a thick shell of casting plaster, as it is easily modeled and has soft tissue equivalent Hounsfield (200HU). The tumor has spherical format and approximately 2 cm diameter also of plaster positioned in the center of styrofoam lung that was parted in half to insert radiochromic film.
For reproduction of respiratory cycle, we attached the produced phantom to the respiratory phantom of the Siemens Anzai® only to take advantage of its longitudinal movement.
We acquired a 4D tomography for planning using Varian RPM® (Real-Time Position Management), which was also used for treatment. Using Eclipse® we planned 18Gy in 2 half volumetric arcs (RapidArc®) for a TrueBeam® with 10MV flattening filter free (FFF) beam and 2400MU/min dose rate calculated with Acuros.
We performed measurements with EBT3 radiochromic film positioned at the center of the moving lesion and Portal Dosimetry® (PD) with RPM.
Results:
The result of gamma analysis for both measurements, film and PD compared to the calculated dose distribution had agreement of 98.86% with criterion 3%/3mm with film and 99.2% with 3%/1mm with Portal Dosimetry.
Conclusions:
The phantom made possible the implementation of VMAT technique with Gating in a reliable and efficient way, besides being a cheap option compared to the commercial models.

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RELEVANT CLINICAL ADVANCES WITH THE IMPLEMENTATION OF NEW RADIOTHERAPY TECHNOLOGIES IN JAMAICA

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Radiation Oncology –Treatment Planning

Cancer is one of the leading causes of death globally and radiotherapy is currently an essential component in the management of cancer patients, either alone or in combination with surgery or chemotherapy, both for cure or palliation. Advances in computer technology have enabled the possibility of transitioning from basic 2-dimensional treatment planning and delivery (2-D radiotherapy) to a more sophisticated approach with 3-dimensional conformal radiotherapy (3-D CRT).
Material and Methods: The planning of patients with malignant pathologies in the head and neck, prostate, central nervous system, Cervix and breast in 2 dimensions, treated in the Cobalt machine, simulated with a conventional simulator and the new plans in 3 dimensions done after the acquisition of the CT simulator and the CLINAC iX of Varian and the complications reported during the treatment were compared.
Results: The patients treated in 2D presented greater toxicity during the treatment than those who received the treatment in 3D dimensions, tolerating it better despite the increase the tumor dose.
Conclusions: the new technologies introduced in the country since March 2018 have allowed to improve the quality of radiant treatments and to personalize the treatments by increasing the dose to the tumor, decreasing to the maximum the dose in healthy tissues.

P-141

NEW QUALITY CONTROL PARAMETERS OF ALUMINA COLUMNS USED IN 99Mo/99m Tc GENERATORS

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Nuclear Medicine

Currently, in Morocco, the demand for radioisotopes and radiolabeled compounds is steadily increasing with the emergence of new nuclear medicine centers. To support this evolution, the National Center for Nuclear Energy, Sciences and Technologies (CNESTEN-Morocco). was placed an ambitious program for the development and manufacture of radioisotopes for medical purposes. The most important one is technetium-99m generators production. In order to improve the efficiency of technetium generators manufacturing in CNESTEN-Morocco), we evaluated the influence of different parameters of molybdenum adsorption by alumina. Firstly, samples in different conditions have been investigated in order to determine the intrinsic surface properties of α-Al2O3, which is a point zero charge, isoelectric point and the number of active sites. These studies show that α-Al2O3 with 63-200 μm of particles seizes oxide, have the best intrinsic surface properties. In the other hand, several parameters have been studied to optimize the fixation of molybdenum on alumina involved for adsorption evaluation, such as: pH, contact time, partial seize of the oxide, chlorination, electrolyte concentration. In addition, ATR-FTIR spectra were investigated to inspect the molybdenum adsorption on the oxide. Finally, we have been able to define the behavior of the molybdenum-alumina complex according the variations of pH and contact time. The influence of the mixture of partial sizes was carried out. The mechanism of adsorption of molybdenum is greatly influenced by pH modification. This investigation needs a very large number of experiences. For many reasons of radio protection; radioactive waste management and economics investment, the study was divided into two parts. In the first one ""cold investigation"" we used stable molybdenum. In the second one ""hot investigation"" we reproduced the most relevant experiments in hot cells using radioactive molybdenum 99mMo solutions.

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STABLE ISOTOPES IN ARCHAEOLOGY: A REVIEW USING MIXING MODELS IN R

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Radiobiology

Introduction:
Isotopes are forms of the same element that differ by the number of neutrons in their nucleus. Information collected through isotopic analysis is important for the reconstruction of past human diets, providing the main sources of protein in the diet. With the advancement of technology and the need to use this information, the usage of tools to aid in processing stable isotope data is necessary. A computational package was developed to solve mixing models' equations for stable isotopic data within a Bayesian structure, called simmr. This work aimed to show the efficiency of stable isotope mixing models in archeology, revisiting a study on Byzantine paleontology in Crete.
Methods and Materials:
The basis for this work was a study published in 2007 on paleontological information of humans and fauna of Crete. The carbon and nitrogen stable isotopic analysis results for bone collagen of adult and subadult skeletons of the middle Byzantine (11th century AD) were processed through the ""simmr"" package, available in R. Thus, it was possible to generate graphs and trophic level and food preference information.
Results:
As a result, all human adult data have high values of δ (_^15)N, indicating that the dietary protein was mainly of animal origin, including meat, milk and dairy, with the most likely candidates being dairy and fish. The δ(_^13)C value of most humans is consistent with a terrestrial diet (based on C_3). In the analysis of the fauna, the results found for pig, deer and sheep were already expected and, for goats, there was a range of changes in δ (_^13)C values, which may indicate consumption of some C_4 protein.
Conclusion:
This work was able to prove the efficiency of the mixing models in stable isotopes applied to the archaeological area, revisiting an already realized study and reaching the same results.

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EVALUATION OF DOSES AT RENAL SCAN OF INTERNAL DOSIMETRY (IMAGE BASED) AND CORRELATION OF THE TRACER BIO-DISTRIBUTIONS OF DTPA, DMSA AND MAG3

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Nuclear Medicine

Introduction:
Renal scintigraphy is a diagnostic procedure that uses nuclear medicine to examine the anatomy and functioning of kidneys. This work has been carried out to evaluate bio-distribution of different agents (MAG3, DMSA, DTPA) for scintillation scan for renal function and measure internal dosimetry of patients by image-based dosimetry. The correlation of the results using different types of pharmaceuticals (MAG3 , DMSA , DTPA) in renal scintigraphy procedures in nuclear medicine has also been studied.
Methods and Materials:
A total of 200 patients (124 male and 74 female) have been selected and studied for renography using 99mTc-DTPA, 99mTc- MAG3 and 99mTc-DMSA scan methods in the present work. The sample patients referred to the National Institute of Nuclear Medicine and Allied Science (NINMAS), BSMMU, Dhaka-1000. This study will evaluate the comparison between these two scans and also will evaluate the bio-distribution of these three agents and measure internal dosimetry using image.
Results and Conclusions:
It has been observed that age group below 20 years got moderated average uptake 67.00%, age group (20-50 years) got highest average uptake 69.51% and age group above 50 years got lowest average uptake 56.49%; which indicates that renal dysfunction arises with the age. To correlate the uptake through image-based dosimetry using two dynamic scintillation scans in same age group, in the study MAG3 and DTPA agents were used. Using MAG3 and DTPA the average uptake in kidney was found 72.36% and 66.91% respectively; which caused by the variation of the clearance flow of these agents. However, DMSA agent was implemented in static scan; which was not effective to measure directly the obstruction of renal flow as we got from dynamic studies using MAG3 and DTPA. The anatomical structures found in DMSA scan may portend the existence of obstructions in kidney caused by renal dysfunctions.

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IRRADIATION OF BLOOD SAMPLES USING A RADIOTHERAPY WATER PHANTOM

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Radiation Oncology – Dosimetry

Introduction:
The Institute of Health Research of the University of Costa Rica, acquired in 2018 a water phantom to place blood samples, which will be irradiated with known doses, to subsequently make biological effect curves at various absorbed dose points. Because the water phantom was developed to perform quality controls in Radiotherapy and not for blood irradiations, an acrylic support was created to place the test tubes. Subsequently, all the dosimetric aspects recommended by the International Atomic Energy Agency for blood irradiation were verified.
Objective:
Verify that the water phantom purchased by the Health Research Institute complies with the dosimetric requirements established by the International Atomic Energy Agency regarding blood sample irradiation.
Materials and methods:
All irradiations were performed at the Radiotherapy Department of the San Juan de Dios Hospital with a Co-60 source. Using the linear attenuation coefficients of water and PMMA, the phantom's irradiation center was theoretically calculated. Subsequently, the location of the irradiation center for opposite beams was verified for 10x10 cm fields with a SSD of 80cm, using 10 radiation beams at 0° and 10 beams at 180°; all for 7 different dose points. Finally, the charge released in each irradiation was measured, as well as the absorbed dose, obtaining the discrepancy for opposite beams in each of the dose points.
Results:
The irradiation center of the phantom was located theoretically and experimentally, obtaining a difference of 1,7 mm between both positions (14,72 cm and 14,55 cm). The greatest discrepancy between opposite beams for the same dose point was 0,7%. Conclusions:
The irradiation center of the phantom is located 14,55 cm from the main irradiation face. As the discrepancy between doses of opposite beams was less than 2%, it is concluded that the phantom is suitable for the irradiation of blood samples.

P-145

COMPUTED TOMOGRAPHY DOSE CALIBRATION: AN EGYPTIAN SURVEY CONTAINING CTDI DOSE MEASUREMENT FOR FIFTEEN CT SCANNERS OF SIX DIFFERENT VENDORS

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Diagnostic Radiology –Dosimetry

Purpose: Because the high risk of cancer incidence due to radiation exposure we tried in this work to estimate our actual level of CT dose index (CTDI).
Material and methods: Radiation dose was measured using a longitudinal ionization chamber dedicated for CT dose measurement. CT head and body phantoms were used. Dose measurement were performed at different tube voltage ranged from 100 to 120 kVp, and time - current tube range of 50 to 250 mAs.
Results: Although this survey is carried out on a random sample whoever, the results showed good agreement between the measured CTDIs and the published one for the most common used imaging protocols (Head, Chest, Abdomen and pelvis protocols. The average CTDIvol for head scan was found to vary from 4.3 mGy (±3.2SD) to 16.4mGy (±7.32SD) for 100 kVp and 50mAs and 120 kVp and 100 mAs respectively. For body scan the average CTDIvol was found to vary from 2.1 mGy to 14.1 mGy for 100 kVp and 50 mAs and 120 kVp and 100 mAs respectively. The DLP for head scan varies from 43.5mGy.cm to 150.26mGy.cm. The average DLP at 120 Kvp and 250 mAs were ranged from 250mGy.cm to 540 mGy.cm. According to our results there was very good agreement between measured DLP using ionization chamber for all imaging protocols and that recorded on the CT monitor.
Conclusion: Quality control program is mandatory for dose optimization and performance evaluation of CT imaging procedures. Qualified Medical physicists must be included into The health care team in diagnostic radiology departments. The calculated DLP which showed on the CT monitor can be recorded and collected to use as the patient exposure record.
KEY WORDS: Computed Tomography, CTDI, Risk of Cancer Incidence, and Qualified Medical Physicists (QMP).

P-146

DEVELOPMENT OF PORTABLE ALPHA-RAY SPECTRUM SURVEY METER

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Nuclear Medicine

Since 2016, RI internal use therapy of radioactive radium chloride (Ra-223 Cl2 half-life 11.13 days), which is a short-lived alpha nuclide, has been started in Japan as an effective treatment for castration-resistant prostate cancer with bone metastasis. In the clinical field, contamination of alpha nuclides occurs. Direct measurement of alpha rays requires a dedicated measuring instrument. Also, energy discrimination is necessary to identify alpha nuclides. Therefore, it is necessary to acquire the energy spectrum of alpha rays. We tried to develop a new portable alpha ray spectrum survey meter with an ion-implanted silicon detector. As a detector, a large area ion implanted silicon semiconductor detector of 2,000 square mm was adopted. A resolution of around 100 keV was confirmed for the alpha nucleus of Am-241. We would like to report the performance of the collected energy spectrum and so on.

P-147

PROPOSAL OF A LEAD-FREE AND NON-METALLIC MATERIAL FOR USE IN RADIATION PROTECTION

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Radiation Protection

Lead is a material that has been used for many purposes for thousands of years. Due to its properties as density, ductility, stability and because it is relatively easy to extract and recycle, it is the most commonly used element as an effective shield against electromagnetic radiation (X and gamma rays) in radiological protection. Despite its excellent properties for the construction of radiation shielding thanks to its great absorption of incident radiation, its easy adaptation to the shielding and its low cost, it has been associated to effects harmful to health. Therefore, the main of this research is to propose a lead-free and non-toxic material that allows reduce the dose received by patients due to dispersion. For this purpose, the characterization of sintered hydroxyapatite (HAp) and potassium iodide (KI) was carried out using different techniques such as X-ray Diffraction (XRD), X-ray Dispersive Energy (EDX), Fourier-transform infrared spectroscopy (FTIR) and Raman spectroscopy, to obtain information on the physical, chemical and structural properties of materials. On the other hand, the attenuation capacity of the X radiation was determined with an X-ray equipment (30-60 kV) and an RTMS (Real-Time Multiple Strip) detector, taking into account the intensity of the radiation as a function of the thickness and density of the sample compared to lead. In conclusion, it was identified that the non-metallic material that best attenuates the X-rays in this study for the possible application in radiological protection is potassium iodide.

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DEVELOPMENT OF PORTABLE RADIATION DEPTH DISTRIBUTION SPECTROMETER

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Radiation Protection

Eight years have passed since the Fukushima Daiichi Nuclear Power Plant accident caused by the Great East Japan Earthquake, and the radioactive fallout from the accident shifts from the soil surface to the deeper layer. The difference from the Chernobyl accident is that Japan is an island country with many mountainous areas, and it has a wet and humid climate, so the influence of sediments is large unlike the flat continent. The developed measuring instrument is a rod-like radiation depth distribution spectrometer length of 40 cm and a diameter of 3 cm, and 20 CsI scintillators are arranged at intervals of 2 cm. It is possible to measure the concentration of radioactive cesium at intervals of 2 cm in each layer at depths of up to 40 cm from the surface layer in approximately 10 minutes. We report the depth distribution survey of radioactive cesium in contaminated areas including Fukushima prefecture using the developed portable depth distribution spectrometer.

P-149

MEASURED AND CALCULATED DOSES IN A UNIQUE EYE APPLICATOR - THE "CLAWS"

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Radiation Oncology – Dosimetry

Introduction:
Brachytherapy is the preferred radiation treatment modality for various intraocular tumours. The "Claws" is a gold applicator that is loaded with I-125 seeds for localized whole-eye radiotherapy, particularly for stage 0 retinoblastoma. Under general anaesthesia, a pericorneal ring is attached to the four extra-ocular muscles, and four appendages, each loaded with I-125 seeds, are inserted beneath the conjunctiva in-between each pair of muscles and attached anteriorly to the ring. The applicator has an inside diameter of 22 mm. A typical treatment prescription is 40 Gy given over four days to the centre of the eye. General anaesthesia is also required for the removal of the applicator.
Method:
A solid water eye phantom was manufactured and doses in the "Claws" were measured with thermoluminescent dosimeters and gafchromic film. These doses were compared to planned doses.
Results:
Normalized doses measured with TLDs and film agree to within one standard deviation. Calculated doses overestimated the dose by more than 20 % in some areas of the eye, because the treatment planning system does not take into account the gold shielding, which becomes evident near the periphery of the eye.
Conclusion:
It is important to know the limitations of the treatment planning system when doing eye intra-ocular brachytherapy. In this case, measurements in a simple eye phantom have shown such a shortcoming. The clinical impact may require an investigation.

P-152

AN INSTITUTIONAL EVALUATION OF RADIATION DOSES TO PATIENTS AND PERSONNEL DURING ERCP; DOSE OPTIMIZATION AND RISK ESTIMATION

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Diagnostic and Interventional Radiology – General

Introduction:
Endoscopic retrograde cholangiopancreatography (ERCP) relies on the use of ionizing radiation but risks to operator and patient associated with radiation exposure are unclear. The aim of this prospective study was to estimate the radiation dose received by patients and personnel during fluoroscopic endoscopic procedures, mainly ERCP. We intended to optimize the radiation dose during therapeutic ERCP, and to estimate the risk for personnel and patients, to compare the doses based on available data and reference levels recommended by international organizations.
Materials and Methods:
Dose Area Product (DAP) measurements can be used to estimate the effective dose (ED) to patients undergoing ERCP. A DAP meter was fitted to the x-ray tube before each of the ERCP procedure. The use of OSLDs to measure radiation exposure to the anterior and posterior body surface of the patient and abdomen, thyroid gland, forehead and hands of the personnel performing the procedure permitted an estimation of radiation doses received. 25 ERCP procedures of therapeutic intent were evaluated in this study. All the procedures were performed on Allengers HF fluoroscope.
Results and Discussion:
Therapeutic ERCP was associated with higher radiation exposure than diagnostic ERCP as the fluoroscopic time was higher for therapeutic procedures. The patient dose can be optimized by the presence of an experienced interventionist in the team by reducing the fluoroscopic time and reduction of radiographic images. The radiation dose to the personnel was well within established safety limits. The radiation absorbed doses to the different organs are relatively low. Proper use of lead curtains and lead aprons also is important in reducing the personnel dose.

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RADIATION OXIDATIVE STRESS DURING RADIOTHERAPY CAN INDUCE SECONDARY CANCERS

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Radiobiology

Radiation therapy involves significant exposure of cells to ionizing radiation, which is responsible for production of intracellular reactive oxygen species (ROS). ROS can act as a primary messenger, modulating several intracellular signaling cascades leading to cancer progression. The balance between ROS generated during metabolic activities and level of endogenous antioxidant is a must for normal function of cells in human body. ROS are responsible for regulation of various functions such as cell division, signal transduction and apoptosis. Patients undergoing radiotherapy experiences cellular oxidative stress which affect cellular function due to ionizing radiation interaction with cell in form of DNA strand break, chromosomal aberrations, gene mutations, alteration in intracellular signaling mechanism and inhibition of apoptosis leading to higher risk of secondary cancer occurrence and other diseases as radiation induced ROS are involved in initiation and promotion of carcinogenesis. Investigation has found significant oxidative stress in cancer patients during radiation therapy. Our study included 127 cancer patients (82 male and 45 female) with age group of (28-50) years, underwent radiation therapy. 40 control samples for the comparison are involved in the study. Investigation on blood serum samples of the patients showed significant higher levels of lipid peroxides (ROS) species and significant reduction in levels of Glutathione (antioxidative response of the body to balance oxidative stress) in comparison to control. This higher oxidative stress levels can affect cellular system of body in significant manner and further may increase the risk factor of secondary cancer generation.

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COMPARISON OF DIRECT AND INDIRECT METHODS FOR ASSESSING RADIATION DOSE FROM DIAGNOSTIC RADIOLOGICAL EXAMINATIONS

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Diagnostic Radiology –Dosimetry

Purpose:
The present study aimed to assess the radiation doses to adults from common diagnostic radiological examinations for optimization purposes. This study also examines direct and indirect methods of entrance skin dose (ESD) measurement. Materials & methods:
This study was carried out on conventional X-ray unit (Meditronics Manufacturing Company Pvt Ltd, India). The quality assurance (QA) of the X-ray machine was performed. The standardized exposure parameters were used for chest (66 kV, 16 mAs), pelvis (66 kV, 30 mAs) and skull (66 kV, 20 mAs) diagnostic radiological examinations to perform the present study. The ESD was measured using MagicMax (IBA Dosimetry GmbH, Germany). The output of the X-ray machine was measured at 80 kV at a distance of 1m normalized to 10 mAs for radiation field of 20x20 cm2. The ESD was calculated using the Davies model. This model used output of machine, applied tube voltage (kV), mAs, focus to skin (FSD) and back scatter factor (BSF) for ESD calculation for the exposure. In this study, the BSF value was used 1.35 for adult patients as suggested in European guidelines.
Results:
The QA parameters of the machine were found within tolerance in compliance with AERB QA protocol. The output of the X- ray machine was measured 0.0273±0.023 mGy/mAs. The calculated ESD for chest, pelvis and skull diagnostic radiological examinations were estimated 0.401 mGy, 0.753 mGy and 0.502 mGy respectively. The calculated average ESD for chest, pelvis and skull diagnostic radiological examinations were observed 0.358±0.027, 0.641±0.033 and 0.428±0.018 respectively. The percentage deviation between calculated and measured ESD for chest, pelvis and skull diagnostic radiological examinations was found 10.70%, 14.89% and 14.79% respectively.
Conclusion:
The present study provided methodologies for direct and indirect assessment of radiation dose optimization purposes. This study examined direct and indirect methods of ESD measurement from diagnostic radiological examinations.

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FURTHER EDUCATION IN MEDICAL PHYSICS: BLENDED-LEARNING SETTINGS FOR STUDENTS AND PROFESSIONALS

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Education and Professional Issues

Introduction:
During the last years we have developed different courses in Medical Physics that adopt the so called "blended learning approach". In 2009 we established online-based Master's programs for national and international students at Heidelberg University, Germany (UHD), and we have extended our teaching activities to a set of long- and short-term courses for students as well as professionals working in the field of Medical Physics for several years (see www.dkfz.de/medphys_edu). Our short- term courses combine an online phase of 4-8 weeks with a 1,5 day attendance phase either in Heidelberg, Germany or in Santiago de Chile. During our long-term programs (1,5 years) our participants attend several online phases (4-6 weeks each) that terminate with an attendance phase of 4 days.
Materials and Methods:
We would like to discuss and explain our teaching and learning settings that are part of our long- and short-term courses and that have been developed as part of our Master's courses. Some teaching activities will be presented in detail, which have been evaluated very positively, but also some less successful examples will be presented to highlight potential pitfalls of our approach.
Results:
In our setting, recorded video lectures including pdf-slides seem to be the most attractive teaching activity for both participants and lecturers. With longer course duration, however, our participants ask for more learner-centered and interactive methods. Our selected examples will show how to avoid student's frustration in online learning.
Conclusion:
The combination of recorded video lectures and learner-centered methods seem to be the key to success in online teaching. We are very glad to continue with our teaching activities together with our Chilean colleagues as part of the "Center of Excellence in Investigation and Teaching" at UHD which is funded by the German Academic Exchange Service (DAAD) and supported by the German Federal Foreign Office.

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EXPERIMENTAL AND NUMERICAL ANALYSIS ON FOCUSED SOUND FOR MEDICAL APPLICATIONS

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Non-ionizing applications

Introduction: Bone mineral density (BMD) has been the gold standard to assess the fracture risk of bones and is measured using X-ray absorptiometric techniques. Focused sound technique could help in the diagnosis, it does not ionize the tissue and its implementation is relatively inexpensive. The most general definition of sound is a longitudinal wave in a medium. The propagation of the acoustic wave is influenced by the bone mass, structure and properties of the material. So that, it can be used to characterize the elastic properties of cortical and cancellous bone for some time. The aim of this work is to analyze the behavior of sound through different materials in experimental and simulation way. Methods and Materials: For the experimental part, an electroacoustic device was used (Bone Radar) this one was built in the Medical Physics Laboratory at the University of Guanajuato. Measurements were made with cylinders of different materials and lengths, placing the transducer and receiver on the cylinder faces. In parallel, it was carried out the simulation for the wave equation by using the finite difference method. Results and Conclusions: It was observed a change in the sound intensities reported respect the density of each material measured, in the same way there were analyzed the variations of the intensities respect to the position in which the transducer was placed. In the part of simulation, it was established a sinusoidal function as Dirichlet initial condition, adding the damping factors corresponding to the medium through which the wave was affected. The method was solved for the wave equation in a simplified geometry in one dimension, allowing the comparison of the experimental measurements with the numerical results.

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NORMAL BRAIN TISSUE IRRADIATION IN INTRACRANIAL METASTASIS TREATMENTS: MULTIPLE ISOCENTERS VS SINGLE ISOCENTER TECHNIQUES FOR VMAT TREATMENTS

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Radiation Oncology –Treatment Planning

Introduction:
The single-fraction stereotactic radiosurgery (SRS) with volumetric modulated arc therapy (VMAT) is commonly used for multiple brain lesions treatments and is typically performed using a multiple isocenter approach (one isocenter per tumor) to reduce the normal brain tissue irradiation. However, these treatments are time-consuming (new setup for each isocenter). Patient plans with two metastases were optimized using one or two isocenters and compared in terms of normal brain irradiation depending on the distance D between lesions.
Methods and Materials:
30 patients plan with two lesions were calculated using EclipseTM TPS (one single-fraction of 21 Gy) with one isocenter (4 coplanar arcs), and with one isocenter per lesion (4 coplanar arcs for each isocenter). The distance between the lesions was registered. For both approaches, a dose normalization of 100%Dp at 95%PTV and Timermann's constraints for the organs at risk (brainstem, optical nerves, eyes, chiasm) were adopted. The volumes of normal brain-minus-PTV that received 4, 12 and 18Gy in both cases were recorded depending on the distance between the lesions: D<6cm (10plans), 6cm<D<9cm (10plans), D>9cm (10 plans).
Results:
For each patient, both plans satisfied PTV and OARs acceptance criteria. For all distances between the lesions, V12Gy and V18Gy differences between 2isocenters vs 1isocenter are insignificant (average±standard deviation: D<6cm: ΔV12Gy=0.13±0.13%, ΔV18Gy=0.00±0.04%; 6cm<D<9cm: ΔV12Gy=0.12±0.13%, ΔV18Gy=0.00±0.06%; D>9cm: ΔV12Gy=0.01±0.05%, ΔV18Gy=-0.01±0.03%). Concerning the low dose irradiation, for 6cm<D<9cm, the use of 2 isocenters reduced the normal brain tissue (ΔV4Gy=8.35±3.53%) but for smaller o larger distances, the influence is lower (D<6cm: ΔV4Gy=2.65±1.37%; D>9cm: ΔV4Gy=2.49±1.12%).
Conclusion:
For all calculated plans, V12Gy and V18Gy of normal brain-minus-PTV were similar using one or two isocenters and V4Gy were slightly lower using 2 isocenters. Given that the use of a single-isocenter treatment leads to shorter treatment times, it appears to be a very interesting approach.

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ANALYSIS OF TRUEBEAM® VARIATION OF DOSEMED EXPERIENCE DATABASE

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Radiation Oncology – Dosimetry

Introduction:
Since commissioning beam data are treated as a reference and ultimately used by treatment planning systems, it is vitally important that the collected data are of the highest quality to avoid dosimetric and patient treatment errors that may subsequently lead to a poor radiation outcome. This study aimed the comparison between data of commissioning tests of four linear accelerators TrueBeam® of Varian Medical Systems for photon beam of 10 MV. The Dosemed database has analised parameters like PDD curves and beam profile.
Methods and Materials:
In this study were used a blue phantom 2 and two ionization chambers cc13 (both of IBA Dosimetry), a CRS phantom and two ionization chambers semiflex 0.125cc (both of PTW).The arrangement of phantoms and ionization chambers was prepared for the commissioning tests, the data were collected and analised by software Omnipro 7.4®.
Results:
The analysis of PDD curves for a field size 10x10 cm2 measured in a water phantom at a depth of 10 cm and SSD of 100 cm were 73.6, 73.3, 73.5 and 73.4, for linacs TrueBeam® 1, 2, 3 and 4, respectively. The analysis of beam profiles for a field size 30x30 cm2 measured in a water phantom at a depth of 10 cm and SSD of 100 cm were 33.03, 33.17, 33.00 and 33.24 cm2, respectively, for linacs 1, 2, 3 and 4. The measures for linac 1 were made with CRS phantom and for the other linacs with Blue phantom2.
Conclusions:
Beam data commissioning should be independent of individuals collecting the data and scanning systems if it is performed with appropriate knowledge and proper tools. Data variation among beam collectors should be as minimal as possible (<1%). The analysis of both dosimetric arrangement showed that the evaluated data do not presented variation, thus the data showed a good reproducibility

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IMPLEMENTATION OF THE AAPM-TG100 FOR THE RISK ASSESSMENT OF STEREOTACTIC RADIOSURGERY (SRS) DEVELOPED IN CUBA

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Radiation Oncology – Quality Assurance

Introduction: In order to improve the safety and quality of the practice of Stereotactic Radiosurgery (SRS), the quality assurance program established for this technique was evaluated at a radiotherapy (RT) service in Havana, Cuba.
Methods and materials: The Process Map (PM), the risk assessment technique Failure Mode and Effect Analysis (FMEA) and the Fault Tree analysis were used; implementing the methodology established in AAPM TG-100 into a computational tool dedicated for this purpose: SECURE-MR-FMEA
Results: Seven subprocesses were identified, starting from ""Placement of the stereotactic frame"" until ""Application of the treatment"". Treatment divided into 43 steps, with 116 potential failure modes, due to 50 possible causes. In total, 603 Failure Modes -Cause (FM-C) were quantified, 10% of which had risk priority numbers (RPN)> = 100 and 63% with severity (S)>= 7. The ""lack of attention"", the ""lack of patience"" and the ""lack of training"" are the main causes that contribute to the occurrence of high-risk NPR and S.
Conclusions: The methodology proposed by the AAPM-TG 100 together with the SECURE-MR form an effective strategy for the knowledge of the risk profile of the radiotherapy service. The results show that human error is the biggest source of potential accidents and incidents in this type of treatment in the evaluated service. Hence, actions to reduce risk, that contribute to the improvement of the quality assurance program of the institution, were proposed. In addition, the FMEA risk pattern for the practice of SRS at the RT service, was deployed and incorporated into the SECURE-MR-FMEA database as a guide for future studies.

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ACCEPTANCE TESTS OF THE NOMEX® SL SURVEY DETECTOR FOR SCATTER AND LEAKAGE MEASUREMENTS

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Radiology – Radiation Protection.

Quality assurance protocols on medical ionizing radiations modalities recommend radiation protection measurements to account for scatter, leakage, and shielding on the installations to evaluate radiation exposure limits to professionals and public, in order to accomplish acceptable levels. For this purpose, the novel PTW NOMEX® SL Survey Detector based on semiconductor technology is designed in combination with the NOMEX® Dosemeter for air-kerma, exposure and ambient- equivalent-dose H*(10) measurements within the diagnostic energy range (33 keV to 1.33 MeV). The response to scattered radiation for different nominal voltages was evaluated on two X-ray devices placing the detector at one meter from the beam. At medical tube, measurements were compared to 1800 cm3 ionization chamber (Radcal Inc.10X5-1800), yielding a mean percentage difference 3.4%, and 4.8% maximum deviation. Measurements at Small Animal Radiation Research Platform (SARRP) were compared to a 350 cm3 ionization chamber (Fluke-Biomedical 451B) achieve 2.9% mean percentage difference with 3.9% maximum deviation. The dose linearity was evaluated through variations on the mAs at fixed tube voltage, on the medical tube the mean deviation compared to the ionization chamber was 2.5% (linear regression coefficient, R2 = 0.999). On the SARRP, the mean deviation was 0.4% (R2=1). The PTW NOMEX® SL Survey Detector response to extended energy ranges was evaluated at radiotherapy installations by measuring the leakage through the primary barrier for different nominal energies as well to variations to dose rate. The response to inverse square distance in front a Cs-137 source was evaluated, as well. Thus, the novel PTW NOMEX® SL Survey Detector provides a solution for radiation protection measurement on X-ray facilities and its measurement results allow further characterization in extended applications.

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MONTE CARLO SIMULATION OF THE ACCURACY OF HD TOMOTHERAPY

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Radiation Oncology – Treatment Delivery

In recent years, the use of helical TomoTherapy equipment has increased worldwide, so that to ensure the quality of the beam, the corresponding dosimetric tasks must be performed. Currently there are protocols to carry out this work. However, due to the large differences in equipment and radiotherapy facilities, it is necessary to conduct studies in a particular way. Monte Carlo calculations allow performing dosimetric tasks indirectly, which can be compared with measurements obtained with other techniques or estimating the dose at points where there is no access. In this paper we present the calculations of radiation transport and dosimetry in 6 MV Accuracy HD TomoTherapy equipment using the code MCNP5. To model the accelerator, we useda1.5 mm thick conical tungsten target, and we included primary collimators and jaws. As a source term, an electron beam of 6 MeV of energy was modeled on the tungsten target. The collimators were modeled to produce an irradiation area of 5x40 cm2 in the isocenter, located 85 cm from the target. The X-ray spectrum at the isocenter, the dose-to-depth percentage (PDD) and the profile curves for the maximum dose depth (d = 1.5 cm within the spectrum) were estimated in a 50x30x50 cm3 water phantom. The estimated values are comparable with the experimental data obtained with an ionization chamber A1SL of the TomoTherapy equipment installed in the State Center of Cancerology of Durango, Mexico.
Keywords: Monte Carlo Simulation, Accuracy HD TomoTherapy, PDD, Profile Curves, X-ray spectrum

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EVALUATION OF OPTIMIZED DYNAMIC CONFORMAL ARC FOR DYNAMIC TARGETS

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Radiation Oncology –Treatment Planning

In our institution, it is common perform the Optimized Dynamic Conformal Arc (DCAopt) technique for lung SBRT, which it is the regular forward DCA technique tuned with bit of modulation. A systematic comparison was performed among DCAopt, VMAT and VMAT with Monitor Units optimized (VMATMU). A retrospective study over 31 patients was done and it was accessed the Conformity Index (CI), Dose Gradient (DG), organ at risk (OAR) sparing and MUs used. A GTV of 2 cm diameter was irradiated in a dynamic thorax phantom using these three techniques in amplitudes of 1 and 2 cm, dictated by a sinusoidal wave of 4 seconds of period, and the dose distribution degradation was evaluated by EBT3 film dosimetry. There were significant differences ($p < 0.05$) in favor of VMAT plans in terms of CI, DG and OAR's sparing (i.e., V20 Gy in lungs), when compared to DCAopt and VMATMU, as follows in terms of 95% of confidence interval, respectively: CI = [(-0.011, - 0.026);(-0.015, -0.027)], DG = [(-0.88, -1.71);(-1.06, -1.79)] Gy and V20 Gy = [(-0.26,-0.06);(-0.22,-0.07)] %. However, it has consumed too much MU. In the opposite, DCAopt and VMATMU were proved that perhaps they assumed equivalent statistically significant results in dose conformity, gradient and OAR's sparing, VMATMU was better than DCAopt for delivering plans with a smaller MU's. The dose degradation was evident for all techniques (i.e. blurring and interplay effect) but less for VMATMU. For this technique, as well as the others, the interplay effect produced higher dose than the predicted and it occurred inside the ITV, which is good once it is guaranteed the safety margins and the properly IGRT protocol. In conclusion, if the total number of MU is a point of concern, one must be use VMATMU technique. If not, VMAT is the appropriate choice.

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HDR - BRACHYTHERAPY IN THE SKIN TREATMENT USING CUSTOMIZED SURFACE APPLICATORS MADE BY 3D PRINTING

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Radiation Oncology – Brachytherapy

Introduction: In the last few years, the High Dose Rate Brachytherapy (HDR-BT) has been gained interesting for its good results in the management of cancer with skin involvement. The objective of this study is to report the manufacturing process of a customized surface applicator using a 3D printer and its use in the treatment of a Fungoid Mycosis.
Methods and Materials: Has been created a custom mold of the patient head surface's and catheters have been placed into it, permitting a uniform distribution over all the treatment zone because the right positioning of the sources. The final surface applicator is composed by 4 pieces printed in a 3D printer and filled by 20% of PLA.
When it has been verified that all the pieces are correctly joined and placed on the patient, a new TC of simulation is done, and the dosimetry is ran. All the material printed and the set up used were previously approved for the clinical use.
Results: It was prescribed a total dose of 12 Gy in 6 fractions. The sessions were executed without incidents in a total time of 25 minutes each one and finally the patient didn't have any complications and evolved with a good clinical response of this treatment.
Conclusions: We demonstrated the feasibility of making HDR-BT on tumors that compromise the skin, using custom surface applicators made by 3D printers. So, this modality could be used in the future for many pathologies and body locations safely.

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DOSE EVALUATION ABSORBED IN ADJACENT ORGANS FOR LUNG CANCER TREATMENT IN RADIOTHERAPY

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Radiation Oncology – Dosimetry

Introduction: Radiation therapy acts as a form of treatment which has two basic modalities for the treatment of cancer: teletherapy and brachytherapy. In teletherapy is used a linear accelerator with photon energy to make the application and before starting the treatment a planning that makes the acquisition of all anatomical information of the patient is carried out and then the classification of areas of interest in the patient.
Objective: This work has the objective of comparing the dosimetric plan of lung cancer in adjacent organs - in this case the organ of risk to the heart - with dose values calculated in the planning system (TPS) using an anthropomorphic phantom. Materials/Methods: All dosimetry was performed with thermoluminescents dosimeters (Lif: Mg, Ti-TLD-100). Were selected 33 TLDs that underwent a calibration process with the following steps: thermal treatment, followed by irradiation and reading. In the heat treatment a furnace manufactured by Grion Industrial Furnaces was used. The dosimeters were irradiated using a Varian model 2100 photon energy / 6 MeV linear accelerator and the reading was done with the Thermo-Harshaw model 3500 reader. With the dosimeters already selected, the treatment plan was elaborated in the system using the Varian Eclipse software and then compared with the dosimetry performed with the TLDs allocated to the anthropomorphic phantom, for this same case. A linear accelerator with photon energy / 6 MeV, model 2100 from Varian was used to apply the dose of 200 cGy using the intensity-modulated radiotherapy (IMRT) technique.
Results: The dose verified in the lungs showed that the planning is within the allowed values according to protocols - less than 5% (206 cGy).
Conclusion: No dose was measured in the heart, which allows concluding that there was a good planning of the treatment that spared the heart and adjacent healthy tissues.

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DETERMINISTIC AND STOCHASTIC COMPARTMENT MODELS FOR TOTAL BODY IRRADIATION

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Radiobiology

We have modified the Jones model of radiation-induced myelopoiesis by adding new compartments for the mutated and cancerous cells populations. This carcinogenesis model is mathematical described by five non-linear coupled differential equations. The objective of this research is to develop algorithms and computational codes (deterministic and stochastic) to mimic a clinical radiotherapy procedure TBI (Total Body Irradiation). Our approach is useful to make a comparison among different TBI regimens used worldwide. For a given TBI regimen we can also study the evolution on time of non-aggressive and aggressive cancers. The developed algorithms allow us to quickly update a planned TBI regime after the patient's treatment was interrupted for a length of time (due to a hurricane, earthquake, or blackout). As other application, we show that U.S. and Canadian TBI regimens kill about the same percentage of malignant cells. However, between irradiations the U.S. TBI regimen is less efficient than the Canadian TBI regimen. Finally, the transition rates that mediate movement of cells among all compartments are replaced for random numbers. This stochasticity procedure after 100 runs shows in average a mortality of 83% of the malignant cells, in agreement with the US and Canadian TBI regimens.

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QUALITY MANAGEMENT OF MEDICAL EXPOSURES IN RADIOTHERAPY AT ONCOLOGY HOSPITAL "CONRADO BENITEZ"

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Radiation Oncology – Quality Assurance

Radiotherapy is a method of treating malignant lesions in which mainly ionizing radiation is used. The International Atomic Energy Agency (IAEA) has issued several documents which focus on Quality Management Systems (QMS) for radiotherapy and clearly define the importance of these for the needs of patients, the institution and in the context from the country. The objective of this work is to design a quality management system, according to the standards adopted by Cuba ISO 9001: 2015, ISO 13485: 2018, in the radiotherapy unit at the Oncology Hospital "Conrado Benitez" in Santiago de Cuba. We made a broad review of the Cuban regulations, which establishes the requirements to establish a QMS, as well as the regulations issued by the National Center for Nuclear Safety (CNSN) and the Territorial Delegations of CITMA, designated in the different territories of the country to fulfill the functions of regulation and control of the safely use of nuclear energy. As a result, we complemented the quality assurance program that will guarantee not only the efficacy of the antitumor treatment, but also the adequate radiological protection of patients, workers and the public. The managers were provided with a tool that will allow it to manage with a process-based approach, guaranteeing radiological safety, to increase excellence in the radiotherapy service.

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A CRITICAL REVIEW OF TRANSLATIONAL PROCESSES IN PRE-CLINICAL RADIOTHERAPY ASSOCIATED WITH THE LIMITATIONS IN THE DOSIMETRY OF BIOLOGICAL CONFORMATIONAL IRRADIATORS

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Radiobiology

Translation of results of pre-clinical radiotherapy research to clinical trials represents an optimization of the resources destined to fight cancer. The development of the most modern micro-irradiators systems, with x-ray photon beams of medium energy (225 kVp) and small fields, has allowed a considerable approximation between the current techniques of radiotherapy and radiobiological research. While in clinical radiotherapy it is recommended that differences between prescribed and absorbed dose to the target should vary maximum 5%, in pre-clinical radiotherapy these deviations can reach very different values, as reported by many authors. In this work through a literature review, were analyzed the differences between the planned and the delivery dose in researches involving micro-irradiator systems. This information was correlated with the impact on the applicability of the results within the concepts of clinical radiotherapy. We present the evolution of dosimetric proposals for these modern micro-irradiators systems, mainly for the Small animal radiation research platform SARRP. The proposals for reference and relative dosimetry for small fields, close to 5mm, are nowadays insufficient for this energy range and are mainly based in a radiochromic film dosimeter. This work aims to highlight the main challenges in the small photon field dosimetry for kV energies and the need for new dosimetric proposals with the same metrological rigor as in the clinical radiotherapy. As a conclusion we suggest the integration of dosimetric methods, considering the uncertainties in the use of different detectors according to the field size, the energy response and response in the medium, as well as the evaluation of the dose distributions based on the gamma index criterion. This would allow an integrated assessment of new dosimetric proposals for commissioning and validation of small animal irradiator systems.

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COMMISSIONING FOUR 50–100 kV "SENSUS SRT-100" X-RAY UNITS FOR SKIN CANCER TREATMENT

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Radiation Oncology – Dosimetry

Surface therapy systems are an alternative or complement to the surgical variant for many patients with basal and squamous cell carcinoma that cannot be treated by surgery. This type of treatment offers excellent cosmetic results and is considerably less invasive than conventional surgical methods. Four treatment units manufactured by Sensus Healthcare (Boca Raton, FL) were studied. All of the same model, SRT-100, with nominal energies of x-rays of 50, 70 and 100 kV. the AAPM Task Group 61 protocol was used for beam dosimetry. The dose to water at the surface of a water phantom was obtained based on an in-air measurement using an ion chamber calibrated in air. The results were compared with measurements in PMMA using a chamber calibrated in terms of absorbed dose in water. A Farmer-type chamber and a thin-window parallel plate ion chamber with IBA Dose1, PTW UNIDOS electrometers and soft x-ray slab phantom were used. Data collected during commissioning were: linearity and end effect, stability of the machines, HVL, absolute outputs, dose profile and applicator cone factors. The data measured were compared between them as well as those reported by the vendor. All treatment units showed excellent linearity in the range of 0.1 to 0.8 minutes. The end effect values were less than 0.0001 min. The HVLs showed a variability between 2%. The absolute outputs showed low variability between machines (CV <3%). There was also a coincidence between the calculations from measurements in air and directly in PMMA phantom. Within a 2 cm diameter circle, the dose profile is uniform, however, the dose decreases as distance from center increases. The cross-line profile is more symmetric than the in-line dose profile, This is expected due to the X-ray target heel effect. All units show good stability and are ready for the use in patients.

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BREAST TREATMENTS WITH AXXENT IORT. COMPARISON WITH MAMMOSITE SYSTEM

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Radiation Oncology – Dosimetry

Introduction:
We have treated 400 patients at our center from May 2015 to April 2019 for breast cancer with Axxent (Xoft Inc.) intraoperative radiotherapy (IORT), in this work we compare the doses in the skin, lung and heart of the first 250 patients treated with the 50 kVp source with the doses they would have received using the Mammosite system using an Ir192 source. Methods and Material:
To the 400 patients treated in our center after removing the tumor, the appropriate balloon size is chosen to cover the tumor area with a dose of 20 Gy on the balloon surface.
Results:
The differences in maximum skin dose for both types of treatment are 8.1 ± 1.2 Gy for the case of Mammosite and 5.7 ± 1.5 Gy for patients treated with electronic brachytherapy source. This explains the very few cases of acute dermatitis at 6 months.We also show the mean and maximum doses (expressed as percentage of prescribed dose) for the left lung (Axxent 1% and 20.4% vs Mammosite 3.9% and 29.9%) and heart (Axxent 0.8% and 4.1% vs Mammosite 3.3% and 10.4%) in cases of left breast tumor for the volumes of 30 and 35 cm3, which are the most common in our hospital (70% of cases).
Conclusions:
It is concluded that the IORT treatments performed with the Axxent equipment with electronic source are a good alternative to those performed with Ir192 and our 400 patients treated to date to the good results presented by other centers are joined.In addition to the low skin toxicity, there is no recurrence in patients treated so far, which makes us very optimistic about the results.

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DESIGN OF A DIGITIZER CARD FOR THE PHOTOMULTIPLIER TUBES OF A GAMMA CAMERA

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Nuclear Medicine

The service provided by the GC (Gamma Cameras) in the Nuclear Medicine departments fails because of their breakdown, generally due to the associated electronics and not to the physical detection components. For this reason, it was decided to develop an electronic system that allows the recovery and optimization of disused GC. Previously, it was designed a preamplifier card for the Photomultiplier Tubes (PMT) signals, so, this work is following with the design of the digitizer card for the PMT signals. The circuit was designed and simulated and the list of components necessary for the construction of the digitizer was generated, as well as the printed circuit board was designed for its assembly. The simulation of the digitizer worked in linear mode; this determines that the digital value of the output signal is proportional to the amount of charge delivered by the detector. The digitizer card associated with the preamplifier card allows an automatic adjustment of the signals of the PMT as do the modern GC. We recommend to mount the proposed circuits for the digitizer of 1 PMT, check its operation, and make the necessary adjustments for the subsequent assembly of the 37 and 75 PMTs cards; develop a processing program for these signals to minimize analog and digital processing electronics in the GC; and develop a Multi- Channel Analyzer (MCA) for the record of the amount of pulse converted by the ADC.

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RADIOLOGICAL SURVEILLANCE DURING THE USE OF DIAGNOSTIC X-RAYS

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Radiology – Radiation Protection.

The radiological surveillance of areas and workplaces and the evaluation of results is part of the of the radiological protection program of any entity that performs radiological practices. The objective of this work was to measure and evaluate the environmental equivalent dose rate of X-radiation in the workplaces and public places adjacent to the departments that use diagnostic X-rays in the Provincial Hospital Dr. Gustavo Aldereguía Lima of Cienfuegos and to reach to conclusions that allow to act to conserve the good practices in the work and to optimize the radiological protection. The environmental equivalent dose rate of X-radiation was measured at important points in the departments where diagnostic X-rays are used, with the portable radiometer RADIAGEM 2000, verified by the Secondary Laboratory of Dosimetric Calibration of the Center of Protection and Hygiene of Radiation. The processing of the data was carried out with Microsoft Office Excel 2007. The interpretation and evaluation were carried out according to the Combined Resolution CITMA-MINSAP Basic Norms of Radiological Safety. Anomalous values of the environmental equivalent dose rate of the X-radiation were detected as a consequence of deficiencies in doors, frames, leaded glass location and deviations of the good practices at work, which demonstrated insufficiencies in compliance with the principle of Optimization in Radiological Protection.

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DEVELOPMENT OF A MONTECARLO MODEL FOR A MEDICAL ONCOR LINAC

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Radiation Oncology – Dosimetry

Introduction: Radiation therapy is an established method in cancer treatment. To obtain a more accurate estimation of the dose delivered in the radiotherapy treatment plan a growing use of Monte Carlo methods is envisaged. Because photon beams of equivalent nominal energies can change substantially between different accelerator manufacturers, a model for Siemens ONCOR linear accelerator was developed and tested, to be later used as an aid in radiotherapy treatment plan. Methods and Materials: The machine geometry is accurately reproduced in the Monte Carlo code using measures and accelerator manufacturer's specifications. The capability of the software to reproduce the dose distributions has been verified by comparisons with standard measurements acquired with ionization chambers in a water phantom. The tests were made for photon and electron beams, considering PDD and lateral profiles at several nominal beam energy. Lastly the configuration was used to reproduce the data of standard dosimetries. Results and Conclusions: Experimental and calculated dose values are in good agreement both in PDD and in transverse sections. The proposed model could accurately reproduce the experimental data and could be used as an aid in the clinical practice.

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EVALUATION OF CARDIAC SPECT IMAGES USING TEW METHOD CORRECTION FOR TL-201

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Nuclear Medicine

Thalium-Chloride (Tl) is a myocardial perfusion SPECT agent with excellent biochemical properties commonly used to evaluate tissue viability. However, the images are severely degraded by scattered photons in the thorax. The precise correction of this dispersion is complicated by the non-uniform density and different thorax sizes, the additional attenuation and dispersion caused by the patients' breasts, and the Tl-201 energy spectrum. The aim of this work was to determine the sub- energy windows for the triple energy window (TEW) scatter correction method using Monte Carlo simulation SIMIND code for (Tl-201) imaging.
Methods:
We used the SIMIND Monte Carlo code to simulate General electric gamma camera with low-energy high resolution (LEHR) parallel whole collimators. The detector is characterized by intrinsic spatial resolution of 0.34 cm. Energy window was set for main energy window width 20% and sub energy window width (3 and 6 keV).We simulated a source routine representing a heart consisting of a combination of a half sphere shell and a cylindrical shell - both with the same thickness. The source distribution can be very accurately being matched to the physical cardiac insert manufactured by Data SPECTRUM Inc, filled with Tl-201 (3,7MBq).We used the main-energy window widths 20% centered on 70 keV and sub-energy window widths (3 and 6 keV).We compared the true primary to total ratio with the primary to total ratio estimated using TEW method.
Results:
Sub-energy 6 keV was found to be optimal for implementation of the TEW method in Tl-201. The primary to total photons ratio (P / T) percentage is higher with the correction method than with the standard one. The difference is around to 2% for activities from 3.7 to 200 MBq.

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COMPARISON OF OCCUPATIONAL DOSE PROFILES OF RADIATION WORKERS WITH LIF:Mg,Ti AND LIF:Mg,Cu,P TL CHIPS IN HOSPITALS

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Radiation Protection

In Ministry of Health (MOH), Oman; recently we have established a new Thermo Luminescent (TL) based Personal Monitoring Service with LiF:Mg,Cu,P TLD chips as the monitoring cards by replacing the existing LiF:Mg,Ti TLD cards. In the ensuing process, we compared the dose profiles of radiation workers in MOH hospitals with simultaneous double badging of radiation workers with the above two types of TLD cards.
We have used two Harshaw 6600 Plus TL readers for the measurement. Though we are employing a variety of Harshaw dosimeters such as 8850MCP, DXT-707H MCP, XD-107H MCP and 8806MT; the current study was done only for whole body badges. Of the 160 MOH health establishments of MOH, we have conducted the present study in three hospitals alone. 37 workers were monitored by issuing the above two TL personal dosimeters every month for three months. End of every month, both the TLD's were collected back and processed for Hp(10) and Hp(0.07).
The measured dose results shown that 62% of the LiF:MCP TLD cards recorded occupational doses, though majority of them were near or just above the threshold detection levels of doses, where as 38% cards yielded dose values below the threshold. On the other hand, only 12 % of the LiF:MT cards recorded doses above threshold and 88% cards recorded values below the threshold limit. Doses above 0.5 mSv, both the cards started picking almost identical way. This indicates that LiF:MCP cards have 50% more detection ability over MT.
Hence, it may be concluded that in a radiation department where lower levels of occupational doses are encountered, LiF:MCP chip is the TL material of choice in a TL based PM service. Of course, the cost vs benefit must be kept in mind, before considering the changeover in an establishment with a large number of workers.

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WIDE CONE BEAM COMPUTED TOMOGRAPHY DOSIMETRY

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Diagnostic Radiology –Dosimetry

The International Electrotechnical Commission developed an efficient methodology based on the equipment traditionally available in the health institutions - thus solving the complications observed by the scientific community - which was described and recommended in the IAEA Human Health Report No. 5 of the International Atomic Energy Agency. The present study was developed in a CT scanner equipped with the technology entitled Dynamic Volume Computed Tomography. The Aquilion ONE ViSION Edition launched by Canon Medical Systems in 2012. As the research developed by our research group has been focused on cardiac and cardiovascular angiographic CT exams performed in pediatrics, the study was based on the recommended protocol for these types of examination – 160 mm maximum collimation provided by the CT scanner and 80 kV X-ray tube potential - in publications of the Image Gently organization. The values of normalized CT dose index measured free-in-air for the dosimetry in 3 steps were not feasible because they were associated with uncertainties 6 times higher. Taking into account, then, the dosimetry in 2 steps, the corrected normalized weighted CT dose index values were as follows: 0.064 mGy / mAs, 0.058 mGy / mAs, 0.051 mGy / mAs and 0.023 mGy / mAs, for bowtie filters extra small, small, medium and large, respectively. In conclusion, the study demonstrated the possibility of health institutions that have wide cone beam CT scanners implemented in their radiological routines are able to use the same equipment classically applied in the field of CT dosimetry, if they follow the methodology recommended by the International Agency of Atomic Energy.

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SOCIAL AND SCIENTIFIC IMPACT OF THE UAEM-ININ M.SC. AND D.SC. GRADUATE PROGRAM IN MEDICAL PHYSICS IN MEXICO: 23 YEAR EXPERIENCE

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Education and Professional Issues

Introduction: In Mexico, cancer is the third cause of mortality. In the last decades, the worldwide tendency has been that of prevention and early detection, as well as, accurate and personalised treatment. The role of ionising radiation in both diagnosis and treatment is particularly important. In Mexico, the presence of advanced diagnostic and treartment techniques in hospitals all over the country, has multiplied in the last three decades. For their successful and optimal application, a multidisciplinary team is required, that includes physicians, medical physicists, biomedical engineers, computer specialists, among others. The number of qualified medical physicists is insufficient.
Methods and Materials: In order to address the later, in 1994 the Instituto Nacional de Investigaciones Nucleares (ININ), sponsored by the International Atomic Energy Agency (IAEA), started in Mexico a teaching and training program (Diplomado) in Radiotherapy Medical Physics. Based on this experience, the Universidad Autónoma del Estado de México (UAEM) and the Instituto Nacional de Investigaciones Nucleares (ININ) launched two years later, the first Graduate Program in Science (M.Sc. and D.Sc.), specialised in Medical Physics in Mexico.
Results: Twenty three years after its creation, an analysis of the social and scientific impact of the UAEM-ININ program is presented in this work, based on the achievements attained, regarding the number of graduated Medical Physicists, their geographic and academic origin, their current professional activities and the number of scientific publications produced as a result of their thesis.
Conclusions: The indicators presented in this work will demonstrate that the UAEM-ININ M.Sc. and D.Sc. Medical Physics Graduate Program, has been achieving its goals in forming clinical medical physicists and researchers and it is continuously aiding in the improvement of health care in México, as well as the advancement of science and technology in the medical physics field.

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MAMMOGRAPHY IN BRAZIL: A DISTRIBUTION OF RESOURCES RELATED TO FEMALE POPULATION AND INCIDENCE OF BREAST CANCER

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Diagnostic and Interventional Radiology – General

Introduction:
Mammography is the main path for breast cancer diagnosis and prevention in early stages, a disease that is known for fast and disordered growth rate of breast tissue. The exam, if done in women of age between 40 and 49 years old, can decrease the breast cancer death ratio by a good margin. That reduction is due to cancer controlling programs, specifically in actions of precocious detection and treatment. In Brazil, the National Mammography Quality Program (Programa Nacional de Qualidade em Mamografia-PNQM) was created by Health Ministry (Ministério da Saúde) to ensure mammography exam quality all over the country. This study focuses on evaluating the overall situation of mammography in Brazil, be it related to equipment distribution, female population, and the breast cancer incidence.
Methods and Materials:
Data were overall analyzed from 2002 to 2018. Information about the equipment distribution were gathered through DATASUS, a digital platform that contains all sorts of data regarding from Health Unique System (Sistema único de Saúde- SUS). For female population data, Brazilian Institute of Geography and Statistics (IBGE) was used instead.
Results:
With all those data, we calculated the number relating from mammography equipment number per million women, the number of women per radiology doctor in Brazil, and the amount of breast cancer per population per region.
The mammography accessibility per region is clearly not uniform, being it biased towards South and South-east regions, with a lower amount of equipment for the North and North-eastern part of the country.
Conclusion:
To ensure quality and regularity in performing mammograms throughout the entire territory, it is necessary a bigger amount of equipment and professionals working the area and ensuring that the PNQM program is established in the correct manner.

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EFFECT OF APPLICATOR DIAMETER ON DELIVERED DOSES TO NORMAL TISSUES IN INTRA OPERATIVE RADIOTHERAPY (IORT)

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Radiation Oncology – Dosimetry

Introduction: Intraoperative radiotherapy (IORT) is a treatment method for cancer, involving the direct application of ionizing radiation to surgically opened tumor bed without irradiating surrounding healthy tissues. Using Monte Carlo (MC) simulation, we aimed to evaluate the dose delivered to normal brain tissues beyond the tumor bed. Brain tissues are extremely delicate, hence the need for simulation studies towards effective management of delivered doses.
Methods and Materials: The Zeiss IORT machine (Carl Zeiss, Oberkochen, Germany) was simulated using Geant4 toolkit (version 4-10.p03). We also simulated the diameter of its spherical applicators ranging from 1.5 to 5 cm in 0.5 cm increments. The accuracy of the MC simulation technique was examined by reproducing several different simulated dosimetry parameters of the primary beams with the experimental data. Experimental measurements were carried out using a water phantom as well as a soft X-ray ionization chamber (PTW Freiburg, Germany, type 23342). With a prescribed dose of 10 Gy to 4 mm depth of head water phantom, the dose delivered to normal brain tissue was evaluated according to calculated relative dose obtained from MC simulation for different applicator sizes.
Results: Our results showed that the relative dose delivered to the normal brain tissue increased with applicator size. With a prescribed dose of 10 Gy, the respective doses delivered to normal brain tissue located at depth of 10 mm had an average of 4.77 ± 1.03 Gy. Our simulated results were in good agreement with experimental measurements, with a statistical uncertainty of 1%.
Conclusions: MC simulation results of this study has shown that the delivered dose to normal brain tissues beyond the tumor bed increases with applicator size. Hence, we recommend the use of smaller sized applicators for brain IORT to ensure that the least dose is delivered to the normal brain tissues.

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EVALUATION OF RADIATION DOSE IN CT CARDIAC IMAGING PROCEDURES: INITIAL EXPERIENCE BASED ON CLINICAL INDICATION

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Diagnostic Radiology –Dosimetry

Introduction:
Computed Tomography (CT) is the most important technological development of the 20th century as far as medical technology is concerned. Its technological evolution led to many new clinical applications such as cardiac CT (for evaluation of coronary angiography disease (CAD), stent placement evaluation, pre Transcatheter aortic valve implantation (TAVI) evaluation, etc.). CT provides excellent quality images at the expense of high radiation exposure. Typical CT effective doses (E) range between 1-10 mSv, easily increased due to protocol used to answer the clinical problem. Literature on complex cardiac CT is limited compared to conventional CT regarding radiation dose. The aim of study was to evaluate radiation dose in CT based on clinical indication.
Methods and Materials:
The study was performed in Heart Hospital in Qatar. The CT scanner Model Somatom Definition Flash Dual-source was used to perform this study. The hospital has a dose management software (Radiation Dose Monitor Software, PACS Health, LLC) facilitating data collection. Apart from clinical data (patient weight, height, etc.) and technical data (kV, CTDI, DLP, etc), the software calculates also E.
Results:
Data from 431 patients with various cardiac clinical indications are presented. Clinical indications were: suspected CAD (93.3%), stent evaluation (2.8%), pre-TAVI evaluation (2.3%) and coronary anomaly (1.6%). Large radiation dose values were observed exhibiting non normal distribution and thus median dosimetric values are presented. Median values of CTDI, DLP and E were 24.5 mGy, 377 Gycm, 5.3 mSv, 22.5 mGy, 343 Gycm, 4.8 mSv, 6.7 mGy, 640 Gycm, 9.0 mSv and 23.7 mGy, 566 Gycm, 7.9 mSv, respectively. Large variations (max/min) were observed for all dose quantities. For E specifically these were 14.2, 5.9, 4 and 11.8 respectively.
Conclusions:
This is the first study on cardiac CT based on clinical indication. The study is continued to establish clinical DRL in cardiac CT.

P-194

MONITORING OF PERSONAL DOSE ON TWO FACILITIES OF NUCLEAR MEDICINE. A RETROSPECTIVE STUDY

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Nuclear Medicine

Nuclear medicine has been developed around last years in Peru, the staff: physicians, technologist, medical physicist have been increased. Actually, there are around 16 facilities on nuclear medicine in Lima. In order to new requirements, dose monitoring of technologist is required by regulatory. The effective dose Hp (10); lens dose and skin dose Hp(0,7) respectively have been parameters to monitoring of personal.
First, the technologist risks on nuclear medicine were estimated accord the system of evaluation of risk on radiotherapy (SEVRRA), then the personal dose was registered using dosimetry reports on two facilities. The Hp (10), lens dose and Hp (0,7) were registered on ORIGIN SRO v8.0724. The effective dose was estimated using a simplified calculation accord the risk evaluation; finally, the results were compared within two facilities. 4 technologists were monitoring around 6 years. The risk evaluation to technologist was high risk to administration and preparation of radioactive source and medium risk to reception of radioactive sources. Accord the personal dose it was verified that at 2010-2016 the effective dose was 2,2 mSv/year – 9,9 mSv/year, lens dose was 2,0 mSv/year -10,5 mSv/year and skin dose was 2,0 mSv/year-10,8 mSv/year respectively. Finally, the dose effective estimated by calculations was 2,43 mSv/year. Accord the results lens dose is less that limit to regulatory Peruvians. The risks evaluation was realized in two facilities on nuclear medicine. The high risk was to administration a preparation of radioactive source and medium risks was the reception of radioactive source. Accord to monitoring results, lens dose limit was not exceeded around 2010-2016 periods. However, in order to the high values to lens doses were necessary investigations. the dose effective estimated by calculations was around 2,43 mSv/year underestimated the dose monitored. Posterior calculations with Montecarlo method can be corrected these results.

P-195

IRRADIATION OF THE CRANIOSPINAL WITH HIPPOCAMPUS SPARING WITH VMAT TECHNIQUE

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Radiation Oncology –Treatment Planning

Introduction:
Historically, craniospinal irradiation represents a challenge when planning conventional treatment with 3D technique since it is necessary to take into account, generally, large field sizes, turn of table and gantry, as well as the position and size of the patient. but currently the VMAT technique offers us other possibilities to face this type of treatment, optimizing the resources when planning and applying the treatment.
Method and materials:
The Monaco TPS was used, with the Infinity Linac, with Agility from Elekta. For the specific patient QA, Octavius 4D and Mephisto mc 2 software from PTW were used. It was prescribed to the PTV 30Gy in 10 fractions. Three isocenters were generated along the patient with two field junctions. In these unions, gradient rings were created with a prescription of 25Gy, 20Gy, 15Gy, 10Gy, 5Gy achieving a total of 5 rings of 1 cm each. In turn, the PTV that includes the whole brain was cut 5mm from the hippocampus for further optimization.
Results:
A treatment plan was obtained with homogeneous doses, with a coverage greater than 95% in all the PTV, complying with the objectives of the RTOG 0933 for the protection of the hippocampus, in addition to the restrictions in all the OARs. The specific patient QA, with a criterion of 3mm 3%, gave a result greater than 95% The application of the treatment in the room was optimized, only having a displacement in the longitudinal direction of the stretcher
Conclusions:
Regarding the 3D technique, this work shows a high practicality in the planning with VMAT for this type of treatment, ensuring homogeneity in the PTV, and low doses in the OAR, including hippocampus, in addition to the simplicity in the daily application.

P-198

BACKSCATTER CORRECTION FACTOR FOR A PERSONAL DOSIMETER WORN OVER LEAD APRONS IN FLUOROSCOPY SCATTERED FIELDS

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Radiation Protection

Introduction:
Medical staff working near the scattered radiation field in fluoroscopy guided interventional procedures may be exposed to high cumulative equivalent doses, thus requiring shielding devices such as lead aprons and thyroid collars. It remains an acceptable practice to derive the equivalent dose to unprotected soft tissues such as the eye lenses with a thermoluminescent dosimeter (TLD) placed above the leaded elements. Nevertheless, it is not being considered that the backscattered radiation for a dosimeter worn above a lead shield differs from that generated during dosimeter calibration. The aim of this research was to study the effect of backscattered radiation in the response of a TLD when is worn over a lead shield and derive a correction factor to be applied to the personal equivalent dose Hp(0.07) calculation algorithm.
Methods and Materials:
A on a card with four LiF:Mg,Ti chips sandwiched in between different filter plates was model led by means of the Monte Carlo (MC) code Penelope. The results obtained were validated against measurements performed in reference conditions in a secondary standard calibration laboratory. Next, the MC model was used to evaluate the backscatter correction factor needed to estimate Hp(0.07) to unprotected soft tissues. For this purpose, the TLD was irradiated over a water slab phantom with a photon beam representative of a fluoroscopy beam scattered by a patient. Several setups were evaluated that consider different incident beam angles and lead thicknesses between the TLD and phantom.
Results and Conclusions:
The TLD readings should be corrected by a backscatter correction factor equal to 1.23 when worn over lead shielding. For leaded shield thicknesses greater than 0.25 mm the response is independent of this thickness. The inclusion of the backscatter correction factor in the calculation algorithm improves the dose estimation to unprotected soft tissues such as the eye lenses.

P-202

RADIATION PROTECTION IN PEDIATRIC COMPUTED TOMOGRAPHY (CT): ASSESSMENT OF COMPLIANCE LEVEL

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Radiology – Radiation Protection.

Introduction:
Despite the benefits of computed tomography (CT) imaging in medicine, there is a need to ensure that possible side effects to patients are minimized, especially in pediatrics, who are more radiosensitive. Hence, adherence to radiation safety standards is important. We aimed to assess the level of compliance to international dose reference levels (DRLs) in terms of effective doses in pediatric CT scans conducted in three Iraqi hospitals.
Methods and Materials:
CT brain and abdomen/pelvis examinations were conducted for pediatric patients (<15 years) in Wasiti, Neuroscience and Omara hospitals using a Somatom Sensation CT scanner. Volumetric CT dose index (CTDIvol) and dose length product (DLP) were collected for 180 patients (60 in each hospital). Afterwards, their effective doses were estimated from DLP values and compared with international DRLs.
Results:
Brain CT: DLP values obtained for Wasiti, Neuroscience and Omara hospitals were in the range; 789-918.8, 833-874.6 and 627.6-810 mGy.cm, respectively, while their corresponding effective doses were; 1.8-2.09, 1.9-2.06 and 1.43-1.83 mSv. Abdomen/Pelvis: DLP values obtained for Wasiti, Neuroscience and Omara hospitals were; 392.9-425.8, 355-395 and 314.8- 383.6 mGy.cm, respectively, while their corresponding effective doses were; 6.65-7.22, 6-6.7 and 5.34-6.51 mSv.
Using the International Commission on Radiological Protection (ICRP) publication 103 as basis for assessing compliance level, for brain CT we observed slightly higher values in Wasiti and Neuroscience hospitals while Omara was similar to the international DRLs. However, for abdomen/pelvis CT examinations, the effective doses in all three hospitals were within the acceptable limits of international DRLs.
Conclusion:
We observed encouraging levels of compliance towards adequate radiation protection management in pediatric CT examinations among the three hospitals. Although, the best compliance level was observed in Omara hospital. Regular monitoring should be enforced to ensure that CT doses delivered to pediatric patients are as low as reasonably achievable without compromising diagnostic quality.

P-204

3D SIMULATION OF OXYGEN AND HYPOXIA-TRACER DISTRIBUTIONS IN TUMOURS: A PARAMETRIC SENSITIVITY STUDY

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Radiobiology

Introduction: Hypoxic tumour cells are known to be more resistant to ionizing radiation. Treatment outcome improvements may be achieved by irradiating hypoxic regions with higher doses. 18F-fluoromisonidazole positron emission tomography (FMISO-PET) can be used to identify hypoxic regions. However, the interpretation of hypoxia-PET images still remains challenging since radiotracer binding and oxygen distribution are not uniquely related. Mathematical modelling is a useful tool to increase the understanding on this topic. The purpose of this study was to implement a model for simulating oxygen and radiotracer distributions in tumours, and to analyse the impact of the different input parameters of the model on the resulting distributions.
Materials and Methods: Spatiotemporal distributions of oxygen and FMISO were described by partial differential equations (PDEs). The simulation domain consisted of a cubic tumour volume with vascular architectures. Vascular fractions (VFs) of 1% and 3% were studied. FMISO binding model parameters were varied within published value intervals. IFs were taken from previous experimental studies.
Results: Similar oxygen distributions were obtained for architectures with parallel and perpendicular vessels. This was reflected in time-activity-curves TACs and tissue-to-blood ratios (TBRs). For most FMISO binding model parameters variations were observed in bound-concentration Cb as a function of pO2 and TACs. TBR varied 9% and 3% for VF 1% and 3% respectively. IF had the most impact on TACs, with TBR variations of up to 21.3% for VF 1%.
Conclusion: Simulations performed in this study showed how FMISO binding is not uniquely related to pO2 and how this relationship is sensitive to the input parameters of the model. TBR as a measurement of hypoxia might not account for TAC variations due to biological or interpatient uncertainties. Sensitivity to the IF arises the question if this function truly represents the arrival of the radiotracer to the tumour.

P-205

THE USE OF A MULTILAYER PERCEPTRON IN IOL CALCULATION

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Biomedical Engineering

Introduction: Determining the power of IOL to be implanted is a key issue in cataract surgery. Though many formulae have been developed, only 80% of cases reach emetropia, there are still a 20% of possible improvement. We aim to determine the capabilities of a machine learning algorithm (Multilayer Perceptron MLP) for calculating the power of an IOL to be implanted, achieving a given postoperative refraction. The research is a collaboration between the Cuban Institute of Ophthalmology and the InSTEC, University of Havana.
Methods and Material: A retrospective review of patients (15728 eyes) who had uneventful phacoemulsification cataract surgery for six years was used as a train data base. Exclusion criteria: previous intraocular or refractive corneal surgery, any corneal disease, pathological or complicated cataracts, intraoperative complications, preoperative astigmatism beyond 3 diopters, postoperative CDVA worse than 20/40, missing postoperative refractive information, eyes with axial length AL<19.36 mm, AL>27 mm, corneal average power K <3 6 D or K>50.9 D, and refractive surprises larger than ± 3 D. Data was used to train a MLP in order to predict the value of the IOL power needed for a given postoperative refraction. Using AL, K, predicted and real postoperative refraction, the MLP predicts lens power. Models were trained using the library of Python Keras with Tensorflow backend in a PC with an Intel core i5 – 4460@3.2 GHz with 4 Gb DDR3 RAM.
Results: MLP predicted the value of the implanted IOL with an error smaller than 0.5 D in more than 95 % of patients, even for a surgeon not included in the training process.
Conclusions: The accuracy attained by the trained MLP is high, indicating the feasibility of a prospective study leading to a new method of predicting the IOL power in refractive surgery with an error smaller than current prediction methods.

P-206

ASPECTS OF PET TECHNOLOGY IN BRAZIL

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Nuclear Medicine

Positron Emission Tomography (PET) scan is a highly sensitive imaging technique used in oncology, cardiology, neurology and in infectious and inflammatory diseases. Due to its applications in different areas it is possible to observe the expansion of this image technique around the world. Objective of this work is to evaluate the PET technology scenario in Brazil. The number of PET equipment's, analysis of density of equipment per capita according to international recommendations, number of 18F-FDG producer's centers and cost of the procedure was analyzed. The data were acquired from government's official sites DATASUS and CNEN. Results showed that there was a significant evolution of the number of PET equipment's in Brazil. However, the number of PET equipment's per capita 67/3.1 million still is below when compared of the international recommendations. Currently, Brazil has 13 18F-FDG producers' centers. This grown of 18F-FDG producers is due the end of monopoly by the government allowing private companies enter on the segment. PET scan it is considered a procedure of high complexity, having high cost per examination. It was observed a high variation in costs, from US$ 726.67 to US$ 1598.12. Even with the evolution of the number of PET equipment installed in Brazil, some regions of the country still lack equipment installed. In addition, the cost of the exam and access to the exams through public funding is still an obstacle to further expansion of the PET exams.

P-207

MODELING A PTW SEMICONDUCTOR PROBE USED FOR PERIPHERAL DOSES DETERMINATION, WITH THE MONTE CARLO CODE GATE

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Radiation Oncology – Dosimetry

The Monte Carlo method has been widely used in medical applications for many years. In Cuba, the introduction of advanced technologies in radiotherapy has greatly improved our ability to administer the desired dose to the tumor site with a high level of complexity, while minimizing doses to organs at risks. There is still a great concern about this unwanted dose in healthy tissues being detrimental to the therapeutic benefits, especially in children, who have high expectations of survival. In this work, a model of a silicon semiconductor probe commonly used for in vivo verification in IMRT treatments at the National Institute of Oncology and Radiobiology (INOR) was developed using the Monte Carlo code GATE. Several calibration tests were carried out in order to obtain the optimal parameters of the simulation and the Venseelar criterion was used as the criterion of acceptability. The 6 MV photon beam energy of the linear accelerator was set up, the best energy / FWHM combination obtained was 5.8 MV / 3 mm for which the percentage point-to-point differences between simulated and experimental values were always below 2%. The diode model was validated for in-field calculations, obtaining a 2.4% as maximum deviation during the comparisons made. Dose profiles outside the treatment field were determined for a field size 10x10 cm2, on the surface of water and at the depth of the maximum, being able to confirm that the peripheral doses decrease as we move away from the central axis. The percentage point-to-point differences between the simulated values and the experimental values were always below 6%, and because we do not find in the bibliography an acceptability criterion for measurements outside the treatment field, based on the comparison with similar works concluded that the results obtained were satisfactory.

P-208

VALIDATION OF A HEAD & TORSO CIRS PHANTOM FOR QUALITY CONTROL IN RADIATION THERAPY TREATMENTS

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Radiation Oncology – Quality Assurance

Introduction:
The growth of radiation therapy in Chile has made it necessary to implement quality assurance protocols for the medical equipment involved. The tendency is to perform an end-to-end quality control process, based on procedures and instruments that allow measuring the administered dose.
Methods and Materials:
A 6MV beam of a linear accelerator (Oncor, Siemens) was used to irradiate created plans in the treatment planning system (TPS) (Eclipse, Varian) on a phantom (Head & Torso, CIRS) with bone, air and ionization chamber (IC) inserts, scanned in a CT (Definition AS, Siemens). The irradiated plans were 10x10, BOX and IMRT. The absorbed dose for each plan was measured using an IC (Farmer, PTW) and compared with the calculated dose by the TPS. A phantom of the same dimensions and Hounsfield Units as the used CIRS phantom was created in Eclipse and another TPS (Prowess), and the measured and calculated doses by both TPS were compared. Two configurations were used for the inserts: air-up/bone-down (AU/BD) and bone-up/air-down (BU/AD).
Results and Conclusions:
The measured dose presented greater difference (±4%) in the plans with IC insert in both configurations and below 2% without IC insert, and less than 1% in plans on the phantom created in Eclipse. When comparing the UM between the 10x10 and BOX calculated plans using the CT images without and with insert for IC a maximum difference of 2% was obtained. The difference when comparing the two TPS is within 2% for AU/BD and 1% for BU/AD. Using the phantom created for IMRT control quality, a difference of 1% was obtained between the measured and calculated doses for both configurations. As the differences of the tests performed are less than 2%, it is possible to use the CIRS phantom for quality control of 3D and IMRT treatments.

P-210

IROC MD ANDERSON POSTAL AUDIT PROGRAM EXPERIENCE AND RESULTS CLINICA ALEMANA RADIOTHERAPY DEPARTMENT SANTIAGO CHILE

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Radiation Oncology – Quality Assurance

Introduction: Reports from various institutions dealing with quality assurance in radiotherapy equipment have established good practice, performing periodic external auditing procedures using dosimetry systems based on radiation detector crystals. The oldest is the one administered by the International Atomic Energy Agency (IAEA) using thermolumiscent dosimetry (TLD) based on lithium fluoride crystals (Lif:Mg). Since the 1980s, the Centre for Radiation Imaging and Oncology, Houston Quality Assurance Center (IROC) has been conducting these types of audits as part of its services.
Method and Materials: Since 2017 the Clinica Alemana Radiotherapy Department is attached to annual audits offered by the IROC (Imaging and Radiation Oncology Core) MD Anderson Houston Texas USA, to check the absolute dose for electrons and photons beams. This center uses as detector element Al2O3:C crystals using optically stimulated luminescence (OSLD). Together with these crystals, Phantoms designed for photons and electrons are attached and irradiated at predetermined points with a required dose, usually 100 cGy. Results: The results obtained for Linac Synergy were: 6MV 1.02±0.02, 15MV 1.02±0.01 respectively and for the 5 electron energies (6, 9, 12, 15, and 18 MeV), was 0.9±8 0.02. In this sense, for Linac Platform the results were: 6MV 1.01±0.02, 15MV 1.00±0.02 respectively and for the 5 electron energies (6, 9, 12, 15 y 18 MeV), was 0.99±0.02.
Conclusions: This program demonstrates, in the period studied, the dosimetric stability of both accelerators and the similarity of one accelerator with the other and Clinica Alemana is within established international standards and tolerances.

P-212

DETERMINATION OF THE EFFECTIVE DOSE IN A RADIATION THERAPY BUNKER USING BeOSL DOSIMETRY

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Radiation Protection

Introduction:
The main uses of effective dose are the prospective dose assessment for the optimization of radiological protection and the demonstration of compliance with dose limits for regulatory purposes. To know the value of effective dose within a radiotherapy bunker can be important in the event of an accidental situation.
Methods and Results:
This study measure effective dose in a radiotherapy bunker using a 6MV photon beam of a linear accelerator (Oncor, Siemens). Different groups of BeOSL dosimeters (OSL Control Chile) were irradiated. These were positioned on the treatment table at different distances from the isocenter (50, 100 and 150cm). A solid phantom centered on the beam axis was used as scatter material. The following dependencies were evaluated gantry and couch angulation, beam energy, monitor units, dosimeters orientation (front-back and front-side), and attenuation effect by interposition between dosimeters. The measurements were repeated using Farmer ionization chamber (IC) located at the same distances from the isocenter, and using buildup cap. Results and Conclusions:
For MU dependence, the average deviation between the measurements obtained with the dosimeters and with the IC was below 1%. For energy dependence, the difference between the average values measured with dosimeters and with IC for both energies at the distances used was below 3%. The maximum differences obtained when comparing the frontal vs. lateral and frontal vs. posterior position were 5% and 2% respectively, for all distances. Likewise, attenuation effect by interposition between dosimeters presents differences less than 5%, being greater for the largest distance. In the case of the gantry angulation dependence, the dosimeters show a deviation below 5% for 0° and 90° angles. This study establishes the parameters to be taken into account in order to use the BeOSL dosimeters in the determination of effective dose in a radiotherapy bunker and its comparison with IC.

P-214

EFFECT OF JAWS COLLIMATOR POSITION ON THE PENUMBRA OF RADIATION FIELD SHAPED BY VARIAN 80-LEAF MILLENNIUM MULTILEAF COLLIMATOR SYSTEM

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Radiation Oncology – Dosimetry

Introduction: Radiation field penumbra has an impact on the sparing of healthy tissue and on field junction. The purpose of this study was to evaluate the influence of jaws position on the field penumbra shaped by Varian 80-leaf Millennium MLC system. Method and materials: We measured MLC-shaped field profiles in the in-plane and cross-plane direction for 6 MV and 10 MV photon energy using Radiochromic EBT3 films. The films were irradiated at 5 cm depth in a water-equivalent phantom with SAD setup and 10x10 cm2 field size. We measured the 80% to 20% penumbra width varying the jaws collimator position. The jaws were placed: (1) with no gap between jaws and MLC; (2) 5 mm distant from MLC in the cross-plane and in-plane direction; (3) in the recommended positions by the software Eclipse version 13.6 (8 mm in the cross-plane and 2 mm in the in- plane direction); (4) at 10 and 15 mm distant from MLC in the in-plane and cross-plane direction, respectively.

Results and Conclusions: The penumbra widths were, in the cross-plane direction, for 6 MV: 3.3, 3.5, 3.8, 4.2 ± 0.3 mm and for 10 MV: 3.9, 4.7, 5.2, 5.9 ± 0.3 mm with the jaws at: zero, 5, 8 and 15 mm distant from the MLC position, respectively. In the in- plane direction, the penumbra widths were: for 6 MV: 3.1, 3.2, 3.2, 3.6 ± 0.3 mm and for 10 MV: 4.1, 4.2, 4.5, 4.8 ± 0.3 mm with the jaws positioned at zero, 2, 5 and 10 mm distant from MLC position, respectively. For healthy tissue sparing, the fields shaped with no gap between jaws and MLC provided the narrowest penumbras. For field junction, the most distant jaws collimator positions from MLC provided the largest penumbras.

P-216

CONTRIBUTION OF HIGH ENERGY ELECTRONS OUTSIDE OF THE FIELD EDGE DUE TO THE LEAK FROM A LINEAR ACCELERATOR HEAD USED IN THE CLINIC

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Radiation Protection

Introduction:
Different research groups have performed Monte Carlo simulation of electron spectra outside of the radiation field edge generated by linear accelerators (linac) used in the clinic. They commonly reported average energies of electrons greater than those for photons, suggesting a contribution of high energy electrons which are not due to the photon interaction. This work investigated the origin of these high energy electrons.
Methods and Materials:
A Varian iX linac has been designed using the Monte Carlo BEAMnrc code to generate the phase space of a 6 MV x-ray beam. The FLURZnrc module of the EGSnrc code was used to calculate the electron spectra produced by the phase space, a 6 MV x- ray point source (without the head of the linac) and a 60Co gamma beam for several field sizes and depths in liquid water. The calculation was made at 10 mm and 20 mm from the edge of each field.
Results and Conclusions:
We observed that for the phase space of the 6 MV x-ray beam, the average energies of the electron spectra outside of the fields can be up to 3 times the photon energy, depending on the distance from the field edge, which decrease with increasing water depth. However, for the 6 MV x-ray point source and the 60Co gamma beam, the average energies of the electron spectra outside of the fields are always smaller than those of the photons, independent of the field size, as expected considering the energy conservation. These results suggest that the high energy electrons are generated from head of the linac and did not contribute to the x-ray production.
This work was partially supported by PAPIIT-UNAM grant IN115117 and Royal Society-Newton Advance Fellowship grant NA150212.

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PRELIMINARY CONCEPTUAL DESIGN OF A NEUTRON MODERATOR USED IN NEUTRON CAPTURE THERAPY

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Radiation Oncology – Treatment Delivery

Introduction:
Since 2015, the research group Biophysics & Structural Biochemistry at the Pontificia Universidad Javeriana (PUJ), in cooperation with the International Atomic Energy Agency (IAEA), has been working on Neutron Capture Therapy (NCT), together with graduate students of the Master Program in Medical Physics at PUJ. Within our research program, one of the goals is to study how neutrons coming from a D-D reaction can be moderated in order to be used in NCT.
Methods and Materials:
In order to establish the most common materials and geometries for a beam shaping assembly (BSA) used in NTC, a review of the specialized literature has been carried out. The selected material for the moderator was FLUENTALTM and the selected geometry was a semi-infinite plane. The neutron flux, for the fast and epithermal neutrons as a function of the FLUENTALTM thickness, has been calculated using the removal-diffusion theory. While the neutron flux spectrum equation for epithermal neutrons has been evaluated with the Placzek's solution of the transport Boltzmann and for the thermal neutrons with the inverse energy law. For all calculations the elastic and inelastic macroscopic cross sections for FLUENTALTM has been considered.
Results:
The maximum flux of epithermal neutrons with energies between 0.5 eV to 10 keV has been obtained for a deepness of 38 cm in FLUENTALTM. For the evaluation of the epithermal neutron spectrum, the cross sections were taken from the Evaluated Nuclear Data File ENDF, with a FLUENTALTM composition of (40% Al60% AlF3). The maximum energy of the epithermal neutron was 25 keV.
Conclusions:
This work has shown that using FLUENTALTM as moderator, the neutron flux is constant, the fast neutrons are effectively moderated. The obtained values for the normalized neutron flux and spectrum agree with the recommended values by the IAEA.

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END-TO-END DOSIMETRY AUDIT USING ANTHROPOMORPHIC HEAD AND NECK PHANTOM TOWARDS CREDENTIALING FOR CLINICAL TRIALS: A SINGLE INSTITUTION STUDY

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Radiation Oncology – Dosimetry

Introduction:
The purpose of this study was to report our institution' result of end-to-end dosimetry audit using anthropomorphic head and neck phantom towards credentialing for clinical trials of intensity modulated radiation therapy.
Materials and Methods:
This study was performed using IROC Houston anthropomorphic head and neck phantom incorporating dosimetry insert. The dosimetry inserts consisted of one primary PTV containing four TLD capsules, a secondary PTV and an organ at risk (OAR), each containing two TLD capsules and also radiochromic films. The phantom was imaged. The PTVs, OAR and TLD capsules were contoured and planned in Monaco treatment planning system (TPS) with 6 MV X-rays beam IMRT using Elekta VersaHD linear accelerator. After phantom irradiation, the analysis was done at IROC Houston and comparison was made between IROC TLDs and radiochromic film measurements and our institution TPS calculations data. The passing criterion was set as that minimum 85% of pixel points should meet gamma index criteria of +7% and 4mm.
Results:
The phantom irradiation results showed that the ratio between institution's reported mean doses and IROC measured doses were 0.99, 0.97, 0.99, 0.98, 1.00, 0.97, 0.95 and 0.98 at four different locations in the primary PTV, two locations at both secondary PTV and OAR respectively. For the relative dose comparison, the pixel passing rates for the axial and sagittal films were 98% and 96% respectively.
Conclusion:
This study demonstrated the ability of our institution's equipment commissioning and QA procedure and met the criteria established by IROC Houston in credentialing for clinical trials.

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TWO STAGED STEREOTACTIC RADIO-SURGERY TO HIGH NUMBER OF BRAIN METASTASES WITH GAMMA KNIFE PERFEXION

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Radiation Oncology –Treatment Planning

Introduction: The treatment options for brain metastasis includes surgical resection, whole-brain radiotherapy (WBRT), corticosteroids, stereotactic radio-surgery (SRS) or some combination thereof. Among radiotherapy techniques, WBRT is traditionally preferred treatment for the patients with high number of brain metastasis. In recent years, SRS alone has become an equal and potentially preferred treatment option for the patients with larger number of brain lesions. The study demonstrates an efficacy of SRS Gamma Knife (GKSRS) in high number of brain metastases over WBRT. Methods: An operated case of ca-breast, presented with multiple brain metastasis after one year of adjuvant chemotherapy and radiotherapy. The patient responded to WBRT (30Gy/10#), however the follow up imaging revealed increased metastases in number & size after nine months. Staged GKSRS was performed to treat multiple brain lesions in view of patient comfort, prolonged treatment time and targeted frame fixation limitations. Results: Nine lesions of volume range 38.9mm3-10.44cc were treated in the first stage whereas 12 lesions of volume range 17.2mm3-1.47cc were treated in the second stage GKSRS. Marginal dose of 12Gy at 50% isodose line was delivered to all lesions. Mean tumor coverage was 98.20%. The mean selectivity, conformity and gradient index were 0.63, 0.56 and 3.5 respectively. An integral dose of 6.2J was observed to the patient skull. Mean V8 (volume covered by 8Gy) and V10 were 60.64cc and 37.63cc in first stage and 9.81cc and 5.66cc in the second stage of treatment. 17.46cc of the normal brain received >10Gy of the radiation dose. The second stage planning MRI showed reduced volume of the tumors treated in first stage. Conclusions: A high number of brain lesions favoured WBRT, however GKSRS may spare normal brain tissue from redundant radiation dose. Localized GKSRS may be an alternative, where the patient received palliative WBRT and have limited treatment options.

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EVALUATION OF INDIAN-MADE SIMULATOR-BASED CONE-BEAM COMPUTED TOMOGRAPHY SYSTEM

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Radiation Oncology – Quality Assurance

Introduction:
To evaluate the characteristics of first Indian make commercial system of Cone Beam Computed Tomography (CBCT) system integrated with Radiotherapy Simulator.
Materials and Methods:
Measurements were performed on indigenously developed Panacea Imagin simulator (Panacea Medical Technologies Pvt.Ltd, Bangalore, India) based cone beam computed tomography (CBCT) system which was recently installed at our institution. The performance evaluation involved comparison of volumetric image data acquired from a Siemens Somatom sensation CT scanner, Philips wide bore-CT scanner and Elekta VersaHD linear accelerator CBCT system. The image quality of CBCT was quantitatively evaluated using Catphantom and CIRS image quality phantom for geometrical accuracy, HU accuracy, uniformity and noise, high contrast resolution and low contrast resolution and CT dose index.
Results:
The Imagin Simulator CBCT performance tests results showed that geometric distortion accuracy of 1mm, the mean pixels of 5 different ROIs based uniformity index of 112.20, signal-to-noise ratio of 2%, maximum HU accuracy of 11.7% deviation for derlin out of seven different materials, smallest resolvable pattern/bar seen as a spatial resolution of 6line/cm and 2mm and Low contrast resolution observed was 7mm at 1% and the image quality results of Philips fan beam CT and Elekta CBCT was little superior than Imagin Simulator CBCT results. The maximum difference in CT dose index was about 2%.
Conclusion:
This evaluation of the CBCT demonstrated that the system currently meets all image quality parameters and suitable for all clinical applications. However, it was suggested that there is room to improve the image quality.

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THE CHALLENGES IN LATIN AMERICA TO IMPROVE RADIATION PROTECTION IN MEDICINE

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Radiation Protection

Attention to medical exposures increased considerably in the 1980s and 1990s. In order to address this issue, in March 2001, the First International Conference on the Radiological Protection of Patients was held in Malaga, Spain, where an Action Plan was drawn up based on the contribution of national and international organizations and whose purpose was ensure that radiation protection is an integral part of medical practice, recognizing the benefits of medical uses of radiation and radiation protection without limiting such benefits. Within the framework of this Plan of Action, various activities have been carried out. Ten years after the adoption of this Plan of Action, the International Conference on Radiation Protection in Medicine: Setting the scene for the next decade, was held, which took place in Bonn, Germany, in December 2012. It was organized by the IAEA and WHO. The main outcome of this Conference was the so-called ""Bonn Call to Action"" that identifies ten priority measures to improve radiation protection in medicine.

With the main objective of verifying the progress in the implementation of the proposed actions, identifying problems and possible solutions as well as defining indicators of progress in these actions, the Ibero-American Conference on Radiation Protection in Medicine - CIPRAM was held in Madrid, Spain (October 2016) with the support of national and international organizations.

In order to identify problems and solutions for the Latin American region, the International Symposium on Radiation Protection in Medicine is held in Arequipa, Peru (August 2017). And at the XI Regional Congress on Radiological and Nuclear Safety held in Havana, Cuba (April 2018), important conclusions were obtained that, like those obtained in the other technical meetings, will be presented in this work. In addition, the actions carried out in the region to comply with the Bonn Call to Action are presented.

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OSL TECHNIQUE OF AGATE STONES SAMPLES

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Dosimetry – Reference quality

Introduction:
Brazilian stones have great interest in studies for use in gamma high-dose dosimetry. At the Radiation Metrology Laboratory of IPEN, Brazil, different stones have been studied for application in high-dose dosimetry as: amethyst, onyx, and jasper and have shown their usefulness for gamma dosimetry, using TL, OSL and TSEE. Agate is a variety of chalcedony, a form of quartz, in which the color appears in bands or concentric zones. The samples for this study were prepared from four different types of agate stones: yellow, moss green, gray and purple. The objective of the work was to characterize agate samples as detectors for gamma high dose radiation.
Materials methods:
To facilitate the process, agate pellets were prepared at the IPEN, using Teflon as binder, and the parts were mixed in the ratio 2 (Teflon):1 (powdered sample). The irradiations of the samples were performed using a Gamma Cell-220 System of 60Co, for doses from 50 Gy up to 10 kGy. The OSL measurements were taken using a RISÖ TL/OSL Reader and Controller, model DA- 20, and the data acquisition was realized using a personal computer.
Results:
In order to verify the possibility of utilization of agate pellets in high-dose dosimetry, their properties were studied using the OSL technique as lower detection limits, reproducibility and dose-response curve. The OSL dose-response curves of the agate pellets were obtained for 60Co, after thermal treatment at 300°C/1h and irradiation in the range of 500 Gy to 300 kGy. Conclusions:
In the studies of agate samples (four kinds) the results on the main dosimetric propertis show that they may be useful for high- dose dosimetry in industrial processes and in the sterilization of materials in hospitals. The main advantage of using agate samples is their very low cost and their usefulness for high-dose dosimetry using the OSL technique.

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DEVELOPMENT OF PET/MR MULTIPARIMETRIC ACQUISITION PROTOCOL IN MARKED BRAIN TUMORS WITH [11C]-METHIONINE

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Nuclear Medicine

Brain tumors are one of the most aggressive and difficult to control among all these that afflict the human body. Its treatment continues to be agree at challenge in clinical neurology due to its invasive characteristics. One of the most difficult tasks is to define its true extent. Currently, magnetic resonance images represent the most commonly used method to determine tumor volume, however, neuro-oncology has shown that glioma cells are found beyond the enhancement area with gadolinium contrast. Given the complexity of the anatomo-physiological phenomena related to these brain lesions, PET is considered a promising imaging technique that complements MR techniques in the diagnosis and treatment of patients with gliomas, by providing metabolic data. Most clinical studies of PET use FDG, but the uptake of this radiopharmaceutical depends on several factors and has demonstrated its lack of specificity in the study of gliomas. On the other hand, the use of L−metil−11{C} methionine as a radio-tracer in neuro-oncological PET images is under investigation, given its specificity in the detection of brain injuries. During this research, an acquisition protocol was developed for multiparameter brain PET/MR study, with [11C]-met, for its implementation with the system SIGNATM PET/MR 3T, manufactured by GE. The protocol includes a list of technical procedures (involving from the preparation of the patient to the administration of the radio-tracer and subsequently the MC), the PET-MET acquisition and finally a list of MR sequences. The creation of the protocol involved the adjustment of a set of specific parameters of both acquisition and processing of series of images. An analysis of the PET-MET studies carried out in FUESMEN was accomplished, allowing to study the tumor delimitation from segmentation techniques in PET-MET images and to relate this information to the results of the main biomarkers provided by the perfusion sequences, diffusion and spectroscopy.

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EVIDENCE OF OVERUSE, UNDERUSE AND MISUSE OF MEDICAL IMAGING: IMPLICATIONS FOR RADIATION PROTECTION IN CHILDREN

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Radiology – Radiation Protection.

Introduction: Overuse of medical imaging implies giving patients care that they do not need, underuse means failing to give patients the care that they need while, misuse of medical imaging implies making errors that can harm people's health. The idea of giving the right radiation dose to patients goes beyond the boundaries of radiation protection to the realm of good medical practice. This is because children by nature and certain pathologies unique to them are more vulnerable to certain forms of cancers than adults.
Objective: this study explores current literature on the subject of overuse, underuse and misuse of medical imaging services in children.
Materials and methods: an in-depth review of current scientific literature on the subject of overuse, underuse and misuse of medical imaging was undertaken. Reputable scientific websites, databases and journals such as the International Commission on Radiological Protection, World Health Organization, the Lancet, and Springer were consulted. Only articles related to the subject were included.
Results; findings from the study show overwhelming evidence of overuse of medical imaging services especially CT in high- income countries while in a number of low and middle-income countries findings are consistent with underuse and misuse of medical imaging. However, there still exists an argument in some quarters as to what defines 'overuse' of medical imaging. Conclusion: overuse, misuse and underuse of medical imaging services most of which involves the use of ionizing radiation is a global trend which is likely to go undetected, undocumented and unreported in developing countries among children with serious radiation protection implication. Hence, a need for a closer collaboration among relevant stake holders to minimize or possibly eliminate this ugly trend.
Keywords; misuse, underuse, overuse, medical imaging.

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VERIFICATION OF SKIN DOSE USING THERMOLUMINESCENT DOSIMETERS FOR EXTERNAL RADIOTHERAPY

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Radiation Oncology – Dosimetry

The skin is the only organ that is always located between the source and the target organ in treatments with external radiotherapy. Treatment Planning Systems (TPS) have algorithms that perform calculations and report absorbed dose in a certain organ, however, the exact calculation of dose in build-up regions as well as the skin, they remain indispensable knowledge for the radiation oncologist in the clinical management of the treatments. Since skin toxicity can occur, in the most severe cases, such as ulcerations, hemorrhage and necrosis, this is a reason to interrupt the treatment. Therefore, the goal of this study is to determine the dose received by the skin using a detector that can be used in "in-vivo" dosimetry. For these, CaF2:Mn thermoluminescent dosimeters (TLD) were used as they are small, easy to localize during irradiation and show linear response and repeatability in the range of doses and energy used. The treatment plans were made for 6 MeV photons beams on RW3 plates and on a physical chest simulator with the AAA (Analytical Anisotropic Algorithm). Additionally, TLD were placed on these surfaces to determine the dose. A better correspondence was found between the values calculated by the TPS and the values measured with the dosimeters in the field of 10x10 cm on the RW3 than on the physical chest simulator. Moreover, the thermoluminescent dosimeters were used to measure the dose on the skin of the jaw and the cheek of a patient, whose symptoms showed a very important affectation in the skin and oral cavity, being able to correlate her symptoms with the dose received. Consequently, it is considered that an adequate estimate of the dose received by the skin in patients can be determined by using thermoluminescent detectors, provided that the correct location of the TLD in the planning is guaranteed.

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IMPLEMENTATION OF A TASK REGISTRATION SYSTEM IN A RADIOTHERAPY CLINIC BASED ON MOSAIQ

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Radiation Oncology – Treatment Delivery

Introduction:
Every health service must have an organizational system that allows the human group to distribute its responsibilities and functions, by defining a specific work methodology. If duties and responsibilities are not clearly delineated and written down, it can cause considerable confusion throughout the organization. Then, the organizational structure must be able to be expressed in a flowchart that determines the dependence of each sector and individual with respect to the rest.
Methods and Materials:
This work shows our experience in the implementation of an organization system based on task registration, using the Record & Verify software MOSAIQ of ELEKTA, in a radiotherapy service. The goal should always be to increase the efficiency and effectiveness of our service in order to improve the quality of the patient's treatment.
To achieve this, the operation of the radiotherapy service must be analyzed; the scope and implications of each sector must be defined; the service must be modeled through a flow chart using free online software; the workflow must be optimized defining the implications of each task through accessible procedures to all users (printed and online); the flowchart must be assembled in MOSAIQ; the feedback of the coworkers must be analyzed to take corrective measures until the model becomes representative of the reality; perform an analysis of the organization system achieved; discuss new modifications for the optimization of it.
Results and conclusions:
As a result, the new system allows the user to constantly monitor the work flow of their clinic. This facilitates decision-making through a quick analysis of the performance of the critical points of the service allowing a study of the time used in each task and user productivity. This allowed to improve the quality of treatment by reducing the time between the patient's first consultation and the start of treatment.

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INDEPENDENT DOSE CALCULATION IN 3D CONFORMED RADIOTHERAPY WITH MLC THROUGH MATLAB SOFTWARE

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Radiation Oncology – Quality Assurance

Introduction:
The institutions that offer radiotherapy treatments must acquire independent dose calculation software, external to the treatment planner (TPS) in order to evaluate them. Commercially there are different programs to perform independent control but the development and implementation of an algorithm by professionals of the institution provides confidence and extensive knowledge of the tools to be used.
The objective of this work is to present an independent dose calculation system developed in the Centro Oncológico Integral for 3D shaped fields with multileaf collimation systems (MLC), through the knowledge of dosimetric parameters of the treatment machine and particular characteristics of each field, which allows to validate the calculations of the treatments of the service and to implement it in the daily clinic.
Methods and Materials:
A calculation software was made under the MATLAB programming platform. The system uses files in DICOM RT format, exported from the MONACO TPS. This file contains detailed information on the dose, UM, position of each MLC lamina and collimators for each treatment field. The equivalent field size is obtained from the positions of each lamina. The depth of the calculation point is based on the 3D coordinates of the isocenter and the normalization point for the treatment plan obtained from the file. From this information the system searches for the dosimetric parameters and calculates the UM.
Results and Conclusions:
The program is used in the daily clinic, analyzing 177 patients for a total of 480 plans so far. It helps to reduce the probability of occurrence of errors in the planning, allowing a detailed analysis of the dose to be delivered and revision of the normalization point (PN). This shows the importance of having an independent software to the TPS since it allows to detect user-dependent errors.

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VERIFICATION OF THE EFFECTIVE DOSE REGISTRY METHOD OF COMPUTED TOMOGRAPHY BRAIN SCANS AT THE HOSPITAL CLÍNICO UNIVERSIDAD DE CHILE

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Radiation Oncology – Dosimetry

The dosimetric indicators registry for radiologic examinations is the first step for the setting of local reference levels and dose management in diagnostic imaging. Although new automated tools have been developed in recent years to obtain and manage these indicators, many of them are expensive or difficult to implement. With the help of a data field enabled in the RIS system (Qdocv6.1.0,AGFA) of the Center of Imaging of the Hospital Clínico Universidad de Chile, manual recording of effective dose for computed tomography was extracted from all patients older than 15 years who underwent CT scan of the brain in the years 2013 – 2014, to perform a first pilot of this modality of registration. To corroborate the validity of the data, DLP values converted from the effective doses recorded using the factors and equations set forth in ICRP publication 102, and then compared with the reports of doses sent as image by the computed tomograph (Siemens, Somatom Sensation 64) to the PACS system of the institution. Finally, a descriptive statistical analysis of the dose indicators was performed with the help of STATA 12 for 3236 studies without contrast and 534 with contrast. The effective dose and DLP values observed were 1.94 ± 0.10 mSv and 924.3 ± 45.8 mGy*cm for unenhanced Brain CT scans, and 3.85 ± 0.21 mSv and 1853.4 ± 98.2 mGy*cm for studies with contrast, being close to those indicated as a reference in international reports. The registration of dosimetric indicators through this method allowed for a reliable analysis of these, being a guide for the management of protocols with the purpose of optimizing radiation doses in radiological studies when necessary.

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QUALITY CONTROL END-TO-END TO IMPLEMENT STEREOTACTIC RADIOCISURGY (SRS)

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Radiation Oncology – Quality Assurance

Introduction:
Stereotactic radiosurgery is a modern and complex radiotherapy technique that is used to treat functional abnormalities and small tumors in the brain. It requires millimeter precision levels because high doses (> 10Gy) of ionizing radiation are delivered to small targets (<2.4cm) located stereotactically in few fractions. There is a high gradient of dose outside the volume of interest, which implies a high conformation of the dose to minimize the damage to healthy tissues. The objective of this work is to present the end-to-end tests to identify the components of the system, to guarantee the connectivity between them, to verify that the clinical personnel understand their tasks; as well as evaluate the accuracy and precision of the treatment process.
Methods and Materials:
To achieve this, all the steps in this type of treatment are executed, which include: immobilization, simulation, planning and administration. The first stage consists of tomo-simulation, in which a tomography of the PMMA SRS phantom with micro- camera and another with Gafchromic films is performed using the necessary positioners. Then the treatment of a non- cylindrical deformed target is planned, which contain the micro-camera and Gafchromic area in the MONACO planning station. Subsequently, the calibration curve for the dose versus optical density was obtained and then the cross-calibration of the micro-camera is performed with the Semiflex used by the service in quality controls. The planned treatment is administered to the fantastic SRS, irradiating both the films and the camera. Finally, the GafchromicTM are scanned and processed with the VeriSoft Software from PTW.
Results and Conclusions:
It is concluded that the process allows familiarization with the different activities of the service, since it must be carried out by the personnel that will be in charge once it is implemented clinically. Also, anticipate possible errors that may occur in this process.

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INTERNATIONAL COOPERATION FOR THE EXPORTATION OF DISUSED HEADS OF TELETHERAPY UNITS

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Radiation Protection

Each Member State must consider all feasible options for the most appropriate management of disused sources which were used in teletherapy. In that sense, the Peruvian Government signed an agreement with the International Atomic Energy Agency in order to promote the repatriation of all the disused heads of teletherapy units with Cobalt - 60. This paper describes administrative and technical details about the agreement, technical requirements about the inventory which considered both, radioactive material and nuclear material and the preparation of the packages Type B, containing eight sources with 65 TBq and 305,2 kg of depleted uranium considered as nuclear material by the Peruvian regulatory body.

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SECURITY MEASURES FOR THE TRANSPORTATION OF A DISUSED TELETHERAPY UNIT

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Radiation Protection

Peru Government has approved a specific regulation to cover the need of security measures in the transport of nuclear and radioactive material. According to the recommendations given by the International Atomic Agency, has defined five categories considering their risks and vulnerabilities, with a graduated approach. The requirements are rigorous in the case of the transportation of a disused teletherapy units taking in account some bad experiences and accidents occurred in other Member States. This paper describes all the technical considerations that were taken for the transportation of a disused teletherapy unit during 600 km of travel by earth and considering different jurisdictions. The teletherapy unit had a cobalt-60 source with an activity of 5200 GBq. The operation had the financial support of the United States of North America, through the Global Threat Reduction Program.

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OVERVIEW OF THE HEALTH PHYSICS MASTERY IN PERU AND ITS COMMITMENT WITH THE BONN CALL FOR ACTION

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Education and Professional Issues

The Bonn call for action considers both, strengthen radiation education and training of health professionals and enhance the implementation of the principle of optimization of protection and safety. Peru recognized the importance of both issues so in 1996 decided the creation of the Master in Health Physics considering an agreement amongst Engineering National University, Peruvian Institute of Nuclear Energy and the International Atomic energy Agency. The education and training of technical professionals with a high level of knowledge has permitted the enhance of the quality of service and the reduction of risks. This paper describes all aspects, updated to the present, related to the evolution of the education training, the number of formed professionals and their real effective contribution for the medical applications, considering radiodiagnostic with X ray, nuclear medicine and radiotherapy. As learned lesson, this paper corroborates the positive considerations of the Bonn call.

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CLINICAL VALIDATIONS OF A DYNAMIC ANTHROPOMORPHIC PHANTOM FOR RADIOTHERAPY QA

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Radiation Oncology – Quality Assurance

Introduction:
A novel dynamic anthropomorphic phantom, ChestPhan-4D has been invented and built in Australia to assist the clinical implementations of advanced radiotherapy techniques since 2015. It is available for clinical research and training purposes, has wide applications due to its broad capabilities of expandable chest and deformable and movable organs included. This paper describes the phantom's clinical validations, readily available and potential clinical applications in 4D treatment and imaging of tumors in the thorax region.
Method:
The published studies on tumor movements due to respiratory and cardiac motions were reviewed. The validations of this phantom's clinical uses are conducted on GE 4DCT and Varian True-Beam-TM platforms. The direct applications on tracking and targeting tumor in thorax using surface surrogate technologies were analyzed from both temporal and spatial aspects. Potential applications in deformable imaging registration (DIR) and proton therapy QA are also analyzed primarily. The application of this device as "dosimetry discrepancy identifier" is explored with 4DCT data sets.
Results:
It has demonstrated that this dynamic phantom has the required capabilities in simulating organ motions and deformities of the chest surface, lung and heart during any breathing cycle. It has direct applications in SBRT, DIBH, DIR planning verification processes. With some improvements, it can be applied in proton therapy QA and to be used for verification of DIR software programs.
Conclusion:
A list of clinical applications with this dedicated, diseases-focused dynamic phantom has been preliminary explored and its clinical values have been confirmed in advanced radiotherapy quality assurance processes in both conventional and emerging MRI-guided as well as proton therapy technologies.

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CALCULATION OF ORGAN DOSE FOR PEDIATRIC PATIENTS UNDERGOING COMPUTED TOMOGRAPHY EXAMINATIONS: A SOFTWARE COMPARISON

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Diagnostic Radiology –Dosimetry

Introduction: The increased number of performed 'Computed Tomography (CT)' examinations raise public concerns regarding associated stochastic risk to patients. Pediatric patients are more susceptible to radiation-induced risks than are adults owing to their rapidly growing tissues and greater post exposure life expectancy. We developed a Dose Archiving and Communication System that gives multiple dose indexes (organ dose, effective dose, and skin-dose mapping) for patients undergoing radiological imaging exams. The aim of this study was to compare the organ dose values given by our software for pediatric patients undergoing CT exams with those of another software named VirtualDose.
Materials and Methods: Our software uses Monte Carlo method to calculate organ doses for patients undergoing computed tomography exams. The general calculation principle consists to simulate: (1) the scanner machine with all its technical specifications and associated irradiation cases (Kvp, field collimation, mAs, pitch ...) (2) detailed geometric and compositional information of dozens of well identified organs of computational phantoms that contains the necessary anatomical data. The comparison sample includes the exams of thirty patients for each of the following age groups: newborn, 1-2 years, 3-7 years, 8-12 years, and 13-16 years (a total of 150 patients). The comparison protocol is the «Head» protocol. Results: The percentage of dose difference between the two software does not exceed 20%. This difference may be due to the use of two different generations of hybrid phantoms by the two software.
Conclusion: This study shows that our software provides a reliable dosimetric information for pediatric patients undergoing CT exams.

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MANAGEMENT OF MAGNETO-PROTECTION OF WORKERS IN MAGNETIC RESONANCE IMAGING

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Non-ionizing applications

Introduction: In the Magnetic Resonance Imaging (MRI) department, all workers involved in preparing the patient, setting it up, tunnel cleaning actions, ... are likely to be exposed to electromagnetic fields (EMF) emitted by the device. Exposure to EMF can cause undesirable radio-biological effects to workers. Several international health organizations (such as the World Health Organization, Medicines and Healthcare Regulatory Agency, American Radiology Society), determine the specific terms of protection against EMF exposure in MRI services. The purpose of this communication is to propose an organizational process to make it easier to integrate these magneto-protection methods into risk management and control. Materials & Methods: The study was conducted in seven MRI departments using 1.5 and 3 Tesla magnets. We performed an exposure assessment for each power by measuring the two electromagnetic fields (static and dynamic) at different points on the MRI machine both inside and around the examination room. We compared our results with British and American references (those of the UK's Medicines and Healthcare Regulatory Agency (MHRA) and the American Radiology Society (ACR)). Results: Following the results of EMF measurements and their comparison with the recommendations of learned societies consulted, a zoning system that adapts to the needs of different MRI services across the country has been proposed. In effect, three risk areas have been identified within the MRI services. This has led to the development of a good practice guide related to the magneto-protection of MRI workers. Conclusion: The guide established by our study is a standard that allows MRI responders to protect themselves against the risk of electromagnetic fields.

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CALCULATION OF ORGAN DOSES FOR ADULT PATIENTS UNDERGOING COMPUTED TOMOGRAPHY EXAMINATION: A SOFTWARE COMPARISON

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Diagnostic Radiology –Dosimetry

Introduction: 'Computed tomography (CT)' use increases rapidly worldwide. CT examinations deliver a relatively high radiation dose to patients. It is essential to have an organ-specific dose estimation tool that reflects the average damage to the organ per unit of its mass and consequently the appearance of deterministic effects. We developed a software solution to optimize patient's dose received from medical imaging techniques that use ionizing radiations. We present the comparison of the dose values given by our software for adult patients with those of another software named “VitrualDose”.
Materials & Methods: Organ doses from computed tomography are calculated based on Monte Carlo simulations. The general calculation principle consists to simulate: (1) the scanner machine with all its technical specifications and associated irradiation cases (Kvp, field collimation, mAs, pitch ...) (2) detailed geometric and compositional information of dozens of well identified organs of computational phantoms that contains the necessary anatomical data. Organ doses can be calculated for any desired scanner machine using scanner specific correction factors and the considered exam parameters. A total of 270 patients were used for the comparison whose data corresponds to exams carried out in France hospital centers ; the comparison dataset includes adult males and females for three different scanner machines and three different protocols : « Head », « Chest », and « Chest/Abdomen/Pelvis ».
Results: The percentage of dose difference between the two software does not exceed 20%. This difference may be due to the use of two different generations of hybrid phantoms by the two software. This dose difference may due to a difference of the anatomical definition of the organs between the phantoms utilized by each software within the same hybrid family. Conclusion: This study shows that our software provides a reliable dosimetric information for pediatric patients undergoing CT exams.

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RADIATION SAFETY TRAINING IN MEDICINE

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Rafik Hariri University Hospital, Lebanon

Education and Professional Issues

The use of radiation in Medicine has been on the rise in many countries. A lot of diagnostic and therapeutic procedures may expose patients and staff to high radiation dose which can be reduced to low levels to ensure the safety and protection against the harmful effects of radiation exposures. The objective of this presentation is to ensure the following:
1. Implementing an effective radiation safety strategy
2. Examining the role of the hospitals in creating a radiation safety program
3. Enforcing radiation safety practice for patients, staff, physicians and visitors.
4. Providing regular radiation safety education to concerned staff
5. Identifying opportunities to improve radiation safety performance
6. Using appropriate shielding devices and related materials

By adhering to the principles and doctrines of radiation safety set forth by international organizations, the safety culture among radiation workers will be enhanced and the productivity as well as performance of the protocols will be optimized.

P-252

MEDICAL PHYSICS EDUCATION AND TRAINING IN MEFOMP COUNTRIES

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Education and Professional Issues

The Education and Training of medical Physics in MEFOMP countries have been evolved since the last decade to better suit the demand and fulfill the market need of physicists in our region. The programs of Medical Physics will be reviled for some countries in our region. The mission of MEFOMP Educational and Training Committee (ETC) is to promote activities related to education and training of medical physicists for the purpose of improving the quality of medical services for patients in the region through advancement in the practice of physics in medicine. ETC helps and provides support for all medical physics trainee in all member countries to understanding of different levels of learning, and the types of knowledge required for higher level functions such as problem solving, creative innovations, and applied clinical applications. Medical physics education can be much more effective and efficient when all regional chapters of IOMP share their knowledge and experience to enhance the outcome with coordination of highly qualified experts of medical physics professionals.

P-253

MEDICAL PHYSICISTS CERTIFICATION PROCESS AND EXAMINATION IN THE MIDDLE EAST

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Education and Professional Issues

Certifying medical physics is becoming an essential part in recruiting medical physicists in hospitals across the Middle East region. Due to the lack of a comprehensive post graduate programs in MP in most of ME countries; hospitals find it very difficult to hire MP without the proper credentials and clinical experiences. Also, MP in the region find it very difficult to apply and travel for certification in Europe or North America due to visa and other related issues. So, if these certifying bodies are willing to cooperate with MEFOMP and/or similar organizations in the ME region so that certifications will be offered in the region for the region in a way to ease the process and save efforts and resources from the burdens of MP. Certifying Medical Physicist requires an individual to obtain a university degree at the level of Master degree in Medical Physics, this is followed with at least a one year of clinical residency program in the Medical Physics fields applied in a Hospital. The existing local/national certifying organization exam models are utilized as reference to design the final exam structure which can be customized for the medical physicists that will be working in the Middle East. Three Exam Model proposals will be discussed here, all of which aim to evaluate the competencies of the individual medical physicist knowledge and skills by following various examination approaches.

P-254

STATUS OF RADIOTHERAPY TREATMENT IN LEBANON

Ibrahim Duhaini

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Radiation Oncology – Treatment Delivery

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 13 Hospitals that offer Radiotherapy Treatment with 20 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 13 hospitals will be revealed. Detailed information will be unwrapped for the newly opened Radiotherapy Center at Ain Wazein Medical Village (AWMV) in Mount Lebanon, which covers one third of the Lebanese population in that region. Also, detailed information will be exposed for the newly Upgraded Radiotherapy Department at Rafik Hariri University Hospital in Beirut.

P-256

BREAST CANCER: FROM DIAGNOSIS TO THERAPY

Ibrahim Duhaini

Rafik Hariri University Hospital, Lebanon

Radiation Oncology – Dosimetry

Breast cancer screening techniques and treatment methods especially external beam radiation therapy and mastectomy increased the survival rate for patient with breast cancer. The early detection of breast cancer helps in the management progression and lessens the complications involved in the treatment modalities used like surgery, chemotherapy, radiation therapy, and other non-traditional therapies. Many countries in the world are performing breast screening campaigns that encourage women above the age of 45 to do mammography at least once every year. Clinicians depend on the progress of tumor in case found to give the best treatment options which could be a mixture of many modalities mentioned above. The most prominent method is using Radiation Therapy approach. Many techniques have been developed from 2D planning, 3D planning, IMRT, Brachytherapy using Mammosite techniques and others will be revealed.

P-257

SENSUS SRT 100: VERIFICATION OF THE CONSTANCY OF DOSE RATE AND QUALITY INDEX

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Radiation Oncology – Quality Assurance

Introduction: SENSUS SRT 100 is alow clinical energies (50KV, 70KV and 100KV) radiotherapy machine for the treatment of skin lesions. Given the high doses that can be delivered to the patient's skin in a very short time, strict quality controls are carried out with different frequencies.
Methods and Materials: Daily, between March 2018 and February 2019, before the start of the delivery of the treatments, the RAD CHECK constancy of the dose rates of each clinical energy was verified and recorded. The constancy of the dose rates for each clinical energy and in addition, the quality indexes, were also verified with a PTW dosimetric system, monthly, as it is recommended by the IAEA TEC DOC 1151.
Results and Conclusions: The daily results of the RAD CHECK measurements between 98% and 100%, indicated the stability of the reference dose rate delivered by the machine (recommended tolerance by manufacturer 97%-103%); likewise, we observed stability for the monthly controls, in which the constancy of the dose rates and the quality indexes showed a deviation less than 2,1% of the reference values, within the internationally recommended tolerance, 3%. It is concluded that the treatments delivered with the SENSUS SRT 100 machine were accurate and precise in terms of doses delivered to patients, which is verifiable with the clinical results in the period analyzed.

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LATTICE BOLTZMANN MODEL FOR TIME DEPENDENT 1-D NEUTRON TRANSPORT IN A HOMOGENEOUS SEMI-INFINITE MEDIUM WITH ISOTROPIC SCATTERING

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Radiation Oncology – Dosimetry

Introduction:
Since 2015, the research group Biophysics & Structural Biochemistry at the Pontificia Universidad Javeriana (PUJ), in cooperation with the International Atomic Energy Agency (IAEA), has been working on Neutron Capture Therapy (NCT), together with graduate students of the Master Program in Medical Physics at PUJ. Within our research program, one of the main goals is to learn and implement new numerical methods to study the neutron transport problem using the Boltzmann transport equation. In this paper we use the lattice Boltzmann method (LBM) to solve the time-dependent one-dimensional transport equation for monoenergetic neutral particles in a homogenous semi-infinite medium with isotropic scattering. Methods and Materials:
The LBM for transient neutron transport problem is adapted from the phase space discretization of the standard neutron transport equation where the collision and streaming processes at each time step are specified through the calculation of the relaxation time and equilibrium particle distribution function suggested by the Bhatnagar-Gross-Krook (BGK) approximation. In order to apply the one-dimensional neutron transport lattice Boltzmann-BGK model for a homogeneous half-space with isotropic scattering problem, a computational algorithm in Matlab has been made. The time-dependent neutron flux and deposited dose for different macroscopic cross section values have been obtained.
Results:
Simulation results show that the LBM can be effectively applied to study the 1-D neutron transport process with a reduced computational cost leading to a consistent description of neutral particles interaction with matter.
Conclusions:
We have shown that the proposed approach provides a powerful alternative for solving the Boltzmann transport equation required to characterize neutron distributions and other ionizing radiations for a given geometry. This methodology can be also considered as an alternative numerical technique for the treatment of particle transport problem.

P-260

MONTE CARLO SIMULATION OF LOCAL DOSE ENHANCEMENT IN RADIATION THERAPY WITH GOLD NANOPARTICLES

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Radiation Oncology – Dosimetry

Introduction:
The use of nanoparticles in radiotherapy has been studied given the dose enhancement that can be obtained in the target volume of the treatment. Studies indicate that gold nanoparticles (AuNP) are among the most biologically viable and can promote radiosensitization. This work aimed to study the dose enhancement factor (DEF) and the local distribution of doses in radiotherapy with AuNPs.
Methods and materials:
Using PENELOPE Monte Carlo simulation package, clinical beams of orthovoltage (50 to 150 kVp), brachytherapy with 192- Ir and teletherapy (6 MV) were simulated, along with a cell model with incorporated AuNPs. Two models of incorporation of the AuNPs were used: homogeneous (HM) and heterogeneous (μM). In the HM, a homogeneous mixture of water and different concentrations of gold fills the nucleus of the cell. In the μM, individual AuNPs (50 to 220 nm) are simulated in the cell nucleus. DEFs were obtained as the dose ratio in the cell nucleus with and without incorporated AuNPs. The dose distributions around AuNPs were used to calculate the extent of dose reinforcement.
Results:
In the HM, beams of 50 and 80 kVp presented DEF of 2.80 ± 0.02 and 2.99 ± 0.04, respectively. In the μM of a cell with six clusters of AuNPs, the DEF found was 1.79, ± 0.01. The dose distributions showed that the dose enhancement is local to the AuNPs. For the 50 kVp, 150 kVp and 192-Ir beams, respectively, the 50% isodose occurs at 1.93 μm, 1.49 μm and 1.38 μm from the AuNP's surface.
Conclusions:
The results show that orthovoltage beams provide the highest DEFs in radiotherapy with AuNPs. Dose enhancement is local, on a micrometric scale around the AuNPs, and may provide cellular radiosensitization if the AuNPs are incorporated into the nucleus of the cells.

P-262

CONSTRUCTION AND CHARACTERIZATION OF MATERIALS EQUIVALENT TO SOLID WATER, ADIPOSE AND LUNG TISSUES USING CODE PENELOPE

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Radiation Oncology – Dosimetry

Introduction:
Equivalent materials or phantoms are used in radiotherapy, radiodiagnostic and nuclear medicine to observe the behavior of ionizing radiation when interacting with matter. The use of these phantoms allows to approximate the interaction of ionizing radiation in the human body, which allows to determine the range of dose in different organs and tissues according to their sensitivity.
Methods and Materials:
The objective of this work was to construct equivalent materials or phantoms to solid water, adipose and lung tissues, in accordance with standard characteristics recommended by international organisms. Materials were constructed with densities of 1.032g/cm3, 0.922g/cm3, 0.320g/cm3 respectively. To verify the equivalence of the constructed phantoms with its respective tissue, was designed the material using the percentage composition, by weight, of the chemical elements of each of the materials equivalented in the code PENELOPE v.2008.
Results and Conclusions:
was obtaining parameter comparisons of interaction of beams from photons and electrons with each phantom constructed, using for this purpose the coefficient of total mass attenuation as a function of energy and stopping power coefficients, which were compared and validated with the results of the International Commission on Radio Protection (ICRP) And International Commission on Radiation Units & Measurements (ICRU). This comparations present relative difference of the 1 to 3% between of equivalent materials constructed and those presented in the reports of the ICRU and ICRP.

P-263

EXPLORING A NEW MICRODOSIMETRIC QUANTITY FOR ESTIMATING RBE FOR ION BEAMS

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Radiation Oncology – Dosimetry

Ionizing radiations induce damages in DNA when interacting with living beings. These damages may lead to biological effects such as chromosome aberrations and cell death. The radiation potential for inducing DNA damages is related to the capacity of radiation for producing densely ionization pattern in the irradiated tissues. This capacity is often related to the linear energy transfer (LET), however, this quantity is not enough for determining the relative biological effectiveness (RBE) of a given radiation quality. For instance, two heavy charged particles (ions) with the same LET show different RBE. So far, researchers have used the dose-mean lineal energy as a quantity for estimating the RBE of ionizing radiations. In this work, we explore a new microdosimetric quantity called dose mean energy transfer. We also implemented a computational tool for the calculation of such variable using Geant4-DNA toolkit. In addition, a comparison with another classical microdosimetric variable known as dose-mean linear energy was made and RBE variable was determine for each of them. The results show consistent values between dose-mean linear energy and the proposed new microdosimetric variable dose-mean transfer energy. Finally, based on the results obtained for the RBE of each of the variables, the impact of the new variable on the RBE estimation was studied.

P-264

INFLUENCE OF THE MEASURING SYSTEM IN MEAN GLANDULAR DOSE ESTIMATION

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Diagnostic and Interventional Radiology – General

Introduction:
Current European protocols use the Robson's method to the setting of tube output and half value layer (HVL) to estimate mean glandular dose (AGD) in digital mammography (DM) and digital breast tomosynthesis (DBT). The dose at the upper surface of the breast is calculated from these data, and by applying conversion factors of Dance calculations based on Monte Carlo, AGD is obtained. The aim of this study is to analyze the influence by measurement with different dosimeters in the AGD results obtained.
Methods and Materials:
Experiments have been carried out in three digital mammography units: Selenia Dimensions (Hologic), Senographe Essential (General Electric) and Mammomat Inspiration (Siemens). Six dosimeters have been used: two ionization chambers with a sensitive volume of 6 cm3 (PTW and RADCAL); and four solid-state dosimeters: multipurpose detector of Barracuda (RTI), NOMEX Multimeter (PTW), NOMEX MAM detector (PTW) and Black Piranha (RTI). All of them are calibrated for the evaluated beam quality. It has been used a second-degree polynomial to set both tube output and HVL.
Results:
AGD was evaluated for 2D and 3D available target/filter combinations. Results from tube output show differences from 0.01% to almost 8%. With reference to HVL, variations are among 0.2% and 15%, reaching 20% in some cases in DBT. For the beam qualities used in 2D, AGD varies to 12% depending on the dosimeter. In DBT with pulsed radiation, differences increase to 20% in some cases.
Conclusions:
This study demonstrates that the results from the measurement of HVL and output, and the subsequent calculation of AGD are highly influenced by the measuring system employed. Consequently, it is very important to know properly the different dosimeters responses since slight variances in measurements affect considerably AGD estimations.

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CT CURVE CALIBRATION FOR LUNG SBRT TREATMENTS WITH AAA

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Radiation Oncology – Dosimetry

Introduction: During the beam commissioning process for radiosurgery and SBRT treatments, the first obstacle encountered was the lack of a survey of the electronic density curve for the CT Hounsfield, necessary for a reliable heterogeneity correction. Given the number of lung SBRT patients treated at the National Cancer Institute (INCA – Brazil), the question was urgent. Therefore, the objective of this present work was to calibrate the tomograph curve with the experimental method and to validate the TPS calculation for all the beams.
Methods and materials: The imaging protocols were defined to have the same kV and the images were acquired in the established protocols in two different FOVs. The phantom 062M (Cirs) was used for this stage. The values of HU found were measured with analysis of the histogram of the image within the Eclipse (Varian) using 1 cm side square and the final table with its mean values, relative electronic density and mass density were fed in the CT calibration configurations. For the validation process, two phantoms were irradiated, a simpler one with heterogeneous slices manufactured to be irradiated with direct field and the second phantom was the IMRT Dose Verification Phantom produced by Standard Imaging.
Results and Conclusion: The values found in the CT scans were in accordance with the stoichiometric analysis and with current literature. The highest density was not high enough to match a metal prosthesis, so the value was obtained by extrapolating the line in the graph. In the irradiation of treatment plans in the two phantoms, different setups and different planes were tested to identify the largest possible variation. The maximum difference in doses was 2.2% in the setup of greater uncertainty in a single energy. It was clear that the calibration was efficient and satisfactory to move to the next step.

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METHODOLOGY FOR IMRT PLANNING BASED ON PET-CT IMAGING

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Radiation Oncology – Quality Assurance

Introduction: IMRT allows delivering of high dose to GTV while effectively sparing the OARs. In order to ensure a higher accuracy in target definition, the use of hybrid imaging based on PET-CT is continuously growing. In order to ensure an adequate use of these images for target delineation purposes in head and neck IMRT treatment planning, a protocol for quality assurance and clinical implementation is proposed.
Materials and Methods: Based on the recommendations of the IAEA TECDOC 1151 (update) and recently published national guidelines (CECMED protocol, 2017), a specific protocol for routine QA of a Phillips Gemini TF 64 PET-CT-Simulator system was designed and implemented, ensuring the adequacy of the hybrid images for radiotherapy treatment planning purposes. As part of a designed clinical protocol, a procedure for optimal values of SUV for GTV delineation was established. For clinical implementation, a single patient was planned, initially only based on CT and then on PEC-CT images. The results of each plan were compared, based on DVH analysis.
Results and conclusions: The designed QA protocol was implemented, demonstrating its feasibility for routine testing of the system and improving the quality and compatibility of images for planning purposes. The clinical protocol has provided the physicians a more consistent procedure for PET-based GTV delineation. Relevant discrepancies were found when PET images were considered for target delineation in head and neck tumors. Further work is ongoing for expanding the QA protocol to 4D imaging and the clinical protocol to other relevant anatomical sites.
This works has been performed as part of the bachelor research thesis of the main author.

P-270

EXPANDING SCOPE OF IAEA TECDOC-1583 FOR COMMISSIONING STEREOTACTIC RADIOSURGERY TREATMENTS

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Radiation Oncology – Quality Assurance

Introduction: Specialized techniques such as stereotactic radiosurgery is not addressed in IAEA TECDOC-1583. Here two comprehensive test cases are presented for dosimetric commissioning of a radiosurgery system.
Materials and Methods: The system to be commissioned consisted of an Elekta Precise linear accelerator, an Apex micro multi-leaf collimator (mMLC), and a Monaco treatment planning system (TPS). The dose calculated by the TPS was compared with the absolute dose measured with ionization chambers. Two radiosurgery test plans were created. Test I use a PTW's IMRT Head/Neck Phantom and two coplanar arcs with IMRT cost functions planned; the purpose was to assess the dose calculation accuracy with small coplanar arc beams. Test II is an end-to-end type test, where a stereotactic frame is fixed to a watermelon and Ergo++ TPS is used for stereotactic coordinates definition; a plan was created using six non-coplanar arcs and IMRT cost functions. The purpose of Test II was to assess the dose accuracy with no-coplanar arc beams and the influence of geometrical accuracy of the whole process. Semi-flex and pinpoint chambers were used for dose measurement inside the phantoms.
Results and conclusions: After successfully passing the conventional tests included in TECDOC-1583, the designed test cases showed being adequate for further assessment of TPS accuracy in more complex treatment configurations, like those used in stereotactic radiosurgery. Results of Test I showed that discrepancies below 1% are achievable, while results of Test II allowed detection of geometric shifts < 1 mm with dose discrepancies lower than 1%.

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PRELIMINARY DOSE CALCULATION FOR NEUTRON CAPTURE THERAPY USING REMOVAL-DIFFUSION THEORY

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Radiation Oncology – Dosimetry

Introduction:
Since 2015, the research group Biophysics & Structural Biochemistry at the Pontificia Universidad Javeriana (PUJ), in cooperation with the International Atomic Energy Agency (IAEA), has been working on Neutron Capture Therapy (NCT), together with graduate students of the Master Program in Medical Physics at PUJ. Within our research program, one of the goals is to study the dose distribution in a phantom due to epithermal neutrons.
Methods and Materials:
In order to determine the dose distribution due to epithermal neutrons coming from a D-D reaction we use a phantom to carry out all calculations. For this work a phantom is as a semi-infinite aqueous medium with a flat geometry and a 10 ppm 10B concentration. The distribution dose calculation due to epithermal neutrons is evaluated using the removal-diffusion theory. The dose rates for thermal and epithermal neutrons, boron and gamma radiation have been calculated using 4 different energy groups and kerma factors taken from ICRU 44.
Results:
We have carried out all calculation with an incident normalized neutron flux. In the case of thermal neutrons, we have obtained a maximum boron dose rate of 7,0 x 10 – 7 cGy/s for a deepness of 2,4 cm and a minimum of 1,9 x 10 – 13 cGy/s for a deepness of 2,8 cm. In the case of epithermal neutrons, the obtained dose rate was of 1,9x10–10cGy/s for a deepness of 1,0 cm. Finally, for the gamma radiation the obtained dose rate was of de 2,8 x 10 – 10 cGy/s for a deepness of 1,2 cm.
Conclusions:
We have successfully implemented an established methodology to calculate a dose distribution in a phantom for epithermal neutrons in NCT.

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IN VIVO DOSIMETRY IN TOTAL BODY IRRADIATION (TBI)

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Radiation Oncology – Quality Assurance

Introduction:
TBI is a technique used as a conditioning regimen before the transplantation of hematopoietic cells, providing a dose difference to the whole body no greater than 10% of the prescribed dose. To guarantee accuracy in the administration of the dose in TBI, an In Vivo Dosimetry (IVD) system based on diodes and EBT-3 films is implemented with the objective of carrying out a direct verification.
Methods and materials:
All the dosimetric parameters for the implementation of the technique are characterized to SSD=3.8m, with 6MV and 15MV for treatment with AP-PA field from the radiological distances obtained in different thicknesses of the patient. The IVD systems implemented are calibrated independently using ionization chambers as a reference, guaranteeing traceability. Recommended tests were carried out by international quality control protocols, such as: drift, repeatability, reproducibility, linear response, subsequent response, shadow effect and independence of dose rate and energy.
Results:
There is a 160cm dosimetric profile for treatment of TBI with energies of 6MV and 15MV less than 2% in homogeneity and the main sources of uncertainty associated with the TBI and the IVD were analyzed. The IVD system was used in several phantom where correction factors were found by backscattering at the pulmonary and pelvic level, correction considerations were made in the measurements by influence of the patient's thickness and the distance source-surface.
Conclusions:
The IVD system based on diodes and EBT-3 films implemented is redundant in measured but is an effective tool for the detection of inaccuracies greater than 10% for TBI dose calculations and carries out an integral verification of the process. Action and tolerance levels are established for the use of IVD with diodes during treatment.

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IMPLEMENTATION OF TRS 483 GUIDELINES FOR FIELD OUTPUT FACTOR DETERMINATION WITH AN ADD-ON MICRO MULTI-LEAF COLLIMATOR

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Radiation Oncology – Dosimetry

Introduction: Stereotactic radiosurgery is a treatment technique that involved the use of very small fields. Recently, an add-on micro multi-leaf collimator (mMLC) Apex has been commissioned at the National Institute of Oncology and Radiobiology, Havana, Cuba, as part of a stereotactic radiosurgery system. The purpose of this work was to evaluate, as part of an IAEA Coordinated Research Project (E2.40.21), the use of the procedures and recommendations established in the TRS 483 for obtaining the field output factors when using add-on mMLC collimation.
Materials and Methods: The measurements were performed in an Elekta Precise linear accelerator. Ten field sizes, ranging from 0.49 cm x 0.49 cm to 11.27 cm x 11.27 cm, were evaluated. A fix field size of 12 cm x 14 cm was set above the mMLC. As machine specific reference field in the mMLC, a field size of 9.8 cm x 9.8 cm was used. The following detectors were employed: ionization chamber pinpoint 3D 31016, unshielded diode E 60017 and microdiamond 60019, all from PTW. The beam energy used was 6 MV WFF. The corrected output factors obtained were compared among all detectors.
Results and Conclusions: The equivalent field size obtained experimentally from the FWHM agreed within ± 0.1 mm among the three detectors. The comparison of the corrected field output factors, for all field sizes, showed relative discrepancies less than 1.3 %. The results have shown excellent agreement between multiple detectors, demonstrating the feasibility of the new code of practice for using with this type of collimation.

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FEASIBILITY EVALUATION OF TANGENTIAL VOLUMETRIC MODULATED ARC THERAPY TECHNIQUE FOR WHOLE BREAST IRRADIATION PLUS CONCURRENT BOOST

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Fundación Médica de Rio Negro y Neuquén, Argentina

Radiation Oncology –Treatment Planning

Introduction:
Intensity modulated techniques (IMRT), particularly the ones denominated arc therapy techniques, have grown in popularity and have demonstrated to be more effective in restricting the prescribed dose to the target in numerous pathologies.
The aim of the present study is to evaluate the feasibility of the application of this new technique in the treatment of breast cancer, one of the most common malignance's worldwide, where today's standard is the tangential field-in-field technique. Methods and Materials:
The comparative retrospective study was performed in 20 patients with breast cancer without nodal involvement. The prescription dose was 50 Gy in whole breast and 60 Gy in concurrent boost, daily, in 25 fractions. For each patient, 2 plans were generated: 1) standard 3D field-in-field and 2) tangential volumetric arc therapy (tVMAT) with two 60° dual arcs. Plans where generated using Monaco® Treatment planning system (TPS), delivered for quality assurance (QA) purposes in Elekta Infinity® accelerator with 5 mm Agility® MLC, and measured in PTW OCTAVIUS®4D with OCTAVIUS® 1500 detector. Results and Conclusions:
Conformality indexes demonstrate the advantages of tVMAT technique versus the standard one, the average volume of breast irradiated with a boost dose (60Gy) in tVMAT technique is roughly 2,21% (±1,71), in contrast with a 9,33% (±7,07) in standard technique. Results indicate that dose to ipsilateral lung and heart can be reduced without compromising dose to target and contralateral structures. However, further assessments of clinical outcomes of treatments with tVMAT technique are needed to justify the need of additional QA and increased Monitor Units. Each particular institution should decide if the dosimetrical benefits of tVMAT technique can overcome the extra demands in time and resources.

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ANALYSIS FOR INTEGRAL FIGURE OF MERIT (FOM) TO THE EFFICIENCY IN COMPARISON OF IMRT AND VMAT COMPLEX DECISION PLANS

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Radiation Oncology – Quality Assurance

Introduction: The techniques of intensity-modulated external radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT) achieve clinical objectives satisfactorily, but due to their complexity, more robust quality assurance programs are needed. The choice of rival plans is complex, and it is necessary to take the best one, since it must be considered from the clinical objectives to the efficiency in the delivery of the treatment. Therefore, analysis tools are needed with parameters that evaluate not only the fulfillment of clinical objectives, but also the quality and efficiency with which they are reached. Methods and Materials: For the evaluation we used a Figure of Merit (FOM) expression constructed from various recommendations and that reveals which is the best plan by an index close to 1. We compared the treatment plans of IMRT and VMAT for 100 patients with the same clinical objectives. for a given region (breast, thorax, head, neck, pelvis), optimized by reverse planning and calculated with a treatment planning system (TPS),

Results: The results with the FOM reveal the strengths of both techniques in some specific situations, both techniques show excellent indexes (1 ± 0.1) of conformality (CI) homogeneity (HI) and gradient (GI), but the FOM reveals that the VMAT is more efficient than the IMRT. In spite of this, it is also shown that the IMRT is superior to the dose of dose / volume dependent organs at low doses such as in breast and thorax.

Conclusions: The choice of the best plan can become a problem when the clinical objectives seem very similar when comparing techniques. A robust figure of merit beyond the clinical, can be of great help for this decision.

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AN ADAPTATIVE RADIATION THERAPY WORFLOW WITH ELEKTA SYSTEMS

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Radiation Oncology – Dosimetry

Introduction:
During the radiation treatment, variations in the patient's anatomy or target volume may occur, which translates into a discrepancy between the planned dose distribution and that delivered to the patient. In response to these variations, it is possible to adjust the treatment plan during the course by means of complementary systems that allow, through the use of images, to adapt the treatment to reach a higher therapeutic quality. This type of treatment is called ""adaptive radiation therapy"".
Methods and Materials:
To execute the clinical procedures of adaptive radiotherapy, a specific set of ELEKTA systems is used. Before the treatment application, the location of the isocenter is verified by volumetric images (CBCT) obtained with the X-ray Volume Imaging System (XVI) that has a kiloVoltage x-ray tube. The radiotherapist, in conjunction with the Physicist, evaluates positioning corrections that are applied through the HexaPODTM RT system that includes the HexaPOD six-degree robotic couch and the iGUIDE® system to controls these adjustments. The CBCT images are exported to the MONACO® Treatment Planning System (TPS) to perform the dose calculation received by the patient in that application. In this instance, the anatomical and dosimetric variations and the need to perform a new planning tomography are evaluated. The dose of each session and the planned Histogram-Volume is compared with that delivered to the patient at the end of the treatment.
Results and Conclusions:
The methodology proposed with the available technology has allowed us to examine accurately the evolution of the patient's treatment, adjust the treatment in a short time to define new therapeutic strategies, deliver the dose with greater precision and maintain the volume treated with a greater conformation on the target volume.

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DETERMINATION OF THE IMPACT THAT IMPLIES THE USE OF REFERENCE DETECTORS IN THE MEASUREMENT OF SMALL FIELDS FOR THE OBTENTION OF OUTPUT FACTORS

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Radiation Oncology – Dosimetry

Introduction:
The behaviour of the physical phenomenon involved in the so called "small fields" represent restrictions in terms of measurements conditions and detector technology because they drift away from the reference conditions stablished in classical dosimetry protocols. The aim of the present study is to analyse the impact that implies the use of different type of detectors to measure the reference signal during the acquisition of transversal profiles of the beam, fundamental for the small field dosimetry procedure.
Methods and Materials:
The International Code of Practice, Technical Report Series N° 483 (TRS483), was applied to obtain Output Factors (OF) in Elekta Infinity® accelerator with 5 mm Agility® MLC. Measurements where made with PTW equipment: unshielded Diode E, parallel plane ionization chamber T-REF, ionization chamber semiflex 3D 0,07 cm3, ionization chamber Farmer 0,6 cm3 and automatic phantom BEAMSCANTM. Different measurements setups where defined, three of them used a reference detector (either Farmer, semiflex or T-REF) and a fourth with no reference detector. For each case profiles were surveyed and used both for the centering of the dosimeter and for the determination of the radiant field, necessary to obtain the correction factor k_(Qclin,Q_msr)^(f_clin,f_msr). Since the T-REF camera was designed specifically for small field dosimetry, these measurements were taken as reference for intercomparison, made with PTW Software Analyze.
Results and Conclusions:
It is observed that the reference signal obtained with T-REF has a greater stability compared to the signals obtained with semiflex 3D and farmer. However, the impact on the determination of field factors, in any case, even without using a reference chamber, is less than 0,25% for 6x6 mm2 fields, this difference becomes even smaller when the field size is increased.

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START-UP OF MANUFACTURED ACCESSORIES WITH 3D PRINTER FOR USE IN RADIOTHERAPY AND BRACHYTHERAPY

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Radiation Oncology – Dosimetry

The bolus used in radiotherapy correspond to uniform gel plates which do not always adapt to the anatomy of the patient, leaving air spaces which produce differences up to 10% in the dose for highly complex treatments. To improve this limitation, bolus with wax are generated, limited by their manufacture and mechanical resistance, until designing specific boluses printed in 3D. This technology is also applicable to brachytherapy creating superficial applicators and intracavitary devices. PLA and ABS are studied, offering a good equivalence tissue with approximate densities of 1.25 and 1.04 g/cm3 respectively. 10x10cm2 and 1cm thick plates are manufactured with 100% and 50% infill percentages with resolution of 0.2mm. These are scanned together with an assembly of RW3, ionization chambers and EBT3 slab. The dose calculation is performed for photons of 6, 18MV and Ir192 and 6 and 9MeV for electrons with the Acuros and eMC calculation algorithms respectively. For its clinical implementation, resistance tests of steam sterilization are carried out. Differences between the calculated and the measured are of 1.8% and 0.7% for photons of 6 and 18MV, obtaining for electrons 5% and 0.5% for beams of 6 and 9MeV. The planar results of the plates evaluating gamma tests are 90% for photons and 96% for electrons. The sterilization tests guarantee that the use of PLA at 100% infill the structure is not altered. This methodology will allow evaluating the materials to take a step towards clinical implementation. It is proposed to evaluate the optimization of printing time by modifying parameters such as resolution, filling percentage and the equivalence of the fabric to the plastic by varying the thickness according to the material used.

P-280

IMPLEMENTATION OF A PAPERLESS QUALITY ASSURANCE PROGRAM

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Radiation Oncology – Quality Assurance

Introduction:
A quality assurance program establishes systematic actions to guarantee the quality and safety of medical exposures to ionizing radiation, both for the patient and for the personnel involved. The advantages of using a digital platform to manage quality controls are mainly the agility in the recording and the access to the information to improve the result´s monitoring and evaluation
Methods and Materials:
The paperless quality program is designed completely in PTW Track-it platform. The implementation is programmed in stages which correspond to different departments (Radiotherapy, Brachytherapy, Radiodiagnosis and Nuclear Medicine), according to international protocols and recommendations specific for each department. Worklists were designed so that radiologists, physicists and engineers can access the platform and record their assigned tasks. Tests are organized in mentioned worklists by frequency and category so that they can be easily recognized. The platform can be accessed by mobile devices to make the task more fluid and the measuring devices used can be linked to the platform to achieve automatic registration of the results obtained in the tests. In order to filter the data and evaluate a specific parameter and analyze its behavior over time, customized templates where applied. This allows to manage the preventive and / or corrective tasks in the equipment in advance. Conclusions:
So far, the first stage of implementation has been completed, which corresponds to the Radiotherapy department.
The Track-It platform has proved to behave as a closed system, with an automatic non-rewritable and non-erasable link between the uploaded data, the device and the user who registered the result. Because of this, the platform has received the approval of The Nuclear Regulatory Authority of Argentina (ARN). In our experience, this system has allowed us to manage the pending tasks and the administration of resources to successfully complete the quality assurance program.

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ADAPTIVE PTV MODELING IN SET-UP MARGIN FOR VMAT HEAD AND NECK TREATMENTS

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Radiation Oncology – Treatment Delivery

Introduction: Radiation therapy of the head and neck is complex due to its target volumes and the proximity of several risk organs. The need for fixation and margins for the planning target volume (PTV) due to the uncertainty of the process, are necessary to guarantee the quality of the treatment. These baseline set-up margins (PTV = 5 mm) can be reduced by means of a quantitative image analysis allowing to create a model that achieves it safely and even adaptively. Achieving this, a greater decrease in morbidity.
Method and Materials: A semianalytical statistical modeling is created, generated by the offline and online measurements of the daily images acquired before each fraction of treatment. We analyze the cartesian displacements of the position of the planned isocenter (digital radiography image) and acquired (electronic portal image), through the bone marks and the relation of the accessory as a validating element. Isocenter displacement measurements are made for 100 head and neck patients with volumetric modulated radiotherapy arc therapy (VMAT). The treatments and their verification are with Linear Accelerator of 6 MV with electronic portal image system. The verification images used are anteroposterior (AP), posteroanterior (PA) and oblique.
Results: Post-modeling verifications show that the reduction of the PTV baseline margins (<5mm in X, Y, and Z) are safe, keeping the white volume covered.
Conclusions: For some anatomical regions where radiotherapy is performed, the movement of organs or internal margin volumen (ITV) is practically null, the set-up margin becomes relevant, and if the fixation elements are safe, these can be reduced by modeling reduction that can guarantee coverage to the PTV.

P-284

MONITORING OF CRYSTALLINE DOSE IN INTERVENTIONAL RADIOLOGISTS. OPPORTUNITY FOR IMPROVEMENT AND OPTIMIZATION

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Diagnostic Radiology –Dosimetry

Introduction: The Santa Fe Foundation within its radiological surveillance program has follow-up on the crystalline readings of interventional physicians since 2016. With the proposed new limit of 20 mSv / year, the readings of the last year were evaluated and compared with references of the European Union project ORAMED (Optimization of Rdication protection for MEDICAL).
Materials and methods: monthly TLD crystalline dosimetry monitoring data were analyzed for the group of 3 interventional radiologists dedicated to performing procedures based on the characterization of fluoroscopy times and accumulated dose (AD) of the most frequent procedures and of higher DA for the procedures performed in the institution, finally the doses in crystalline-month versus DA-month were normalized by interventionist for the last quarter of 2018.
Results: crystalline dose for 2018 of 25.3mSv 55.63mSv and 123.42mSv for each specialist exceed the proposed new limit of 20mSv. In the institution the most frequent studies are the placement and revision of endovascular devices with 21.9% and 10.6% respectively and the ones that contribute the most are Pharmacoangiography with 6224mGy and Arterio Pulmonar with 5860.6mGy. The values of Drystalline-month / DA-month for each collaborator in the last quarter of 2018 were compared with data from ORAMED, obtaining an average of 2.8 e-4 compared to 2 of the reference.
Conclusions:
Both the DA / Dc ratio and the readings of the three interventional doctors surpass the values of the reference and in all cases the proposed limit of 20mSv / year respectively, values that agree with the ORAMED data. What leaves open the discussion of the implementation of this limit in different countries, as well as the adoption of radiological protection strategies to optimize the doses found.

P-285

IMPLEMENTATION OF THE TRS-483 CODE OF PRACTICE: DOSIMETRY OF SMALL STATIC FIELDS USED IN EXTERNAL BEAM RADIOTHERAPY

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Radiation Oncology – Dosimetry

Introduction:
In 2017, between the IAEA and the AAPM, the CoP TRS-483 was published for the dosimetry of small static fields, where the formalism, the physics of small fields and the recommendations dosimetry reference and relative are established. CoP TRS- 483 is implemented seeking to improve dosimetric accuracy when using small static beams of photons.
Methods and Materials:
Quality Control (QC) is performed in the ionization chambers (3 semiflex 31010, 1 PinPoint 31023, 1 microDiamond 60019) using CT images to verify their status and rLCPE value, the QC tests are also performed in the tandem electrometer, cables and water scanning systems MP3-M. The measurements of CoP TRS-483 in beam of 6 MV are made for each Linac that allows the supply of dose of intensity modulated: precise with MLC 10 mm, synergy with MLC Agility 5 mm and Axesse with mini-MLC Beam Modulator 4 mm.
Results:
The calibration factor NDW of each of the ionization chambers is determined, the beam quality is determined for the Axesse from a fmsr=4x4cm2 and compared with the one made in its commissioning at 10.4x10.4cm2, the depth profiles (PDD, online, cross line) of small fields with different detectors and output factor values are compared between the TPS and each Linac. A program of dosimetric intercomparison of the calibration factors with their associated uncertainties is created and it is expected to create an inter-institutional intercomparison program in the Bogota city.
Conclusions:
The measurement of the NDW is established as an annual frequency test within the QA of the measuring instruments and the output factor in the QA to the planning system. The field size limit of each segment is established for the inverse planning process in Monaco IMRT or VMAT in: 1.5 cm (Precise), 1.0 cm (Synergy) and 0.8 cm (Axesse).

P-286

TYPICAL VALUES OF CONCOMITANT DOSE IN EXTERNAL RADIOTHERAPY TREATMENTS

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Radiation Oncology – Treatment Delivery

Introduction:
Image Guided Radiotherapy (IGRT) uses 2D and 3D images during treatment administration in order to test reproducibility and reduce uncertainties. In this technique concomitant dose can be excessive and typical dose values specification defines a good strategy to evaluate dose to patient and optimize the image quality required for therapeutic purposes. Considering that in this aspect the ICRP publication 135 does not provide numerical values or implementation details, we propose a method to determine typical dose values through the calculation of DLP for CT, D for iView system and CTDIvol for XVI.
Methods and Materials:
We compare quality assurance recomendations for image radiotherapy systems suggested by AAPM TG. No. 142, IAEA HH No. 16, ESTRO and SEFM. We implement, security, mechanic, imaging and dosimetric tests, where the optimization process is performed between the quality of the image and dose to the acquisition protocols. We study the statistic concomitant dose values obtained from simulation to treatment reproducibility for 30 patients clasified for clinical pathology, where the typical dose values are specified using the median of the data set.
Results:
With the proposed statistical analisys we designed a quality assurance program which leads to a improvement on the imaging process and treatment accuracy. for example: registration correction, calibration curve DER vs UH at different kV, optimization of gain and frame parameters in iView, and collimation, filter, angle of gantry and kV in XVI.
Conclusions:
The magnitude of typical dose values in radiotherapy treatments is determined, being no greater than 0.5% of the dose prescription. The quality assurance program for the institutional image system is established and the optimal protocols for image acquisition are defined.

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CORRELATION FACTORS BETWEEN DOSE TO WATER AND TISSUE OBTAINED FROM MCNP CODE FOR LOW ENERGY BRACHYTHERAPY PHOTON SOURCES

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Radiation Oncology – Brachytherapy

Introduction - Nowadays, it is well known in the literature the need to consider the composition of the medium in brachytherapy planning systems, especially in procedures that use low-energy photon emitting seeds. Despite this knowledge, the best way to report the absorbed dose is still a matter of debate, with favourable points for both water and tissue absorbed dose estimates. In order to perform a dosimetric calculation closer to reality, but still report the dose in water, was introduced the notation Dw,m (radiation transported in medium, dose scored in water). The goal of this work is to explore different estimates of Dm,m and Dw,m obtained from Monte Carlo (MC) simulations for a subset of human tissues of interest in brachytherapy, seeking to estimate conversion factors between them and to compare with the values obtained in the literature. Methods and Materials - State-of-the art MC calculations are used to score absorbed doses in spherical geometries centered on three types of low energy brachytherapy sources: 125I, 103Pd and 131Cs. In addition, the photon fluence differential in energy is estimated, since the correlation between the doses in water and the doses in tissue is performed through the cavity theory, which generally assumes that the fluence of the photons in water and in tissue are identical.

Results and Conclusions - The calculated conversion factors showed that the absorbed dose to water underestimates the absorbed dose to bone by up to 80 % but overestimates the dose in adipose tissue by approximately 75 %, emphasizing the need to consider the composition and the density of tissue in the dose estimates. All the results obtained showed that the estimation of the dose absorbed in low energy brachytherapy procedures differ significantly when performed in water and in biological tissues, emphasized the need to accurately consider tissue composition.

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COMMISSIONING OF GENERALISED GAUSSIAN PENCIL BEAM ALGORITHM FOR IRREGULAR FIELDS

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Radiation Oncology – Dosimetry

Introduction:
Many centers usually measure the electron output for each field with insert. We want to use the methodology proposed by the AAPM Task Group 71, to calculate the output factors and PDDs for different clinical inserts, from different square inserts measurements.
Methods and Materials:
Output factors (OF) values and extended SSD were measured for all the electron beams available using the Trilogy linac at the Hospital de Clinicas Caracas's (HCC) Radiotherapy Department, for all the applicators available and square field sizes from 2x2 cm2 to 25x25 cm2 (according to the applicator), using a PTW diode model 60017. In order to validate our methodology for other energies, measures of the 9 MeV electron beam were compared to the dosimetric data published by TG71. We feed our Eclipse Treatment Planning System (Generalised Gaussian Pencil Beam) with this data because initially it only considered the data of the OF for open fields and didn't consider the effect of inserts into the applicators for the monitor units (MU) calculation. Then, test treatment plans were created using rectangular and squared fields, different energies and different values of source- surface distance to the regularly used (100 cm). Test treatment plans were calculated by the TPS, calculated manually and dosimetrically measured in order to be able to compare the calculated with the measured data.
Results and Conclusions:
Results of the comparison between the MU's calculated by the TPS, manually and measured were within the tolerance value for most cases. This methodology simplifies the constant routine of measure the electron output for each patient.

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MULTIPLE BILATERAL LUNG LESIONS SABR TREATMENT: SINGLE-ISOCENTER Vs MULTIPLE-ISOCENTER VMAT APPROACH

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Radiation Oncology –Treatment Planning

Introduction:
Stereotactic ablative radiotherapy (SABR) with volumetric-modulated arc therapy (VMAT) is used since 2008 to treat limited lung disease. In this study, we proposed to compare single-isocenter vs multiple-isocenter approach in case of synchronous multiple bilateral lung lesions SABR.
Methods and Materials:
Six patients with bilateral lung disease were calculated in EclipseTM TPS (five fractions of 10Gy). For the first approach with one isocenter (located between the two lesions), two coplanar arcs were used. For the multiple-isocenter approach (isocenters placed centrally in each target), four coplanar semi-arcs were used for each isocenter. All plans were normalized to at least 95% of the PTV receiving 100% of the prescribed dose and Timmermann's constraints for the organs at risk were adopted. Conformity indices (CIs), normal lung V5Gy, V10Gy and V20Gy, spinal cord Dmax, D0.35cc and D1.2cc, heart Dmax and D15cc, esophagus Dmax and D5cc, trachea Dmax and D4cc were recorded in order to compare the two planning methods. Results:
PTV and OARs acceptance criteria were reached for all plans. No significant differences were observed in CI mean values (1.01±0.02 for single-isocenter vs 1.03±0.02 for multiple-isocenter). Mean normal lung V5Gy, V10Gy and V20Gy differences between single vs multiple-isocenter were 0.08±0.06%, 0.04±0.03% and 0.01±0.01% respectively. In the same way, the other OARs absolute dose differences between both methods were insignificant (spinal cord: ΔDmax=3.67±2.75Gy, ΔD0.35cc=3.56±2.14Gy and ΔD1.2cc=1.88±3.26Gy; heart ΔDmax=1.39±1.57Gy and ΔD15cc=2.77±1.84Gy; esophagus ΔDmax=-0.66±4.48Gy and ΔD5cc=0.03±1.90Gy; trachea ΔDmax=-0.28±4.1Gy and ΔD4cc=0.18±2.79Gy).
Conclusion:
The results obtained in this study show that single-isocenter approach is dosimetrically equivalent to multiple-isocenter plans and can be recommended to obtain excellent plan quality with faster treatment time (single set-up) in bilateral lung lesions SABR.

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AN ALGORITHM FOR MEDICAL MAGNETIC RESONANCE IMAGE NON LOCAL MEANS DENOISING

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Non-ionizing applications

Magnetic resonance imaging uses a magnetic field and pulses of radio wave energy in order to make pictures of organs and structures inside the human body. Reading MRI can give different information about organs. For medical image processing noise is one of the major problems which undesirably corrupts medical images. Removing the noise from an image can be done through a non-local means filter which has its own parameters. For this method it is necessary to find the optimal parameters for different levels of noise so that the filter be adaptable to the characteristics of the noise in the magnetic resonance images. In this paper, we propose a novel medical image denoising approach which is based on traditional NL-means algorithm. Non-local algorithm calculates pixel similarity weight of the entire neighborhood. The accuracy similarity weights depend on the level of the noise intensity. Non-local means algorithm is based on a process of averaging to incorporate all pixels in the image. In the filter processing, the process of averaging may be restricted to M ×M window matrix that includes only some pixels, so that the window matrix M × M is smaller than the dimensions of the entire image. Value of centered pixel of window matrix is calculated as weighted average of pixels that belong to that window.

P-292

ESTIMATION OF MAMMOGRAPHIC DENSITY IN WOMEN OF THE MAIN CITIES OF COLOMBIA – PRELIMINARY STUDY

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Diagnostic and Interventional Radiology – General

Introduction:
In Colombia, screening mammography was implemented as a strategy for the early detection of breast cancer, which seeks to facilitate the diagnosis of disease in early stages and generate a positive impact in reducing the mortality rate. The sensitivity of the mammography depends on the mammographic density, decreasing for the case of dense breasts. In addition, a high breast density increases the likelihood of developing breast cancer. This study aims to estimate the mammographic density of women who undergo screening mammography, allowing to improve the effectiveness of early detection programs for breast cancer. Methods and Materials:
In institutions that provide health services in the main cities of Colombia, a sample of 768 women who had digital mammography of screening was taken. The craniocaudal view and mediolateral oblique view for each breast were used to estimate the mammographic density. Only asymptomatic women were included, with ages between 50 and 69 years old. Mammography of breast that have prostheses, operations, microcalcifications or masses were not included. With each image, an estimate of the mammographic density was made using the open software Dmscan 4.0.
Conclusions:
· This study seeks to increase the positive impact on the screening of breast cancer, providing more information that may lead to changes in public health strategies.
· This study does not quantify the risk of developing breast cancer associated with breast density, but the information obtained from this analysis could be very useful for future studies on this topic.
· This is the first phase of a study in which the results found will be corroborated using a commercial software and the reports made by two radiologists.
· The national average corresponds to low density values (BI-RADS-2), so screening mammography in Colombia is in most cases an effective early detection method.

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THE EXPERIENCE OF 6 YEARS WITH VOLUMETRIC MODULATED RADIATION ARC THERAPY (VMAT) FROM AN ACCREDITED RADIOTHERAPY CENTER TO PERFORM IT IN HEAD & NECK PATIENTS: FROM COMMISSIONING TO TREATMENT

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Radiation Oncology – Quality Assurance

Introduction: Volumetric Modulated Radiation Arc Therapy (VMAT) is one of the most used techniques in head & neck treatments. The VMAT technique must be commissioned following several recommendations. This process can last a long time (fine tuning) to reach a high standard of quality. This work describes the processes that must be carried out according to the experience of 6 years, which led not only to an important accreditation, but to the successful treatment of hundreds of head and neck patients.
Method and Materials: The commissioning was carried out by acquiring mandatory curves for each calculation algorithm according to the manufacturer for depth profiles and doses for fields from 1 cm x 1 cm to 40 cm x 40 cm. In addition, the transmissions and dosimetric leaf gap (DLG) of the multileaf collimation system (MLC) were measured. All data was processed and formatted for the treatment planning system (TPS). Several cases recommended internationally were calculated and the respective adjustments were made to achieve accreditation with an anthropomorphic phantom of the PRC. Planning integrates Virtual Simulation with fixation with 3 and 5 point masks and clinical dosimetry must be verified with control by specific patient by dosimetry by ionization chamber, portal and radiochromic. The machine is a Linear Accelerator of 6 MV x- ray with electronic portal system (EPID).
Results: The results of the process obtain in the verifications by specific patient a gamma index standard of 2% / 2mmL for 2D dosimetry and <3% for 1D.
Conclusions: A robust Quality Assurance Program gives good results as planned. The development is done by sharing experiences and making improvements in time.

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CONSTRUCTION OF GYNECOLOGICAL PHANTOM FOR VERIFICATIONS OF THREE-DIMENSIONAL HIGH DOSE RATE BRACHYTHERAPY

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Radiation Oncology – Brachytherapy

High-dose rate brachytherapy is the main treatment for uterine cervix cancer. Brachytherapy based on three-dimensional images requires a quality control prior to its implementation to ensure that the prescribed treatment is delivered properly. The objetive of this work is to design and construct a phantom that allows reproducing 3D-brachytherapy treatments based on Computed Tomography images. The phantom consisted in polystyrene blocks and a block made of agarose gel with a mass concentration of 3%, where gynecological applicators and dosimeters were inserted. Dosimetric measurements were made at different points on the phantom using a PTW Farmer chamber type 30013, and compared with the results calculated by the brachytherapy planning software BrachyVision. TLD 700LiF:Mg,Ti and Gafchromics EBT2 films were also used to verify the feasibility of their utilization in the built phantom. For measurements with the cylindrical chamber, an absorbed dose in water calibration factor for Iridium-192, previously obtained according to the formalism proposed by the German Society of Medical Physics, was used. The measured dose with the Farmer chamber and the planned dose differs in ±1.0%. It was possible to insert the TLDs and films in the desired positions, obtaining point dose values and a planar distribution respectively. However, the analysis of these results is not quantitative, since these dosimeters were not calibrated in the energy of the Iridium-192. The evaluations carried out on the phantom propose the agarose as a tissue-equivalent material adaptable to the desired shape and size. The phantom turned out to be useful and very ductile, allowing measurements with the different types of dosimeters. In particular, it was demonstrated that the values calculated by the TPS are reproduced when measurements are made with appropriately calibrated ionization chamber, and in case of having a good calibration, TLD and films can be inserted with ease in the desired positions.

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COMMISSIONING OF BRAQUITERAPIA WITH 3D ACQUISITION AT THE ONCOLOGICAL HOSPITAL OF CÓRDOBA

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Radiation Oncology – Brachytherapy

The path taken towards the commissioning of 3D Brachytherapy with Co-60 at the Oncology Hospital of Córdoba is presented in full, in conjunction with the Quality Control Program implemented. Until 2017, the hospital had a Nucletron Microselectron Ir192 unit, using a reconstruction procedure based on semi-orthogonal radiographic plates for treatment planning. In the year 2018, a Co-60 ""Flexitron HDR"" team was acquired with gynecological applicators suitable for Computed Tomography and Magnetic Resonance, which in conjunction with the Treatment Planning System ""Oncentra Brachy""; The Siemens Somatom Emotion 16 tomograph and the Phillips MAC D digital portable device, make up the equipment of the brachytherapy service. It also has a dosimetric set suitable for the development of controls consisting of a well chamber and a PTW electrometer. Acceptance and Commissioning of the brachytherapy equipment and planner were carried out, developing the necessary safety tests; mechanical and dosimetric. The steps related to the procedure involving a treatment session were then adjusted: image acquisition, planning and administration. The change from 2D to 3D brachytherapy meant a decrease in spatial uncertainties in the reconstruction of applicators. The precision in the volumetric delivery of doses and the protection of organs at risk was clearly superior. While the times of the new procedure were similar to those previously recorded. In conclusion, the transfer achieves a great leap of quality in the hospital's Brachytherapy treatments. Currently there are more than 50 patients treated with 3D brachytherapy. It is expected to expand the use of MRI and incorporate complementary systems such as ultrasound to optimize the application of the treatment. Also develop a 3D printing phantom for accurate dosimetric measurements.

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SHIELDING CALCULATION USING MONTECARLO METHOD, FOR A CYCLOTRON OF HOSPITAL. DESIGN OF LOCAL SHIELDING ELEMENTS

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Radiation Protection

In the last decade, cyclotrons have been widely disseminated in industrial facilities, hospitals and research sites. In the field of medicine, they are used in the implementation of diagnostic techniques, from the production of radioisotopes used as tracers and in radiotherapy in the treatment of cancer. The radioprotection in the use of accelerators, is a concept that presents many aspects, the knowledge of the radiation fields is necessary for the design of shielding. There are numerous guides related to planning and installation as well as radio-protection protocols, however, these documents offer analytical methods for the calculation of shielding only in idealized geometries. Given the complexity of the physical phenomena related to the transport of particles, Monte Carlo simulations have become an increasingly popular tool. There are numerous Monte Carlo simulation packages, these codes equipped with libraries for the transport of radiation and neutron and charged particle interactions, together with the increase in the power of the computer, allow to perform evaluations of the radiation fields, the shielding equipment and magnitudes for radio protection. During this research was developed a Montecarlo model of the RDS-112 ""Radioisotope Delivery System"" installed in FUESMEN, through the use of the FLUKA code. The model includes the main geometric details of all the constituent systems of the accelerator and the complete architecture of the bunker. It was used to study the behavior of the current shield during the production of 18F. Multiple measurements allowed us to document the current levels of H * (10) doses of neutrons and gamma, during the irradiation of the new target with Niobium insert in the production of 18F. Two alternative proposals for shield optimization, called Model A and B, were modeled, based on the reuse of the present shielding pieces, for their subsequent evaluation based on the Montecarlo simulations.

P-297

APPLICATION OF THE SEVRRA RISK MATRIX IN A BRACHYTHERAPY SERVICE

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Radiation Protection

Introduction: Radiotherapy is a treatment characterized for being a complex process with multiple steps, in which the safety of its execution must be granted to avoid accidents. There are matrix of risk, like the System of Evaluation of Risk in Radiotherapy (SEVRRA) which allows the evaluation of radiotherapy facilities through a combined analysis of the frequency of occurrence of events that can initiate accidents, the probability of human mistakes or failures of safety barriers and the severity of the consequences of the events. This allows to define criteria of acceptability of the treatments and to identify the events that generate high levels of risk with its adequate proposal of barriers to avoid or mitigate such events. The objective of this work is to present the implementation of this tool in the Brachytherapy service at the Instituto Nacional del Cáncer (INC) its results.
Materials and Methods: The SEVRRA methodology was applied during March 2019 in the Brachytherapy service at the INC. Results: An 8% high risk was identified, corresponding mostly to the acceptance and start-up phase of the treatment, 57% moderate risk and 22% low risk, while the other practices used as references did not apply to activities carried out in the service.
Conclusions: This study allowed us to quantify and identify the defenses and weaknesses of the Brachytherapy service at INC that contribute to its safe use. In the present, work continues on the appropriate recommendations and considering the low percentage of high risk in its application, it's appreciated that there's no imminent risk of an actual accident. Finally, the applicability of the SEVRRA method in Brachytherapy and its great utility in the prevention of accidents is confirmed.

P-299

PREDICTION OF ISCHEMIC RISK BASED ON CARDIAC PRESSURE WAVES: AN APPROXIMATION FROM ARTIFICIAL INTELLIGENCE

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Biomedical Engineering

Introduction: Fractional flow reserve (FFR) is considered nowadays as the gold standard to indicate whether a stenosis can be held responsible for ischemia. FFR is measured in cardiac pressure wave during the state of maximum hyperemia induced by the drug Adenosine, where a value of FFR≤0.8 indicates risk of ischemia. This is an expensive and invasive procedure with possible side effects. In the last years, machine learning algorithms have demonstrated their potential in medical decision making, by predicting results based on a large amount of clinical data.
Methods and Materials: We worked with 141 patient's data. 54,6% of them have FFR≤0.8. For each patient, 43 features of the pressure wave in resting state were extracted, including physical and clinical interest features. The database was divided in a stratified way: 80% for training set and 20% for testing set. Seven different machine learning algorithms were trained using 10- fold cross-validation method. After that the performance of each model was evaluated.
Results and Conclusions: The algorithm that achieved the best prediction was Linear Discriminant Analysis (LDA). LDA has shown an accuracy of 0.85 ± 0.05 and area under the curve (AUC) of a Receiver Operating Characteristic curve (ROC) of 0.93 ± 0.04, compared to the prediction of another method: the ratio of distal pressure to aortic pressure in diastole region (accuracy of 0.79 ± 0.03 and AUC of 0.89 ± 0.5). When these two methods were compared a p-value of 0.05 was obtained. Therefore, the development of an algorithm based on pressure waves can be a useful tool in the prediction of ischemic risk without the need for Adenosine administration. We expect to validate this algorithm by achieving good predictions in a new group of patients and obtain the final classification model.

P-300

SRS MAPCHECKTM CHARACTERIZATION

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Radiation Oncology – Quality Assurance

The use of different detectors in CEMENER for patient-specific quality assurance (PSQA) in radiosurgery has been essential for pre-treatment verification. The SRS MapCheckTM is a specialized small-fields detector, since it contains 1013 diodes in an area of 77x77 mm2. The SRS MapCheckTM was characterized for energies of 6 and 10 MV. The calibration was carried out under manufacturers conditions, using the corresponding accessories. In addition, we used a StereoPHAN phantom for the response of the SRS MapCheckTM, as a function of monitor units and angle of incidence. Dependencies were determined relatives to source-surface distance, field size and dose rate. The results showed that the signal was linear in relation to the monitor units with a adjustment equal a R=1, it remained constant regarding the angle of incidence and the dose rate; also showed an increase respect to the field size but decreased with the source-surface distance. Therefore, the SRS MapCheckTM detector was ideal for pre-treatment verification in radiosurgery, since it varied less than 1% relative to linearity, angle of incidence and dose rate and less than 2% field size and source-surface distance. In this last version it was possible to calculate couch shifts in 6 degree of freedom, it had immediate response, it was necessary to use the StereoPHAN phantom and that measurements were in dose units.

P-301

DETERMINATION OF TRANSMISSION FACTORS FOR PHOTONS IN MULTILAYERED SHIELDINGS USING 4 MATERIALS: COMPARISON BETWEEN ANALYTICAL FORMULAE AND COMPUTATIONAL MODELING

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Radiation Protection

The aim of this paper is to determine the Transmission Factors (TF) for photons in multilayered shieldings using 4 different materials, through analytical calculation methods and computational modeling. The thicknesses and materials considered are as follows: 1.00 cm of ordinary concrete, 0.15 cm of aluminum, 0.10 cm of iron and 0.11 cm of lead. The layers were permuted in 24 different sequential arrangements. It was considered an isotropic point source emitting monoenergetic photons of energy 0.661657 MeV for interactions with matter. Analytically, the exponential attenuation and Taylor's buildup factors (TB) were calculated for infinite medium, it was also used the Broder's Equation (BE) and then, Microsoft Excel to calculate the TFs for different arrangements. In the computational modeling, the Monte Carlo N-Particle code (MCNP), based on the Monte Carlo Method (MCM), was used. MCNP simulations were performed to obtain dose values with and without the use of shielding arrangements, respectively, I and I0. The ratio I/I0 is termed as TF. The TFs of the 24 possible permutations has shown good agreement between the analytical methodology and MCNP simulations. Simulated TFs presents a slightly higher value in each combination. Regarding dose attenuation, the most appropriate order of materials in the source-detector direction is as follows: ordinary concrete, aluminum, iron and lead.

P-304

CORNEAL TOPOGRAPHY ACCURACY AFFECTED BY THE IMPROPER LOCATIONS OF THE CORNEA

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Radiology – Radiation Protection.

In this paper, we quantified the error of the corneal elevation due to the improper location of the cornea (defocus and decentration). We have been studying the effect in the evaluation of the corneal topography when is assesses by a reflection- based topographer. We have found important deviations from the actual values of the corneal reconstruction.

A prolate cornea (good approximation for a normal cornea) with radius $r = 7.80$ mm and conic constant $k = -0.25$, was simulated with its vertex in ten different locations (range: – 1 mm to 1 mm with step of 0.2 mm) respect to the optical axis. During these simulations both the radius and conic constant of the prolate cornea do not change to guarantee that the errors in the corneal reconstructions are only due to the improper locations of the cornea.

The RMS error increase as the defocus and decentration is larger. When the cornea has defocus of ±1 mm, the RMS error is not greater than 0.2 mm. While that, when the cornea has decentration of ±1 mm, the RMS error is not greater than 0.02 mm. Therefore, the defocus has a greater impact than the decentration in the accuracy of the corneal reconstruction. The reconstructed corneal surface at different defocus and decentration positions do not match with the actual cornea simulated in this study. The greater the defocus and decentration, the reconstructed values, move away respect to the actual value.

Results obtained in this study are of interest, because the effects described above could be associated to the corneal surface imperfections and not to an improper location of the corneal vertex as really happens, since the reflection-based topography system measures the deviations of the pattern imaged in the CCD to relate these with changes in radii of curvature, astigmatism, keratoconus, among others.

P-305

COMPUTATIONAL SIMULATION OF THE FLOW OF MAGNETIC NANOPARTICLES IN A NEWTONIAN VASCULAR FLUID

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Radiology – Radiation Protection.

The drugs transport through the bloodstream is a problem which has generated a large number of research and applications in bioengineering and has gained great relevance to combat tumors and vascular diseases. Among the available techniques, special attention is drawn to magnetic targeting drug-delivery by nanoparticles through the bloodstream to provide medicines to specific places within the human body where tumors and malignant tissues may be detected.

The principal dynamic variables to be considered in the study of the nanoparticle movement are usually the thrust forces, Stokes forces, magnetization force, and diffusion and reflection coefficients. The present work evaluates the scope of the implementation of a theoretical model which links these dynamic variables through the Newton dynamics formulation and the principles of hydrodynamics and hemodynamics.

The physical situation takes into account a cylindrical contour, adapting some geometrical characteristics to the large blood vessels. A set of magnetic nanoparticles is directed, through a vascular fluid with constant viscosity, by the incidence of external magnetic fields. This physical situation is simulated by the finite-element method to solve the differential equations obtained from the theoretical model, and the comparison of the results with other existing models let us find aspects to validate and to improve in the development of the implemented physical model.

P-306

RADIATION DOSE OPTIMIZATION IN CHEST X RAY: PHANTOM STUDY

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Radiology – Radiation Protection.

Introduction: Radiation dose optimization is a subject of constant concern in the field of radiology research. In order to reduce radiation doses, image quality parameters must be evaluated in order not to negatively impact the diagnosis of a patient due to a non-evaluable image.
Objective: This study sought to evaluate and optimize the radiation dose for the posteroanterior (PA) projection in the chest radiographic study, decreasing the exposure factors obtained from the literature.
Methods: For this, an acrylic model with attenuation characteristics similar to those of an adult standard thorax was manufactured, which is associated with a realistic analysis to simulate x-ray absorption and dispersion. Image quality was evaluated quantitatively using the NORMI 13 test phantom. Dose measurements included kerma in air at the entrance surface with ionization chamber, as well as an analysis of the variation of radiographic Exposure Index and Deviation Index were conducted.
Results: The exposure factors were reduced to 100 kVp and 2.5 mA in compliance with the appropriate image quality parameters. A dose value of 0.118 mGy was obtained with the use of such parameters.
Conclusion: This research provides a useful guide for medical technicians to optimize the radiation dose for this projection, in addition to clarifying concepts such as the Radiographic Exposure index and Deviation index.

P-307

CHARACTERIZATION OF OSL DETECTOR FOR IN VIVO DOSIMETRY

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Radiation Oncology – Quality Assurance

Introduction:
The accurate in radiotherapy is very important because compromise the treatment result. As part of the quality assurance in radiotherapy the in vivo dosimetry is an effective tool to detect errors or misadministrations. The most common detectors used for in vivo dosimetry are diodes, mosfets and TLD. This work characterized optically stimulated (OSL) dosimeters for in vivo dosimetry; that are designed primarily for external dose in radioprotection.
Methods and Materials:
Based on Report 87 of the AAPM, OSL dosimeters were characterized. With a 6MV beam (Compact Elekta). Factors were obtained: linearity with dose, reproducibility, field size, distance and angles.
Optical stimulated luminescence system that use dosimeters with aluminium oxide Al_2O_3:C, which are readout by a device connected to a software and use a calibration to determine the dose.
Results:
The corrected factors obtained for the detectors, it was found similar behaviour that we expect with diodes.
Conclusion:
The optical stimulated luminescence system with the detectors used in this work have the potential to use in clinic for dosimetry in vivo taking in account with the action levels.

P-309

EVALUATION OF PATIENT´S DOSE FOR CORONARY ANGIOGRAPHY AND PERCUTANEOUS TRANSLUMINAL CORONARY ANGIOPLASTIC PROCEDURES

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Diagnostic Radiology –Dosimetry

Over the past years, the application of fluoroscopically-guided interventional radiology (FGIR) procedures has spread to diagnostic and treatment centers, evolving into more complex procedures. These procedures are characterized by prolonged exposure times due to diagnostic and therapeutic needs, which implies an increased risk of deterministic effects, as well as an increased of the probability of stochastic effects in patients. In view of the above and following the recommendations of the ICRP Report No.135, typical values (TV) applicable to groups of patients undergoing coronary angiography (CA) and percutaneous transluminal coronary angioplastic (PTCA) procedures were determined in a hemodynamics service that counts with two angiographers from the Allura Clarity family. The evaluation and characterization tests of the radiation beam were carried out with the Radcal Accu-gold system, adopting the recommendations of the IAEA Safety Reports Series No. 59. The monitoring and analysis of 27 and 15 patients of CA and PTCA procedures, respectively, was performed. The entrance surface air kerma rates was evaluated using a solid water phantom. Our results show a VT for PKA of 4,5 y 12,3 Gy·cm2 for AC and PTCA procedures. The phantom entrance surface air kerma rates for the same techniques were 23% and 17% of the tolerance for the high and normal fluoroscopy modes, without magnification. Using a magnification of 22 cm, the values were 56% and 33% of the tolerance. The VTs found in this study are inferior to the published NRDs obtained in international studies. This study represented an advance in Colombia in terms of interdisciplinary work between interventional physicians and medical physicists, which is essential for the determination of reference levels and the optimization of patient´s doses for the interventional radiology procedures in the country.

P-311

COMPUTED RADIOGRAPHY EXPOSURE INDEX AS A DOSIMETRIC OPTIMIZATION TOOL

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Diagnostic and Interventional Radiology – General

Introduction: The screen-film radiography system limits the operator to use a limited range of technical factors to obtain adequate exposure. The implementation of the digital system had the advantage of a wide dynamic range of the detector that allows operators to use various exposure parameters, this led to an increase in patient doses, since technicians tended to use higher exposure parameters given the response of the detectors. the exposure index was developed In order to know the exposure received by the detector. So, this indicator allows the operator to objectively know if the exposure was adequate, sub or overexposed. Objective: The aim of this study was to obtain the lowest possible value for the IgM (AgfaTM Expo Index) by modifying the exposure factors without affecting image quality. Methods: Radiographic exposures were made to simulated diameters of a standard patient´s thorax, lumbar spine and pelvis in a computed radiology system. Simulated patients were designed using acrylic blocks. Based on the technical parameters indicated in a previous research, these were reduced by at least half, with the values of Kerma in Air in the Entry Area and Exposure Index recorded. Image quality evaluation was performed quantitatively using the NORMI 13 test object.
Results: It was possible to demonstrate that the IgM decreased by at least 0.3 with respect to the reference IgM. Kerma in Air at the Entrance Surface decreased to half with respect to the initial exposure factors and image quality was not impaired, therefore, the exposure index is a tool that allows to better guide the doses given to patients in each radiographic examination. Conclusion: The value of the Exposure Index should be considered as an essential data in the evaluation of the quality of a radiological projection with dosimetric.

P-314

EVALUATION OF A FREE TOOL DEVELOPED TO PERFORM MECHANICAL QUALITY CONTROLS ON LINACS USING THEIR OWN PORTAL IMAGING DEVICE

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Radiation Oncology – Quality Assurance

The present work was motivated by need to perform quality controls on linacs in a low-income institution such as a public hospital, optimizing use of resources. The objective is to obtain a tool easy to use and quickly to implement clinically, that facilitates control documentation. The work was implemented in a Siemens Artiste linear accelerator with Optiviue portal image system, which was proposed as a replacement for radiochromic films for routine controls. For the analysis of these images, the pylinac library written in python was available as well as several language libraries such as Scikit-image, Numpy, SciPy and Matplotlib. Through the use of these libraries and the acquisition of the portal images, Picket-Fence Starshot, Winston-Lutz, flatness and symmetry tests, orthogonality of MLC, coincidence of asymmetric fields and superposition of the symmetrical and parallel opposites fields were performed. The results obtained were compared with films, typically used to validate them. Finally, a graphic interface was developed in order to facilitate the analysis and documentation of these controls. In conclusion, a simple tool was obtained that allows the fast analysis and documentation of controls and thus increasing the frequency as well. This allows that the taking of images is done by the therapyst staff and that the controls will be then evaluated by the physics personnel.

P-317

DOSIMETRIC COMPARISON IN SMALL FIELDS SHAPED BY JAWS AND MULTILEAF COLLIMATOR

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Radiation Oncology – Dosimetry

Small fields of radiation are used often in the current external beam radiation treatments, since the advent of techniques such as intensity modulated radiation therapy and both intracranial and extracranial radiosurgery. Small fields present loss of lateral electronic equilibrium and most commercial detectors are too bulky to be used for this characterization, and when these are used it is necessary to take into account various correction factors. For this reason, it is important to perform a dosimetric characterization of small fields with appropriate detectors as used for this work (PTW microDiamond), this characterization ensures the use of small fields in a service of external radiotherapy with treatment techniques as above is showed. Dosimetry was made for small square and rectangular fields shaped by jaws and MLC Millenium from 0.5 cm x 1 cm with an increase of 1 cm in each axis, up to 4 cm x 4 cm for a photon beam with energy 6 MeV. Dosimetric characterization includes measurements of OARs at different depths: 15 mm, 50 mm, 100 mm, 200 mm, 300 mm; and PDDs. These dosimetric parameters were measured in a linear accelerator Clinac iX with a PTW Scanlift, and a diode PTW micro Diamond. From these measurements it was found: first, the penumbra of transverse axis of fields shaped by MLC is greater than with jaws because of the interleaf transmission of the multileaf collimator. Second in rectangular fields shaped by the jaws collimator when the field size in radial axis increases, the penumbra is modified in the transverse axis. A shift was also observed in the percentage depth dose to resize the field using both jaws collimator and MLC. It is noteworthy the importance of type of detector in performing dosimetric characterization small fields, which is not affected by the lack of lateral electronic equilibrium.

P-322

IMPLEMENTATION AND TRAINING OF ADVANCED RADIOTHERAPY TREATMENT TECHNIQUES TO RADIATION ONCOLOGY PERSONNEL – SERVICES PROVIDED BY HRS ONCOLOGY INTERNATIONAL

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Education and Professional Issues

Introduction:
The purpose of this work is to describe the methodology employed by HRS Oncology on the IMRT, VMAT and SBRT clinical implementation for prostate and Head and Neck in the Hospital Naval and Instituto Nacional del Cancer in Mexico City, Mexico.
Methods and Materials:
The following methodology was used: i.- Internal audit of dosimetric parameters required for linear accelerator commissioning, ii.- Optimization of required dosimetric parameters: Dosimetric Leaf Gap (DLG) and transmission factor (TF) to achieve correct delivery of advanced treatment techniques of IMRT, VMAT and SBRT, iii.- Internal audit and personnel training on treatment planning for advanced techniques using AAPM task group report TG119, iv.- Training on anatomical structures contouring and volume delineation in radiotherapy using ICRU 62 and 63 guidelines. Training on strategies for simulation, patient immobilization and positioning, and treatment planning for prostate and head and neck previously planned in 3DRCT. v.- Last but not least, obtain certification for this methodology by implementing an external audit from IROC, MD Anderson.
Results:
Results from internal audit of both relative and absolute dosimetry parameters show differences less than 0.8% compared to published references. Optimization of dosimetric leaf gap (DLG) and transmission (T) improved results of gamma index analysis from 95.7% to 96.7%. Implementation of TG119 demonstrates that current TPS installed in these sites calculates treatment plans according to this guideline and verifies that delivered doses by the linear accelerator corresponds to those calculated by the TPS
Conclusions:
The methodology implemented allowed radiation oncology department staff to perform in a safe and independent way all aspects related to simulation, planning, verification and treatment delivery of prostate and head and neck clinical cases for IMRT, VMAT and SBRT treatment techniques. These processes are within international quality standards and all obtained certification by IROC.

P-323

EVALUATION OF LONGITUDINAL TELEHEALTH COURSES FOR SRS/SBRT TRAINING IN LATIN AMERICA

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Education and Professional Issues

Introduction:
Stereotactic body radiation therapy (SBRT) and stereotactic radiosurgery (SRS) are effective treatments that can reduce treatment times and increase tumor control. While a growing number of Latin American clinics have acquired advanced technologies capable of administering SBRT and SRS, there are few accessible training opportunities and experienced clinicians that feel comfortable treating patients with SBRT/SRS. Rayos Contra Cancer (RCC) seeks to measure the effectiveness of telehealth support (providers assisting other providers) for practical skills in SBRT/SRS, which would greatly expand training opportunities for low-middle income country clinics worldwide.
Methods and Materials:
RCC performed telehealth training using the Project ECHOTM model for two high-volume cancer centers in Lima, Peru. During January to March 2019, twelve telehealth virtual classroom sessions were conducted through a SBRT/SRS curriculum developed by RCC. Sessions featured U.S.-based radiation oncology educators using the Zoom Web Conference platform. Surveys were given pre- and post-curriculum to measure participants' confidence in practical aspects of SBRT/SRS, based on Likert-scales of 1 to 5. Confidence in Identifying Structural Anatomy, Contouring Ability, Evaluating DVH, Plan Evaluation, Delineation of Tissues, Port Film Evaluation, and Cone Beam CT Evaluation was recorded through a RedCap Database. Results:
Pre- and post- surveys were completed by 31 telehealth participants: 8 radiation oncologists, 7 medical physicists, and 16 medical technologists. Participants' mean change in confidence was +0.2 (4.6 to 4.8) in Identifying Structural Anatomy, +0.1 (4.3 to 4.4) in Contouring Ability, +0.3 (4.3 to 4.6) in Evaluating DVH, +0.4 (4.3 to 4.7) in Plan Evaluation, +0.3 (4.2 to 4.5) in Delineation of Tissues, +0.2 (4.1 to 4.3) in Port Film Evaluation, and +0.0 (4.5 to 4.5) in CBCT Evaluation.
Conclusion:
Training for SBRT and SRS can be augmented via telehealth virtual classroom sessions for radiation oncologists, medical physicists, and medical technologists.

P-327

FABRICATION OF A BIO-CERAMIC BONE SUBSTITUTE BY USING SPONGE REPLICA METHOD

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Biomedical Engineering

Hydroxylapatite has its good biocompatibility and similar chemical composition to the mineral part of the bone. It has an important role and various application in bone tissue engineering. Porous hydroxyapatite scaffold has a high surface area, which leads to excellent osteoinductivity as well as reabsorbability and also providing fast bone in growth at the site of injury. In this study highly porous body of a nano structure hydroxyapatite scaffold was successfully replicated by sponge replica method.
Characterization: The compressive strength and the morphological structure of the scaffold were characterized by UTM machine and SEM image respectively. XRD technique was used to investigate the proof of formation of BCP powder.
The result of SEM analysis that, the prepared scaffold has highly interconnected spherical pores with a size in the range of 100- 500 micrometer and the compressive strength of the scaffold with the value of 1.425 ± 0.15 mega Pascal, Strut Diameter is 91 ± 53.27 μm; Porosity 80.57 ± 1.58 % and Standard reference value of porosity is 71 %.
The mentioned properties could make the Bi Phasic calcium phosphate (BCP) ceramic scaffold as a good candidate for bone regeneration application.

P-329

IMRT COMMISSIONING: IMPLEMENTATION OF AAPM'S TG 119 TO ONCENTRA EXTERNAL BEAM PLANNING SYSTEM

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Radiation Oncology – Dosimetry

Due to the recent clinical commissioning of the intensity modulated radiotherapy technique at the Hospital Oncológico of Córdoba, and to perform an independent check of the intensity modulated's algorithm available in the planning system that complements the TECDOC 1583's tests already performed on the system, the tests of American Association of Physicists in Medicine's TG 119 report are applied to the Oncentra External Beam planner.
Plans indicated by the report were made with targets and pre-defined structures drawn on the tomographic images of a solid wáter phantom 15 cm high to fulfill the objectives established in the document.
The obtained plans were irradiated with a Siemens Artiste linear accelerator, 160 leaf collimator.
Absolute point doses were measured with a PTW 31003 cylindrical ionization chamber and relative dose distributions by using a MapCheck 2 diode array from Sun Nuclear.
The maximum deviation of the measurements with ionization chamber was lower than the 3% limit recommended by the document. While the percentage of points passed the gamma criterion of 3%, 3mm was greater than the 95% recommended.

P-333

EVALUATION OF THE UNCERTAINTY IN THE POSITIONING IN RADIOSURGERY WITH THE ANGLED TREATMENT COUCH USING IGRT SYSTEM

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Radiation Oncology – Dosimetry

Stereotactic radiosurgery delivers a high dose (≥ 18 Gy) in small brain lesions in a single session. Therefore, it is extremely important to obtain high accuracy in the positioning and this can be achieved by using IGRT systems. The objective of the study was to evaluate the positioning uncertainty in radiosurgery technique with couch angulation, as well as to validate MV images for position verification. Using skull phantom printed in 3D, MV images were taken on the same incidents as HyperArc software. The linear accelerator used was the TrueBeam STx of the Hospital Israelita Albert Einstein and the immobilization of the phantom was performed with thermoplastic mask. The MV image was first validated with the CBCT, determining the residual uncertainty. In order to evaluate the identification of these errors using MV image, errors of 0.1 to 5 mm were inserted. Such errors were inserted through the displacement of the robotic couch.
The validation results of the robotic couch were within the expected range with an uncertainty near to the value obtained in the MPC test. A standard deviation of the order of 0.05 mm was obtained for the translation coordinates and 0.05 ° for rotation. The inserted errors of 0.1 to 0.3 mm showed reasonable compatibility in the longitudinal and lateral coordinates, but the rotational correction was not efficient for errors smaller than 1 ° since the correction was compensated in the other coordinates.
From the statistical analysis of measurements and other factors of influence, we can conclude that the MV image of verification during a frameless radiosurgery procedure in positions based on the HyperArc® technique can be used with confidence. It was possible to identify positioning errors greater than 0.2 mm with a 95% confidence level, due to the variation of the automatic correction software.

P-334

THE FIELD OF MEDICAL PHYSICS IN BRAZIL: (DIS)CONSTRUCTION IN PROGRESS

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Education and Professional Issues

This paper addresses the paradoxical construction condition of the Medical Physics field in the Brazilian scenario through an analysis of the representativeness of area, subarea and specialization in governmental agencies of science promotion and scientific-academic production. Therefore, the objective is to critically understand the state of Brazilian medical physics in its academic dimensions. The methodology was based on webscrapping and quantitative and qualitative analysis tools (such as ScriptLattes, Gephi, etc.) to collect and analyze data collected in public and open databases (Lattes curriculum, Sucupira platform, Lattes etc.) that have as a refrence the dissemination and the Brazilian technoscientific communication. The preliminary results point to the fact that the greater areas of medicine and physics produced in their overlap a field, or community of practices, whose knowledge of this egress does not necessarily contribute to the consolidation of a supposed field or area independent of physics. So, it is necessary to create a new scientific culture for the creation, maintenance, and reproducibility of the independent field of medical physics.

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ANALYSIS AND INTERCOMPARING THE SMALL PHOTON FIELD PROFILE ACQUIRED WITH DIFFERENT COMMERCIAL ACTIVE DETECTORS, EBT3 FILMS AND SOLID STATE DETECTO, BeO CYLINDERS

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Radiation Oncology – Dosimetry

Introduction: Advanced techniques introduced in radiotherapy, such as IMRT and stereotactic radiotherapy (SRS / SRT) use small photon beams, where the measurements of the profiles can lead to uncertainties that affect the treatments. These measurements are challenging due mainly to the absence of equilibrium conditions of charged particles, the size of the detector and the effects of composition and positioning problems [Pappas et al., 2008].
Methods and Materials: This study has been performed at the Royal Portuguese Hospital of Pernambuco, using a 6 MV, 10 MV, 15 MV, 6 MV FFF y 10 MV FFF beams of an STX linear accelerator model TrueBeam; measurements were carried out with a Blue Phantom2 (IBA) type beam scanning system and the OminiPro Accept v.s7 (IBA) software was used for data processing. The profiles were measured at 10 cm in depth with field sizes of 1x1cm2, 2x2cm2, 3x3cm2, 5x5 cm2, 8x8 cm2 and 10x10 cm2 (reference), and source-surface distance (SSD) of 100cm. The measurements were performed with the silicon diode (IBA-RAZOR), the ionization chambers (PTW-31022, PTW-31010, IBA-Razor Nanochamber), the solid state detector, BeO discs (Thermalox 995, Materion Ceramics Inc) with 3mm diameter and 1.5mm in thickness and were compared with radiochromic system, composed by EBT3 films and a scanner Epson 11000 XL.
Results: The silicon diode RAZOR and nanochamber penumbra widths are in good agreement with those obtained with the EBT3 films. Profiles measured with the PTW-31022 and PTW-31010 ionization chambers overestimated the penumbra of the fields, mainly due to their larger detection volume.
Conclusions: The silicon diode RAZOR and nanochamber presents an excellent spatial resolution for dose profile measurements, due to its small detection volume. The field sizes generally used in radiosurgery can be measured correctly, without producing significant uncertainties in the acquired data.

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A RETROSPECTIVE ANALYSIS OF CYBERKNIFE TRACKING ACCURACY THROUGH E2E RESULTS

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Radiation Oncology – Quality Assurance

Background: One of the most important parameters that must be accomplished during SRS/SBRT treatments is geometrical accuracy, which could be achieved by means of rigid immobilization devices. However, in frameless systems such as Cyberknife a set of trackings specified in accords to anatomical areas are applied in real time during treatment using online image guidance. Any residual displacements are made by the robotic arm. Total targeting error could be addressed by E2E tests. Comparing results against machine specifications is part of present scope of this work.
Materials and Methods: E2E results for a Cyberknife M6 were evaluated for 6D Skull, Xsight Spine and Fiducial tracking modalities using both cones and MLC collimators. An anthropomorphic head and neck phantom were used during the measurements. The mean value, standard deviation and coefficient of variation have been calculated. The latest parameter normalizes the standard deviation by its mean values and allows a better understanding between sample dispersions.
Results: Total mean accuracy of 0.35 ± 0,17 mm was found as a composite of all trackings. Individual results of 0,38 ± 0,16 mm, 0,35 ± 0,16 mm, 0,45 ± 0,16 mm were calculated for 6D Skull, Fiducial and Spine respectively. A maximum deviation of 0.84 mm for spine tracking was observed. The coefficient of variation applied for cones and MLC samples, regarding the same tracking, revealed a smaller dispersion for MLC.
Conclusions:
E2EtestshavebeenshowntobeaverypowerfulmechanismtoaddressmachinespecificationsforCyberknife.
Moreover, provide a description of the entire process, providing a meaningful evaluation of the human handling process and not merely mechanical behavior of the machine.

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PLAN COMPLEXITY ANALYSIS AND ITS CORRELATION WITH ARC INCREMENTS DIMENSIONS IN MONACO TPS

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Radiation Oncology – Dosimetry

Purpose/Objective: The correct understanding of the treatment planning system parameters is paramount to avoid creating plans that could not be representative or that might cause extra machine stress during delivery. From the numerous parameters available in Monaco TPS for VMAT planning we have tested how arc increment dimensions would affect other treatment parameters such as MU, treatment time and number of segments.
Materials and Methods: Ten prostate plans were evaluated using the increment sizes of 10, 20 and 30 in Monaco TPS. In order to avoid asymmetries in MLC distribution related to leaf over travels, isocenter was placed in the geometric center of the PTV. Despite of the increment values, all parameters such as number of arcs, minimum segment size and prescription remained the same. Values for modulation factor, number of segments, treatment time and total MU provided by Monaco console were evaluated and compared.
Results: Using smaller increment allows the system to create extra number of sectors in the arc, meaning that leafs will sweep back and forward more frequently. In terms of complexity metric, calculated by the modulation factor in Monaco it had a small impact. Modulation factors were spread from 2,3 to 4,5 regardless the increment size being used. However, by reducing the increment size from 30 to 10 have showed to duplicate the MU for the majority of the cases. Treatment time has been also affected.
Conclusions: Although changing arcs sector dimensions will not dramatically impact on modulation factors for prostate, it can be seen that increasing this value could reduce treatment time and MU. Nevertheless, it's important mention that it could potentially also increase the number of segments with less MU that could lead to dosimetric error during delivery.

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GOING CLINICAL WITH THE FIRST VARIAN HALCYON® MACHINE IN ARGENTINA

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Radiation Oncology – Dosimetry

Introduction: The first Varian Halcyon LINAC in Argentina had been installed replacing an older machine in a very busy office. Therefore, it was required that it went clinical in the vendor's specified time for that. This work describes the basic and clinically relevant tasks conducted by the Physics Department to achieve that goal.
Methods and Materials: A set of safety checks and a radiation area survey were conducted to assure a safe environment for public and staff before initiating the Installation Product Acceptance procedure as per the vendor's IPA-AL-ICP-A document. Percentage depth doses and off axis ratio dose distributions for Halcyon's 6X FFF beam were obtained using 2D automatic scanner and 0.125 cm3 ionization chambers, for different field sizes from 2 to 28 cm @ 90 cm SSD. Beam profiles were obtained at five different depth from Dmax to 30 cm. Detector positioning and water surface detection were achieved using a detector cap with radio opaque BBs. SSD verification was performed as per the vendor's image-based method too. 1D gamma fit analysis between measured data and both pre-configured and TPS calculated data was evaluated. Absorbed dose at reference depth was adjusted following IAEA TRS 398 protocol. MLC alignment, speed, positioning accuracy, repeatability and RapidArc Gantry speed/dose-rate/MLC speed tests were performed and analyzed with Portal Dosimetry. Several E2E IMRT and VMAT plans were produced using Varian Eclipse TPS on the CIRS thorax phantom and on a H&N phantom. Dose was determined in different points and compared to TPS calculation. Plans were also evaluated using Portal Dosimetry. Results and Conclusions: Mechanical and dosimetrical specifications were in tolerance as per the vendor's IPA-AL-ICP-A document. PDDs and OARs dose distributions passed 1D gamma fit analysis for 2% 2mm. E2E point doses were under 3% of TPS planned dose in all points.

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PORTAL DOSIMETRY IMAGE PREDICTION (PDIP) VALIDATION: COMPARATIVE BETWEEN COLLIMATOR SCATTER FACTORS (Sc) MEASURED AND CALCULATED

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Radiation Oncology – Dosimetry

Introduction: Our center implemented VMAT in a high-energy linear accelerator Trilogy® (Varian Medical Systems) installed in September 2017. Trilogy has an EPID detector with a software that allows to measure fluences from planning treatments and their comparison with calculated fluences. Portal Image Prediction Dosimetry Portal model (PDIP®) requires commissioning data and standard data provided by Varian. The outcome of this process is a kernel curve that is used to generate theoretical fluence planes. Validation of the whole system is a prerequisite prior to clinical use. Our goal was developing a complementary PDIP validation method by a comparative of measured collimator scatter factors (Sc) and calculated Sc by output factors (Scp) provided by Varian.
Materials and method: Sc from rectangular fields was measured with semiflex ion chamber with build-up cap. To obtain phantom scatter factors (Sp) from PDIP calculations, standard Scp data for PortalVision® IDU20, the final kernel curve and a script programmed in Python with related libraries were used.
Results: Our results show differences between measured data (Sc_IC) and calculated data from PDIP model (Sc_PDIP) for rectangular fields from 3x3cm to 30x30cm, with 6MV and 10 MV energies respectively. Until to 15x15cm, the results show differences less than 2.0%. Larger fields show concordant discrepancies with limitations reported by Varian.
Conclusion: The methodology shown, with other validation forms, allows us to implement the EPID / PDIP set and begin its clinical use for treatment arcs with fields smaller than 15x15cm. The advantage of this complementary validation is done through Sc, which is an independent parameter not used in the PDIP model generation.

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USE THE DRR IMAGES FOR 3D PLANNING IN BRACHYTHERAPY

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ONCOSALUD - RED AUNA, Peru

Radiation Oncology –Treatment Planning

Purpose:
Use the DRR images for 3D planning in brachytherapy.
Materials / Methods
Cone beam Elekta. Serie 335587 with program DRR XVI Version: 5.0.2. b72. 2014 Acelerator lineal Elekta Infinity with Agility Head. Serie153350
Planificador HDR Plus for Braquiterapy Version 3.0.6
Equipment for Brachyterapy Multisource HDR-Plus
Tomografo Optima
Methods:
Treatment was planned in 3d brachytherapy for cases of cervix and prostate in 30 patients, using the DRR images of the Cone Beam Linear Accelerator.
Results:
The reconstruction of needles and the dosimetry were compared with images of conventional Tomografo vs DRR images of Cone Beam. And a smaller difference of 3mm of positioning was obtained in the needle reconstruction for the case of prostate and intrauterine devices for the case of cervix. Regarding dose, no appreciable difference was observed.
Conclusion:
1. It is recommended to use the volumetric DRR to plan cases of 3D Brachytherapy.
2. A considerable saving of time was observed in the acquisition of the images during the treatment.
3. There was a noticeable benefit in the monetary cost for the center.
4. In case the brachytherapy service is inside the radiotherapy service, a great time gain is observed.
5. In centers that do not count, or their access is limited to tomographic images, they may choose to use the volumetric DRR images.

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SURVIVAL AND MIGRATION ASSESSMENT IN BREAST CELLS EXPOSED TO RADIATION MAMMOGRAPHIC

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Diagnostic and Interventional Radiology – General

Introduction: Mammography is a diagnostic imaging practice that uses ionizing radiation, which when interacted with DNA can cause mutations and may contribute to the carcinogenic process. The objective of this study was to evaluate whether the exposure to mammographic doses (8mGy and 16mGy) and the high dose of ionizing radiation (2000mGy) are capable of altering cell survival and migration capacity in human breast cancer cell lines (MDA- MB-231) and non-tumor (MCF-10A). Methodology: The cell survival assay is standard and determines reproductive cell death after exposure to ionizing radiation. This parameter, survival, was mathematically determined. To evaluate cell migration at low doses of ionizing radiation of 8 and 16mGy the Wound Healing test was performed.
Results: For cell survival, low doses of 8 and 16mGy X-rays were not able to induce cell death in the studied strains. On the other hand, the dose of 2000mGy produced the death of 50% of the population of irradiated cells, reducing the formation of colonies by 50%. In the evaluation of cell migration, the data suggest that low doses of ionizing radiation do not induce changes in the cellular microenvironment that lead to an increase in the migratory capacity of the analyzed cell lines. Conclusion: These data together suggest that low doses of ionizing radiation (8 and 16mGy) similar to those used in breast screening were not able to induce molecular changes leading to decreased cell survival and increased ability to migrate and eventually metastasize to secondary sites, in normal cell line and triple negative mammary tumor line, characteristics considered important in the process of carcinogenesis.

P-343

CALCULATION OF THE STOPPING POWER RATIO WATER-TO-AIR FOR REFERENCE DOSIMETRY IN HADRONTHERAPY

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Dosimetry – Reference quality

Accuracy in the Stopping power of liquid water and air is of fundamental interest in reference dosimetry for Hadrontherapy. In particle therapy, ionization chamber dosimetry requires the knowledge of the water-to-air stopping power ratio (SPRT). According to the International Atomic Energy Agency Technical Report TRS-398, the SPRT for swift proton beams can be calculated using a semi-empirical law as a particle range function. However, due to the complexity of the particle-energy spectrum for heavier ions, the protocol recommends taking a constant value of 1.13 with an estimated uncertainty of 2%. In more recent publications, a parametrization of the water-to-air stopping power ratio is proposed, but it depends strongly on the ionization potentials of water and air used. Other authors propose an approach based on indirect experimental measurements. In the present work, Stopping power of proton, helium, carbon and oxygen ions in liquid water and air are calculated using a distorted-wave model to approximate the ionization cross sections required. Taking into account only the primary particle spectrum (at the entrance channel), the SPRT can be approximated as the ratio of the stopping powers of water and air. The ratios of theoretical Stopping powers as a function of the incident energy and charge are compared with the obtained using the values recommended by ICRU Reports 49 (for proton and helium) and 73 (for carbon and oxygen ions). The dependence of the SPRT with the charge and energy of the incident ions is analyzed. Results are compared with the proposed by TRS-398 and the calculated by the semi-empirical approaches.

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COMPARISON OF HALF VALUE LAYER MEASUREMENT METHODS IN RADIOLOGY: DIRECTLY BY A SOLID-STATE RADIATION DETECTOR AND BY X RAY PRIMARY BEAM ATTENUATION USING 99% PURITY ALUMINUM WITH KNOWN THICKNESS SLABS

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Diagnostic and Interventional Radiology – General

The Half Value Layer (HVL) is a parameter used in the quality control to evaluate the x ray beam quality. The HVL can be obtained directly by a multifunction dosimeter with a solid-state radiation detector (method 1) or through the dosimetry of the x ray primary beam attenuation using aluminum with known thickness slab with 99% purity (method 2). The main problem of the method 1 is the under-checking x ray source equipment should be equal and operated under the same conditions as the tube reference quality diagram (graphic that presents the relationship among total filtration and HVL for certain tension). Knowing that the equipment is not alike or operated by the same manner, there are an uncertainty associated to these HVL measurement obtained automatically. Therefore, using a NOMEX® (PTW) and Cobia Smart®(RTI) dosimeter, and as source, x ray conventional (RX) equipment and mammographic (MM), the measurement of HVL were performed by both methods, using the tension of 28 kVp, for MM, and 80 kVp for RX, and the current-time product of 50 mAs. Using a NOMEX dosemeter the greatest percentage differences found were 30,8% for MM, presenting with as result (0,529 ± 0,001) mmAl and (0,7646 ± 0,0007) mmAl by the method 1 and 2 respectively. For RX the greater difference was 14,3% for fixed RX fine focus. For mobile RX (unique focus), 2,2%. For Cobia Smart detector the results were 3,1% for fixed RX fine focus, and for mobile RX, 2,8%. The discrepancy in the results, varying from 2,2% for mobile RX to 30,8% in MM, show the need of a calibration factor for the measurements of HVL performed when using method 1.

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DEVELOPMENT OF RISK ANALYSIS MODEL FOR RADIOTHERAPY

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Radiation Protection

In the radiotherapy process, it is essential to guarantee the quality of all the activities that ensure consistency between clinical prescription and administration to the patient, the prescribed dose in the target volume, minimum dose in the healthy tissue, treatment verification that determine the patient outcome and minimize the risks associated with the use of ionizing radiation. Worldwide, during the past 25 years, the growth in radiological incidents or accidents in the radiotherapy area have been documented, most of which are caused by events associated with human failures and not by failures associated with equipment, occurred more frequently in centers classified as high technology institutions. The aim of this study was to develop one model for risk assessment of the linear accelerator teletherapy process in Radiotherapy Services, using the risk matrix method proposed by the International Atomic Energy Agency (IAEA) and using a Risk Index (IR), which considers the frequency of initializing events, their consequences and the probability of failure of the security barriers involved. This model allows a regressive risk analysis, facilitating the identification of the safety barriers not implemented in the Radiotherapy Service and which ones have a considerable impact on the total risk. The model was tested using the information obtained through data collection in ten Radiotherapy Services located in Brazil, through interviews and filling out a form developed based on the auditing system of the International Atomic Energy Agency (IAEA) and the mapping of the linear accelerator teletherapy process. From the value of the Risk Index, it was possible to classify the level risk for each Radiotherapy Service. The results of this study indicate that the proposed model for assessing risk was sensitive enough to identify the areas that need improvement and the safety barriers that should be implemented to decrease the risk.

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PRELIMINARY STUDY OF THE EFFECT OF PROPOFOL, REMIFENTANIL AND VECURONIUM ON DYNAMIC VISCOELASTICITY OF HUMAN RED BLOOD CELLS

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Biomedical Engineering

Several studies have shown that Propofol, a drug commonly used in anesthesia, can alter the rheological properties of human red blood cells (RBCs) but there are poor reports about hemorheologic effect of Vecuronium and Remifentanil. In the present work, we have studied the effect of Propofol, Remifentanil, Vecuronium on dynamic viscoelastic parameters of erythrocytes from healthy donors using a newly developed instrument called Reómetro Eritrocitario Computarizado (Erythrocyte Computerized Rheometer), which is based on laser diffractometry technique. For this, healthy donor blood samples (n = 2) obtained by venous puncture and anticoagulated with EDTA were used. Samples were incubated at 37oC diluting equal volumes of blood with saline solution added with the corresponding anesthetic drug (Propofol 4 mg/mL whole blood; Vecuronium 0.15 mg/mL plasma; Remifentanil 5 and 10 ng/mL plasma). The following dynamic viscoelastic parameters were determined by quintuplicate for each RBC sample: elastic modulus (μ), membrane surface viscosity (η), deformability index (DI), shift phase and complex viscoelastic parameters (G', G", n´, n”) at oscillation frequencies of 0.5, 1 and 1.5Hz. Results show that all anesthetics used for treatment produced changes in the rheological behavior of the erythrocyte membrane, but in different ways. Finally, this type of study would be important to prevent possible postoperative microvascular complications.

P-353

INFLUENCE OF CALCULATED DOSE MATRIX RESOLUTION IN PATIENT-SPECIFIC VMAT QA RESULTS: SINGLE-POINT AND 2D MEASUREMENTS

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Radiation Oncology – Quality Assurance

Introduction: TG-218 recommendations have been implemented in our institution for the patient-specific VMAT QA measurements. Absolute dose verification is carried out with a single-point ion chamber, comparing dose measurement with volume average dose calculated by TPS. 2D measurements are carried out with a diode matrix detector attached to the gantry (perpendicular field-by-field method), with a plane dose comparison for each arc. In this study, we analyze the influence of the calculated dose matrix resolution from TPS calculation (Eclipse 13.6) in the QA results

Materials and method: Patient-specific QA calculations in phantoms were carried out with three different dose matrix resolution: 1.25mm, 2.5mm and 5mm for twenty patients. Difference found in average dose for single-point and dose plane distribution were recorded for each resolution.

Results: For single-point measurements, differences up to 1.3% can be found depending on the resolution used for TPS phantom calculation. In all cases, decrease the matrix resolution implies a higher average dose in the ion chamber. For 2D measurements, the low gradient regions were not affected by the changes in the dose matrix resolution, but areas with high gradient changed significantly. The 95% passing rate with 3%-2mm gamma analysis was achieved with the three-resolution matrix, but only the 1.25mm resolution was able to achieve it with the 3%-1mm gamma analysis.

Conclusion: Dose matrix resolution is a parameter that has an effect in the patient-specific VMAT QA results, so it has to be taken into account when comparisons are carried out between measurement and TPS calculations, especially if the TG-218 new recommendations are followed.

Keywords: TG-218, dose matrix resolution, patient-specific VMAT QA

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ANALYSIS OF THE VMAT-ARC PLANNING CONFIGURATION FOR SBRT PATIENTS: OPTIMUM TECHNICAL DELIVERY AND TOTAL TREATMENT TIME

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Radiation Oncology – Treatment Delivery

Introduction: In SBRT lung patient, number of VMAT arcs used is a parameter that has to be selected during TPS planning. In a standard 2Gy/daily fraction using two arcs, Eclipse/Trilogy® system (Varian Medical System) is configured to obtain the best plan keeping constant the maximum gantry speed (4.8º/s) whenever possible, in order to avoid gantry accelerations and decelerations. For 18Gy/fraction scheme, this is no longer possible with two arcs. A decision must to be made about numbers of arcs used. This study analyses the gantry speed variation and total delivery time in a SBRT scheme (3fraction x 18Gy) when a two VMAT arcs technique is used, compared with the minimum number of arcs necessary to remain 4.8º/s constant gantry speed recommendation.

Materials and method: Five dummy patients were planned with the SBRT scheme (18Gy x 3 fractions) with two different techniques: a) two coplanar VMAT arcs and b) the minimum number of VMAT arcs necessaries to remain gantry speed constant during the delivery. The speed gantry distribution and the total treatment time was analyzed in both cases.

Results: For the a) option, speed gantry varies between 1.4º/s and 2.5º/s, with a mean delivery time of 7.5 minutes. The minimum number of beams necessaries for keeping constant the speed was eight arcs, with a total treatment time of 10 minutes. In both techniques, the treatment plans achieved the RTOG-0915 constrains.

Conclusion: We have evaluated the minimum necessary number of VMAT-arcs for delivery 18Gy in a fraction remaining constant the maximum gantry speed (something desirable to avoid gantry accelerations and decelerations). A secondary advantage of using more VMAT-arcs would be that more control points are included during the inverse dosimetry. The disadvantage is that delivery time is increase in around 2.5 minutes.

Keywords: Treatment planning, delivery, SBRT, VMAT.

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DETERMINATION OF REFERENCE LEVELS FOR SOME CONVENTIONAL RADIOLOGY STUDIES AT THE NATIONAL UNIVERSITY HOSPITAL OF COLOMBIA

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Diagnostic Radiology –Dosimetry

Reference levels in radiology work as a guide to apply actions which ensure doses of patients exposed to ionizing radiation and begin through them processes of optimization, with the aim to obtain an acceptable diagnosis image quality. A fundamental issue for determining the so-called indicative levels was the development of the quality control of the X-ray conventional equipment in order to ensure the reliability of the measurements. Two methods were used to measure the surface entrance dose, the former through the use of the tube efficiency with specific parameters for each exam including a backscatter factor, the latter by using thermoluminescent dosimeters. The reference levels were established at the Hospital Universitario Nacional for thorax exam as it is the most frequent, lumbar spine since it involves greater radiation doses and abdomen. The clinical evaluation of the image was made for every exam at least on one of its projections. Results produced reference levels below the international levels, which can be explained by the advances in digital radiology. However, it is suggested that the process of optimization of the installation is started by introducing the scrap factor and training in the operation of the automatic exposure control as an essential tool to diminish radiation doses with the purpose of reaching the standardization of the acquisition protocols of the majority of conventional radiography exams.

P-356

QUANTITATIVE AND QUALITATIVE EVALUATION OF THE EFFECT OF ATTENUATION AND SCATTERING CORRECTIONS IN DEEP AND PERIPHERAL REGIONS ON SPECT IMAGES

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Nuclear Medicine

Two phenomena that influence the formation of images within nuclear medicine are the scattering and the attenuation of photons. The first one deflects the path of the photons in order to make it difficult to locate the emitting source within the patient and thus to form images. The second reduces the number of photons, causing the count to change and again we have an interference in the produced images. Due to the above-mentioned facts, it is important to use corrective methods for these effects, since both generate a decrease in the quality of nuclear medicine images. In this work we will be using some methods for correction of attenuation and scattering in order to compare them and to verify which one presents a more significant improvement in the quality of SPECT images. In addition, we will observe the influence of distance in these processes, when evaluating the emission of radiopharmaceuticals housed in deep and peripheral regions of the objects of study, due to the fact that the greater the path traveled by the radiation, the more interactions will occur. The main methods for correction are Dual Energy Window (DEW) and Factor Analysis for scattering, and correction considering a single attenuation coefficient (Chang) or considering an attenuation map by means of CT for attenuation. In this study, these methods were developed in the form of software in Matlab, and were applied to images obtained by simulations using the GATE software. After GATE imaging, corrective methods were performed and corrected images were compared by quantitative methods (such as gamma function) and qualitative methods (improvement in the visualization of structures) in order to observe the positives and negatives of each method.

P-357

BREAST CANCER: IMMOBILIZATION SYSTEM FOR HYPOFRACTIONATED SCHEME IN PATIENTS WITH INCREASED BREAST VOLUME

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Radiation Oncology – Treatment Delivery

Currently, in our institution 30% of the patients are treated for breast cancer and in some cases, we use hypofractionation scheme, mostly in early stages, with equal oncological and long-term cosmetic results. Patients with increased breast volume are frequently excluded from the hypofractionation scheme due to the toxicities associated with the organs at risk (lung, heart, maximum point of global dose and in the areas of folds). The purpose of this work is to earn experience with a thermoplastic thorax/breast immobilizer, thus improving key factors such as: dose homogeneity, reproducibility of treatment fields, percentage reduction of dose in organs at risk and minimization of toxicities in areas of folds, to be able to incorporate this group of patients to the hypofractionated scheme.
Methods and Materials:
From the breast immobilizers that we have available in our service (WingBoard/Breast Ramp) an adaptation was made to incorporate a thermoplastic mesh with dimensions of 290x530mm and 2.4mm thickness. A group of patients were selected according to clinical characteristics and then two tomographies were performed (with or without immobilizer) to make a dosimetric comparison with the Eclipse treatment planning system. A clinical evaluation according to RTOG criteria was made to follow up these patients.
Results and conclusions:
The study showed:
A dosimetric reduction in 30% and 40% of the maximum dose and V20 in ipsilateral lung, respectively. Decreased diaphragmatic movements improving the uncertainties associated with positioning. Skin toxicity RTOG grade 1 and 2 in all cases. We observe good versatility of the device to reduce/eliminate skin folds and to improve positioning reproducibility in these groups of patients with large breast volumes.

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BEHAVIOR OF THE CT NUMBERS USING SEVERAL RELATIVE ELECTRONIC DENSITIES PHANTOMS IN A CONE BEAM CT

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Radiation Oncology –Treatment Planning

Introduction: Our center VMAT with IGRT was implemented in a high-energy linear accelerator Trilogy® (Varian Medical Systems) installed in September 2017. This accelerator has a conical-beam (CBCT) X-ray source/detector (OBI) that allows to correct the planned target volume (PTV) location prior to patient irradiation. In order to use 3D-OBI images in clinical dosimetry planning, with inhomogeneities corrections, is mandatory to perform a CT number (#CT) to respect a relative electronic densities (RED) calibration curve. Our goal was to determine the #CT behavior in CBCT with respect to its reference behavior in a fan-beam CT.

Materials and methods: CIRS062® and CATPHAN604® cylindrical phantoms were used to determine the #CT behavior with a length of 5 cm and 20 cm (Z-axis), respectively. These have calibrated RED inserts with soft tissue, bone, water, air and dense polymers. The #CT were obtained from images acquired from CBCT in half-fan mode at 125kVp.

Results: Our result shows the #CT behavior in a CBCT with respect its reference behavior in a CT. In CBCT, #CT from CATPHAN604 showed a similar behavior to the reference behavior, both with positive slopes in DER > 1.000 zone. In another hand, CIRS062 showed an anomalous behavior with #CT significantly lower in DER > 1.000 zone. This alteration is a consequence of the increase in scattered radiation that reaches the OBI detector panel.

Conclusion: The behavior of #CT in a CBCT for DER phantoms of different lengths was determined. For #CT calibration in a CBCT, the use of phantoms designed for fan-beams is not recommended, since their #CT are computed in an altered manner.

P-359

EXPERIENCE OF 14 YEARS OF QUALITY AUDITS IN RADIOTHERAPY IN CHILE

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Radiation Oncology – Quality Assurance

Introduction:
With the modernization of the radiotherapy public services, the evaluations carried out by the Institute of Public Health of Chile (ISP) in these services were modified and from 2006 they acquire the character of quality audits. At present, these audits have expanded to all services and have also incorporated different evaluation methodologies depending on the new technologies installed in the country.
Methodologies:
Through technical visits, the reference dosimetric systems of the radiotherapy services are compared with the dosimetric system of the ISP. The calibration of photon beams is verified, according to the TRS-398 protocol. The calculation and administration of the dose is verified using type fields. Postal dosimetry system is also used, developed by the Radiotherapy Quality Program of the National Cancer Institute in Rio de Janeiro, Brazil, which allows the verification of the dose under reference and non-reference conditions.
Results:
The number of equipment included in the evaluation of the audit, from 2006 to 2019, increased by more than 300%. The comparison of the reference dosimetric systems has shown satisfactory results within ± 2%. The deviations detected in the calibration of the photon beams during the technical visits have been within the research level.
Conclusions:
The work developed through quality audits has demonstrated the importance of redundant checks on radiological protection of the patient. The incorporation of the postal audit allowed increasing the number of equipment evaluated per year. The need of the incorporation of new evaluation methodologies for advanced and more complex techniques that are implemented in radiotherapy services is confirmed.

P-360

IMPLEMENTATION AND MONITORING OF SERVICE THE HIGH-DOSE THERAPY WITH IODINE 131

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Radiation Protection

Iodine 131 in high doses is used for treatment of thyroid cancer, all the therapeutic procedures that are carried out in nuclear medicine, iodine 131 is the most exposure generate for staff and public. During therapy with Iodine 131, external exposure is considered the patient which is itself a radiation source, there is risk of internal and external exposure through secretions in urine, saliva, sweat, patient waste between others.

MEDINUCLEAR, implemented the therapy service with Iodine 131, taking account the optimization practice and dose limitation, dedicated area was designed with rooms, solid waste management, washing and external area to visit by video call , shielding calculation was established; the risk of internal exposure due to contamination in the rooms is handled by cleaning protocol, protection of contact areas and separation of excreta, the handling urine is carried out with a system of EDEC decay tanks from TEMA SINERGYE. The service was implemented in 2015. During the first year dosimetric follow-up was performed to the nursing assistant where the average monthly dose was within the allowed dose of the public, the dose for medical physicist and specialist in nuclear medicine are within the levels for personnel occupationally Exposure, the risk to external radiation for clinic staff was optimized with the use of an internal barrier with 6mm lead shielding, the patient is educated in the food they eat and making use of disposable implements, annual discharges of 3000 liters have been released to the environment fulfilling the levels of dispensation.

P-361

REDUCTION OF THE ACQUISITION TIME TO HALF IN THE MYOCADIAC PERFUSION IMAGING BY IMPLEMENTING THE OSEM-3D RECONSTRUCTION METHOD OF THE OASIS SOFTWARE PACKAGE

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Nuclear Medicine

Results of Myocadiac Perfusion Imaging (MPI) using OSEM3D reconstruction and half-time acquisition were compared with the results of FBP reconstruction and MPI full time by mean of CardiacREquant-Cardiogam (Oasis 1.9.4.2 sp2.10735 on Windows 7 x64) for the same patient. The images were evaluated by a clinical expert. Fifteen patients suffering or suspected coronary artery disease were included in this study. Gated-SPECT of MPI were performed to all patients. Full time (25s and 20s per angle, for 8-10mCi and 30-35mCi, respectively) and half time (12s and 10s per angle, for 8-10mCi and 30-35mCi, respectively) acquisitions were carried out to each patient. We evaluate that the MPI half-time applying OSEM3D reconstruction is clinically acceptable for use. Correlation between FBP- MPI full time and OSEM3D-MPI half time result is within reasonable clinical parameters in patients included in this study.
Myocardial perfusion per segment, ejection fraction and wall motion and thickness were evaluated in each patient by an expert nuclear medicine doctor. As results, a good correlation between FBP-MPI full time and OSEM3D-MPI half time result within reasonable clinical parameters was obtained in patients included in this study.

P-363

MEASUREMENT OF PERFORMANCE CHARACTERISTICS OF PHILIPS GEMINI TF64 PET/CT

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Nuclear Medicine

The Philips Gemini TF64 PET/CT is integrated by a third generation fully tridimensional whole body PET scanner with time- of-flight technology (TOF) and a 64-slice Brilliance CT scanner. The main purpose of this study was to measure the performance characteristics of PET component of the PET/CT scanner. Spatial resolution, sensitivity, scatter fraction, counting rate performance, image quality and accuracy were measured according to the NEMA NU-2 2007 procedures. Additionally, to characterize the effect of TOF reconstruction on lesion contrast and noise, the standard NEMA image quality phantom was reconstructed with and without TOF capability. The measured values of transversal and axial resolutions, absolute sensitivity of the PET scanner at the center and at 10 cm off-center, scatter fraction, counting rate performance, accuracy of correction for count losses and random coincidences as well as image quality measurements of lesions contrast and background variability were within manufacturer specifications. A modest improvement of lesion detectability was observed when standard NEMA image quality phantom was reconstructed using TOF capability. The measurements of performance characteristics of the PET component of Philips Gemini TF64 PET/CT scanner installed at the Institute of Oncology & Radiobiology satisfies the manufacturer specifications.

P-365

DOSIMETRIC EVALUATION OH THE LINEAR ACCELERATOR MODEL SYNERGY AIMING THE IMPLEMENTATIONS OF THE TECHNIQUE VMAT

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Radiation Oncology – Dosimetry

In recent decades radiotherapy lived with a great technological evolution, not only in equipment but also in treatment techniques. The rotational intensity modulated technique also known as VMAT is even more complex when compared to IMRT due to their higher number of degrees of freedom, such as gantry rotation and dose rate. Despite few centers have VMAT as a treatment option, this technique is already a reality in Brazil and its clinical implementation requires a rigorous quality control program. Aiming to ensure that the linear accelerator, using this technique, delivered the correct dose to the patient, in this work a dosimetric study was performed to implement this technique. The work was adapted by TG119 and divided into three parts. It was assumed that all mechanical tests had already been performed, so the End to End tests were performed for dosimetric verification. In the first step a solid water plates phantom with two ionization chambers was used to measure dose in the low and high gradient region. In the second step the main TG119 tests were adapted for the VMAT technique and performed following the TG119 recommendations. In the third step a phantom with heterogeneity was used in order to force a more complex fluencemap. In all tests satisfactory results were found, since the objectives planes until the planning quality controls and the point dose comparison with the ionization chamber. The plannings were evaluated by the Gamma evaluation method and approved following the criteria proposed by TG119 and TG128, were all points has an approval beyond 95% as the previous documents named recommend. The dose comparisons between the TPS and the ionization chamber had smaller differences than 3% suggested by TG119.So it can be concluded that the dose delivered to the patient will be performed in a correct way under the established limits.

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DOSIMETRIC ANALYSIS BY MONTE CARLO SIMULATION OF PHOTON RADIATION THERAPY IN THE PRESENCE OF ORTHOPEDIC FEMUR PROSTHESIS

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Radiation Oncology – Dosimetry

A factor that affects the quantification of dose in an external radiotherapy treatment is the presence of artifacts, such as those generated by femoral prostheses, which have high density and high atomic number Z. Since in these cases it is a challenge to accurately calculate the dose distribution, one of the most common method to solve the problem is contouring in the treatment planning, as if they were water, the high density and high-Z materials and the artifacts around. Recalling the higher incidence of prostate cancer in elder men, the goal of this work was to determine by Monte Carlo simulation how dose distributions in 3DRT and IMRT prostate cancer treatments are affected due to the proximity between the prostate and the femur. A titanium (Ti) prosthesis submerged in an elliptical water phantom (representing the pelvic region of the human body) was simulated and irradiated by photons of 6 and 18 MV using the Geant4/TOPAS Monte Carlo code. The dose distribution was analyzed and compare with the simulation without Ti prosthesis. It was found that in the presence of Ti implants the dose increases between 20% - 35% due to scattered radiation. Additionally, different prostate tumor sizes were simulated with the presence of prosthesis, finding that around of the PTV the relative dose increases by approximately 2%.

P-367

FEASIBILITY STUDY: USE OF CINE-MRI FOR MR-GUIDED PT

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Radiation Oncology – Treatment Delivery

Introduction:
Cinematic Magnetic Resonance Imaging (cine-MRI) are fast time-resolved 2D MRI sequences that allow online visualization of organ motion without exposing patients to ionizing radiation. In this study, the potential of cine-MRI for the definition of an image-based gating criterion in particle therapy of pancreatic cancer is investigated. Transversal cine-MRI are employed to segment the pancreas, since they can provide information on tissue changes in the beam-path during delivery.
Methods and Materials:
Volunteer data were acquired on 10 different acquisition days. An image-based gating window was defined based on the breathing-curve (BC) of the first day (end-exhale breathing phase). The superposition of the pancreas segmentations in this window was calculated. For other days of data acquisition, the agreement with this initial superposition contour was evaluated by using different segmentation image similarity metrics.
Additionally, a motion analysis of the pancreas was performed.
Results and Conclusions:
From the metrics comparisons, a gating criterion was defined to establish when irradiation can be allowed. An evaluation of the dosimetric differences due to differences in the segmentations achieving the criterion and the spatial location of the organs was carried out for a proton treatment. This study shows the potential of an image-based gating window definition by using similarity metrics and cine-MRI. Although the method applied was subjected to several limitations, it was proved to be feasible.

P-369

AMORPHOUS SILICON PANEL USAGE TO DEVELOP A NEW CYBERKNIFE M6 LASER SYSTEM-RADIATION COINCIDENCE VERIFICATION METHOD

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Radiation Oncology – Quality Assurance

The Cyberknife-M6 laser system is used to visually represent the radiation field centre within 1 mm tolerance. It is used for important tasks like positioning detectors in water tanks, paths verifications and calibrations for each collimator type (Fixed and MLC) and user recorded points shifts over time. Thus, a high constancy of laser position is required. Manufacturer recommended test requires use of films, result time consuming, user dependent and a low precision method. To develop and establish a filmless, less time consuming, less user dependent and higher precision test is the objective of this work. Methodology makes use of an amorphous silicon (aSi) panel, the Ciberknife conventional film method and an IBA® water tank to measure laser-radiation deviation. ASi-panel measurements were done right after water tank and film measurements taking into account aSi-panel effective point position. These 3 sets and methods were used to determine precision and accuracy among the three. Knowing the panel resolution, pixel position was transformed into distance. Controlled displacements, from 0.2 until 3.3 mm, were introduced in Crossline and Inline directions in order to test device response.

Results: water tank method: 0.24 mm average deviation, 0.03 mm standard deviation and 11.47 % variation coefficient. aSi- panel method: 0.8 mm initial deviation and deviation measurements for introduced displacements are between 1.02 mm and 3.44 mm. film conventional method: 0.68+/-0.34 mm average deviation. As for objective compliance, a simple experiment and calculation have been necessary to determine acceptable precision and low accuracy for aSi-panel. Therefore, it is recommended to use aSi-panel for constancy only tests. Correlation with water tank deviation values should be determined by a new software development. Film method has shown no overall process advantage. Time saving is notable aSi-panel 15 minutes, films (1 hour), water tank (4 hours).

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CONVERAY: CONVERGENT BEAM RADIOTHERAPY

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Biomedical Engineering

Introduction:
Converay® is a novel technology suitably designed to be adapted to LINAC head producing convergent photon beam, which is produced by the perpendicular impact of LINAC electrons on thin cap target.
Methods and Materials:
Initially, device concept was studied and optimized by Monte Carlo simulations. Then, the first prototype was constructed demonstrating the feasibility for the electron beam control by high intensity magnets as well as the production of convergent photon beam by bremsstrahlung.
Results:
Remarkable improvements in dosimetry performance are achievable by CONVERAY®, obtaining high peak dose at convergence focus, this strongly minimizing surface and surrounding tissues.
Conclusions:
The CONVERAY® device demonstrated to be feasible and reliable with noticeable advantage when compared with traditional (divergent) beams. CONVERAY® output can be adapted for photon as well as electron convergent beams.

P-372

INFLUENCE OF THE KILOVOLTAGE VARIATION IN THE PET-CT QUANTIFICATION

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Nuclear Medicine

PET-CT studies have great relevance in the diagnosis of pathologies associated with neoplasms and tumor, due to the fused images with anatomical (CT) and metabolic (PET) information. Despite the benefits provided by this type of study, there are some disadvantages, such as the high radiation doses received by the patient, from the radiopharmaceutical administered and the dose provided by the CT. Therefore, the radiation dose optimization in these studies is very important. In this work, we proposed to evaluate the effects of the kV level on the CT part, in the quantification of PET images. To do that, a cylindrical phantom filled with water and four FDG sources fixed in its interior was used, and PET-CT images of this phantom were acquired using different values of kV. The images were processed with the OSIRIX/HOROS software, obtaining SUV values from each source of FDG. Subsequently, a statistical analysis was carried out in order to evaluate the significant differences between the SUV values of each sources for the different kV. As conclusions, it was corroborated that the variations of the kV in the CT did not affect the quantification of lesions in the PET images. Due to, we proposed that the dose provided by the CT can be decreased, without affecting the detectability of PET lesions.

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KIDNEY MOTION DURING RESPIRATION - IMPLICATIONS FOR SABR TREATMENTS

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Radiation Oncology – Treatment Delivery

Introduction: Stereotactic ablative radiation therapy (SABR) is a promising option for treating kidney tumors. This study aims to investigate the normal kidney motion and its implications for margin definition in such treatments.
Materials and Methods: 50 patients were imaged using 4D computed tomography for SABR to the abdominal region other than the kidney. Images at inhale and exhale phases of the natural breathing were obtained with the aid of a commercial bellows system and transferred to a registration system (MIM v. 6.5, MIM Software Inc.). We assessed volume changes, displacements of the center of mass and organ rotations between the two phases.
Results: No population trend for renal volume change due to breathing was observed despite individual variations of up to 25%. Mean displacements were 0.3mm±0.8mm (range -1.7mm to 3.4mm), -0.5mm±0.9mm (range -4.7 to 1.4) and 3.6mm±3.3mm (range -0.4mm to 16.4mm) in the left/right, anterior/PA and superior/inferior directions for left kidneys, and 0.2mm±0.9mm (range -3.0mm to 1.3mm), -0.9mm±1.5mm (range -4.5 to 1.0) and 3.9mm±4.1mm (range -1.3mm to 18.3mm) in the corresponding directions for right kidneys. Mean rotations about the left-right and anterior-posterior axes were zero for both kidneys (standard deviations of 0.3° to 0.6°) but with individual kidneys showing rotations of up to 3 degrees. Rotations about the superior-inferior axis were -0.6°±0.7° (range -3.0° to 0.2°) for the left kidney and -0.6°±0.7° (range -3.0° to 0.2°) for the right kidney. The impact of these deviations on SABR plans was examined through test cases involving the largest motions observed.
Conclusions: Although mean displacements about the center of mass and rotations of the kidneys were small, large individual deviations were observed. Our results suggest that care should be exercised on an individual basis when choosing SABR margins around renal tumors and that an assessment for each patient may be warranted.

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PRELIMINARY CONCEPTUAL DESIGN OF AN ION ACCELERATION COLUMN FOR A COMPACT NEUTRON GENERATOR EMPLOYED IN NEUTRON CAPTURE THERAPY

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Biomedical Engineering

Introduction:
We have been working on the development of a neutron source suitable for the application in NCT. In this paper we focused on the construction of ion accelerators that enable the implementation of a compact neutron source.
Methods and Materials:
With the purpose to establish the basis design for a Compact Neutron Generator CNG for NTC applications, the ion column acceleration is of great importance. We have reviewed the specialized literature and focused mainly on the different types of ion sources, extraction and acceleration systems and also on the used targets for the CNG. After choosing the geometry for the acceleration column we have solved the Laplace equation for this specific geometry using numerical methods and obtained the equipotential surfaces and the ion trajectories. We have also experimentally validated these particular set of electrodes. Finally, we have estimated the neutron flux as a function of the column accelerating voltage and its ion current for a given target.
Results:
Considering the necessary absorbed doses for a tumor, the design parameters chosen in the present study for a CNG corresponded to an ion source chosen corresponds to an RF source that generates a monoatomic deuterium D+ beam. The linear acceleration system of 100 kV consists of three regions: one of extraction, one of acceleration and one of suppression. With extraction voltage changeable of 0 -10 kV, acceleration voltage of 100kV and suppression 10 kV, for a deuteron current 1500 mA, generating neutrons with a of fluence 1x1010 n/s, a flux of 1x109 n/s cm2 with a current density between 10 mA/cm2 and 100 mA/cm2.
Conclusions:
In this work we present the preliminary basis design of the ion column acceleration of a CNG used in NCT. We also present an estimated of the neutron production in this CNG.

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A NOVEL METHOD AND ASSOCIATED DEVICE FOR TUMOR THERANOSTICS

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Diagnostic and Interventional Radiology – General

Introduction:
A novel method and device for simultaneous tumor diagnosis and treatment is presented. The main strategy is based on detection of deep X-ray fluorescence (produced at deep positions due to a suitable convergent beam) by tumor targeting with high atomic number nanoparticles, which can be adhered to the tumor through the antibodies. Moreover, the proposed confocal irradiation-detection configuration may significantly improve the overall process for step-by-step sample scanning. Materials and Methods:
During first stage, PENELOPE Monte Carlo simulation code served as study tool for several setups and GNPs concentrations that served to design the prototype, currently in construction (Pat Pending).
Results:
According to the obtained results, position of the X-ray fluorescent emission point (inside target area) was defined according to focal point of the convergent beam. Infusing with suitable non-toxic GNPs concentrations, it would be possible to detect deep tumors (more than 5 cm deep, at least).
Expected spatial resolution was assessed to be around 1mm, thus improving functional techniques typical of nuclear medicine. The first experimental results were already obtained capable of mapping Au distribution within a bioequivalent phantom. Conclusions:
Preliminary results are promising and supporting the development of a novel theranostic technique capable of imaging and/or simultaneous treatment.

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EXPERIMENTAL AND MONTE CARLO ANALYSIS OF ABSORBED DEPTH- DOSE CURVE INDUCED BY 20 KV-160 KV X-RAYS IN LIQUID WATER

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Diagnostic Radiology –Dosimetry

The use of low energy photons in medical applications varies from mammography beams (~ 20 kV) up to computed tomography and conventional radiography (~120 kV). It is well known that at these energies, the photon fluence decreases drastically with increasing distance from the source due to the photoelectric effect. Consequently, a high dose gradient exists. Therefore, very few accurate and precise data are actually available for low photon energy beams. This work aims at investigating, experimentally and through Monte Carlo (MC) simulations, the absorbed depth-dose curve induced by 20 kV- 160 kV x-rays in liquid water. For the experimental part, the measurements are performed in a home-made water phantom using 3 ionizations chambers; whereas for the MC simulation, the calculations are done using the NIST M-series x-ray spectra measured in our lab with a high purity germanium detector and the N-series x-ray beams measured and reported by PTB Germany. The analysis will be done to determine the influence of the beam qualities in the depth-dose curve.

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STUDY OF THE PARAMETERS OF CALCULATION OF DOSE IN THE PLANNING SYSTEM FOR RADIOCIRURGICAL TREATMENTS

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Radiation Oncology –Treatment Planning

One of the important aspects in the application of treatment with radiosurgery is the conformity of the white volume, for such, it is used: Index of homogeneity (IH) which evaluates the distribution of doses that are homogeneous and the index of conformity (IC) measures the conformity of dose distribution and it was developed as a section-by-section extension of the dose-volume. Histograms can be defined as an absolute value result from the relationship between the volume of the lesion or a fraction of this volume and the volume delimited by an isodose or a fraction of this volume. This work aims to carry out this dosimetric evaluation by means of the IC proposed by Lomax, for this evaluation were considered a group of 98 plans performed with Radiosurgery stereotactic (76 arteriovenous malformations, 8 neurinomas of the acoustic, 7 tumors, 5 meningiomas and 2 cerebral cavernomas), the planning system was used Computerized MNPS (MEVIS), with the technique with cones with diameter sizes between 9 and 33mm (BlueFrame NS/SRS), for the immobilization a stereotactic frame and the lesion to be used, as well as position the skull in relation to the irradiation device. The results obtained were: IH average 1.89, IH $\leq$ 2 (66%, the treatment is considered to comply with the Protocol), 2 < IH < 2.5 (34%, the treatment violation is considered minor), IH > 2.5 (0% The protocol is completely violated) and the average IC was 0.98, IC = 1 (73%, treatment is considered ideal), 0.8 < IC < 1 (28%, treatment is considered to violate the protocol but in a small proportion) and IC < 0.8 (0% treatment is considered to violate the protocol completely), which can be concluded that the treatments given were appropriate.

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CALIRAD: A TOOL TO EVALUATE QUALITY RADIOLOGY SERVICES

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Diagnostic and Interventional Radiology – General

The main objective in radiology is to obtain images of good quality for certain diagnosis, without unnecessarily irradiating the patient. Each element in the chain of obtaining radiographic image must be verified in order to achieve such goal. This paper shows an informatic tool that help to evaluate quality in the radiology service of the Hospital “Abel Santamaría Cuadrado”, Pinar del Río, Cuba. The basic indicators of quality: rate reject films, clinical image quality and patient dose were the basis for this tool.
Methods and materials: National and international protocols were useful like guides for evaluation of the quality's indicators. The unified modeling language UML, Enterprise Architect, Axure RP, Symfony, MySQL and PHP, were utilized in order to develop the application.
Results: A multiplatform web server-client online 24 hours a day was developed with an authentication access for the registered users. The patients' data, their studies, medical reports and image quality evaluations must be registered in this tool by X-ray technicians, radiologists. The quality control, the radiographic and mammographic equipment's data, maintenances status must be showed by the web after that medical physicist, electromedical introduce important data. This informatic tool calculates rates rejections films, scores of clinical image quality evaluations, estimates patients' dose and records the online time of medical equipment. This tool evaluates, generates graphics and reports of the department quality.
Conclusions: An informatic tool was developed to controls and evaluates the performance of the radiology department. It's a useful tool for comparisons between health institutions and to carry out external and internal audits.

P-383

DOSIMETRIC LEAF GAP AND TRANSMISSION FACTOR MEASUREMENT: INFLUENCE IN PATIENT-SPECIFIC QA

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Radiation Oncology –Treatment Planning

Introduction:
Among parameters that must be determined for Multileaf Collimator (MLC) characterization and commissioning, and of importance for intensity modulated techniques (IMRT, VMAT), are Dosimetric Leaf Gap (DLG) and Transmission Factor (TF). This study aims to determine the influence of both factors in patient-specific quality assurance.
Methods:
DLG and TF were measured with Farmer ionization chamber (IC), Mapcheck2 (MC2) and Portal Dosimetry (PD), according to the procedure described by Varian, with 6MV photons in a Varian Trilogy LINAC, in order to compare the values obtained with each detector.
The Chair Test was measured with MC2 and PD, and then compared with the calculated plans in the treatment planning system with different values of DLG and TF, by global gamma analysis of 1%-1mm and 3%-2mm, with a 5% dose threshold.
Then, DLG and TF values that showed the best results in gamma evaluation in the chair test were used for IMRT and VMAT plan comparisons.
Results:
We found differences between the resulting DLG and TF values when measured with IC, MC2 and PD.
In Chair Test with MC2, an improvement up to 8% was obtained over the results with the commissioned values in 1%-1mm gamma evaluation, and near about 1% in 3%-2mm evaluation. In PD, an improvement up to 1% was obtained over the results with the commissioned values. In patient-specific measurements (IMRT and VMAT plans), an improvement of less than 1% was obtained in 3%-2mm gamma evaluation with both detectors.
Conclusions:
Minor variations of commissioned DLG and TF values do not show significant differences in patient-specific quality assurance. Only large variations in DLG and TF can significantly affect gamma analysis in the comparison of patient-specific measurements.

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EVALUATION OF CALCULATION ALGORITHMS ACUROS XB (AXB) AND AAA (ANISOTROPIC ANALYTICAL ALGORITHM) FOR PHOTON BEAM IN HYPOFRACTIONATED BREAST PLANS

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Radiation Oncology –Treatment Planning

The objective of this study was comparing the Acuros XB algorithms to AAA algorithm, in dosimetric impact, in treatment volumes and Organ on risk (OAR), especially involving pulmonary heterogeneities. Strategies used as assessment, CI (Conformity Index) and IH (Homogeneity Index), dose distribution with V95% and V107% for PTV. In OARs, the evaluations were performed observing reference values for hypofractionated treatments, proposed by QUANTEC and RTOG 1005. Two methodologies used (constant UM and re-optimization), treatment plans were elaborated based on twenty tomographic studies of female patients with left breast cancer, opposing tangential fields in the field in field technique, 6MV and 10 MV photon energy, integrated reinforcement fields with a 45o or 60o dynamic filter. For a constant, V107% the PTV breast where AAA underestimates at -7.52% and AAA SCH at -18.71%. In OAR evaluations for the left lung, between AAA and Acuros XB algorithm the difference was 1.62% for V5Gy, AAA being overestimating the dose. While for AAA SCH the percentage difference underestimates at -18.67. For average dose in cardiac region, AAA presented 2.14% and AAA SCH 3.30% in relation to Acuros XB, overestimating the dose. For region-delimited skin, the mean dose for AAA presents -5.54% and AAA-SCH-11.70%, underestimating the dose relative to Acuros XB. For re-optimization the largest difference observed for V107% in PTV breast, in comparison of AAA SCH with Acuros XB of 34.32%, and AAA found 13.34%, overestimating the dose relative to reference. For average dose in cardiac region, AAA presents 2.20% and AAA SCH 5.70% in relation to Acuros XB, overestimating the dose. In delimited skin region, the mean dose for AAA presented -4.54% and AAA-SCH - 8.50%, underestimating dose relative to Acuros XB. In clinical transitions from one algorithm to another, these should be accompanied by studies and simulations in planning systems, before considering clinical implementation.

P-387

DOSIMETRIC COMPARISON WITH DIFFERENT HYPOFRACTIONATED IMRT TECHNIQUES FOR PROSTATE CANCER RADIOTHERAPY

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Radiation Oncology –Treatment Planning

Dosimetric comparison with different hypofractionated imrt techniques for prostate cancer radiotherapy. Prostate cancer is a diagnosis that can be treated with radiotherapy in multiple ways. Considering that control patient position and treat and control the position of the tumor and organs at risk at the same time are relevant dosimetric goals to achieve in any hypofractionated treatment. In a hospital with different kind of technologies could be useful to well understand the capabilities of each one of them in such an important dose delivery. Calculating plans for different machines in order to compare dosimetric aspects has been the objective of this investigation.
Methodology: 10 cyberknife plans of patients with located prostate cancer have been selected, prescription dose was 36,25 gy delivered in 5 fractions of 7,25gy each one. Alternative treatment plans for every patient were carried out with Vmat and helicoidal tomotherapy technique, using the same dosimetry protocol in order to evaluate the PTVS and organs at risk. In addition, conformality and homogeneity index were calculated as well. As a result of the dosimetric comparisons no differences between the techniques to achieve the dose in the PTV and low dose in organs at risk was found, being cyberknife which delivered less doses in rectum and tomotherapy calculated less doses in bladder, urethra and femoral heads. Conclusion: the three techniques are useful for the treatment of the located prostate cancer from the dosimetric point of view, but the great superiority of cyberknife is the ability to follow the movement of the organs with registration of images, online or intrafraction, which guarantees a greater quality during the fraction.

P-388

Geant4 SOFTWARE FOR IN SILICO COMPARISON OF THE BRACHYTHERAPY DOSIMETRY DUE TO Co-60 AND Ir-192 HIGH RATE DOSE SOURCES

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Radiation Oncology – Dosimetry

Introduction:
In this work we developed a program for the study of dose distributions due to different sources of brachytherapy with Ir-192 and Co-60 Isotopes. Experimental validation is done in water using literature data and experimental measurements using radiochromic film.
Materials and methods:
Using Geant4, we simulate the geometries of different brachytherapy sources of high rate dose with Ir-192 and Co-60 in detail. Based on ICRU 44 and using the Monte Carlo method, a Geant4 program was building and the dose distributions deposited in water and soft tissue were studied, making a comparison of the spatial distribution for the two cases and different source geometries. Subsequently, a radiochromic film was irradiated with a MicroSelectron-HDR-192Ir-V2 brachytherapy source in order to measure the deposited dose distribution and compare to Monte Carlo calculations using the gamma index.
Results:
The PDDs for Co-60 and Ir-192 brachytherapy sources and dose distributions in different axes were obtained through Monte Carlo method. A comparison of the dose distribution in the points near the source was made it observing the variations due to the shape of the nucleus. The Monte Carlo's does maps were compared with measurements through the gamma index getting results higher than 95% with 2% / 2 mm criteria.
Conclusions:
The software was building under Geant4 and were validated with experimental measurements, it can be used for studding dose distribution in detail for cases were measurements are very difficult to perform. The shape of the source influences in the dose distribution and for this reason it can not be taken like an isotropic point source. The Co-60 and Ir192 doses are similar in first millimeter depth.

P-389

EXPERIMENTAL DETERMINATION OF THE GADOLINIUM DOSE ENHANCEMENT IN PHANTOM IRRADIATED WITH LOW ENERGY X-RAY SOURCES BY A SPECTROPHOTOMETER -GAFCHROMIC-EBT3 DOSIMETRY SYSTEM

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Radiation Oncology – Dosimetry

This work reports the experimental determination of dose enhancement produced in phantoms containing target volumes doped with Gadolinium and irradiated with low-energy X-ray beams. EBT3 Gafchromic films were immersed into 5 ml target volumes to mimic tumor filling with 100% ultra-pure water (blank sample) and ultra-pure water infused with Gd solution (Omniscan®) in different concentration (9-24 mg/ml). The dose enhancement due to excitation of Gd K-edge (50.2 keV) was evaluated in terms of the increment in the optical density, obtained by a Spectrophotometer-Gafchromic-EBT3 dosimetry system calibrated in terms of the dose-response for the range of 1-8 Gy. The dose enhancement was evaluated in two condition: a beam quality with spectrum above the absorption edge in a medium with and without Gd; and two beam qualities (above and below the absorption edge) in a medium with a fixed concentration of Gd (18 mg/ml). The obtained results confirmed increments in relative dose enhancement according to Gd concentrations up to 18 mg/ml, with a dose enhancement of 1.1 Gy and an average percentage enhancement of 28.4%. For higher values of concentration, the attenuation interaction of the primary beam is more relevant instead of dose enhancement process. On the other hand, the dose enhancement obtained to comparison the spectra above and below the absorption edge, shown results up to 3.6 Gy of enhancement and average percentage enhancement of 86%. These results constitute a promising future alternative for replacing radioactive sources by implementing electronic brachytherapy together High Z agents, achieving local high dose levels.

P-390

CHARACTERIZATION, DOSIMETRY OF SMALL FIELDS AND QUALITY CONTROL OF THE PLANNING SYSTEM OF RADIOSURGERY

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Radiation Oncology – Dosimetry

The present work develops a method, capable of implementing a radiosurgery dosimetry system by means of Monte Carlo Simulation (CM), in such a way that the dosimetric data can be obtained in a truthful and reliable way, and with the optimization of the acquisition time. It is developed counting on the Radiosurgery System installed in a Linear Photon Accelerator (LINAC) with energy of 6 MV, experimental dosimetric measurements were made to the system, by means of the use of a Wellhofer 700 automatic Fantoma, a micro ionization chamber ""Pin Point"" Chamber PTW "", an electrometer Model KEITHELEY 35617EBS, a collimator and collimators used for radiosurgery (cones) of different diameters. The PENELOPE code was used to perform the MC simulation under the same experimental geometrical conditions, for which the data of the LINAC Configuration were granted by the Siemens Medical Systems and Oncology Care Systems. The Winston- Lutz test was used to perform the quality control of the planning software together with a phantom adapted to perform in vivo dosimetry. We can be obtained by means of MC simulation: Percentage of Dose in Depth (PDD), Off axes doses; both for the 24 mm diameter cone; the Output Factors were obtained by MC, for in cones of diameter different. These measurements obtained by MC when compared with the data obtained experimentally show a maximum percentage difference of 2%.It should be mentioned that for the comparison of experimentally obtained data for field factors, these were corrected using the new protocol, TRS 483 of the AIEA. Noting the importance of using this protocol to obtain the dosimetry of small beams. In relation to the quality control of the planning system (TPS)and to the dosimetry performed on the system, the results obtained show a percentage deviation of 1.8% in relation to the planned dose and the dose delivered.

P-392

ASSESSMENT OF LINEAR ACCELERATOR COMMISSIONING BY EVALUATING THE ACCURACY OF THE AAA ALGORITHM

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Radiation Oncology –Treatment Planning

The evaluation of the dosimetric accuracy was performed over a treatment planning system (TPS) called Eclipse in its version 11.0.31 for AAA photon dose distribution algorithm using a comparison between some measurements and its counterpart of dose calculations. That quantitative comparison was developed for absolute and relative dosimetries under controlled conditions to ensure its feasibility, and following international recommendations like Task Group report 53. Additionally, we did absolute dosimetric measures in an anthropomorphic thorax phantom to evaluate the accuracy of this algorithm under high heterogeneity mediums. The overall results were not like we expected and other author found, but gave us some clues that in somehow the measurements obtained for the commissioning stage were not getting in the best way. Some consequences could imply a possible sub estimation of dose in the umbra region and at considerable depths, so this work could be apply as a quality control over a TPS after the commissioning stage is done, those implications may yield us a possible complications for side effects mainly in sensitive organs for radiation.

P-393

MONTE CARLO EVALUATION OF THE RADIATION SHIELDING OF HEALTHY TISSUE SURROUNDING TUMOR TISSUE DOPED WITH GD, BY AN ENDOCAVITARY BRACHYTHERAPY SYSTEM BASED ON A 241AM SOURCE

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Radiation Oncology – Dosimetry

In this work we evaluate the increase of protection to healthy tissue surrounding irradiated tumor tissue, for an endocavitary brachytherapy system based on a source of 241Am and doping the tumor zone with Gd agents for a simultaneous production of dose enhancement. This source offers advantages over the traditional 192Ir, such as a much longer half-life, and the possibility of greater dose enhancement by having an energy closer to the absorption edge of the Gd. As also the lower energy spectrum allows secondary use of the agent as a radiopaque element decreasing the dose in regions outside the tumor. For this, a geometry of concentric cylinders with different diameters was simulated. The first was fixed at 0.6 mm in diameter and the 241Am source was located on it. The second was fixed at 2 cm in diameter represents the tumor area to be treated which was studied with or without Gd doping. The last one was fixed at 10 cm in diameter and its composition was exclusively water representing the healthy tissue. The evaluation of the protection was determined as a function of the reduction of the dose achieved in the external region of the phantom due to the attenuation of the Gd over the primary beam and given the total absorbed dose is increased in the area doped with Gd, causing shorter irradiation time to reach the prescribed dose in the region of interest. The results obtained for a Gd concentration of 20mg / ml show percentages of protection of 64.2 ± 0.5% with an uncertainty lower than 0.6% and a reduction of 55% in the irradiation time, product of the dose enhancement achieved. This result showing the advantages of a future system based on this type of long life and low energy sources together new high Z agents.

P-394

DOSIMETRIC COMPARISON OF MULTIPLE BRAIN METASTASIS RADIOSURGERY PLANNING USING CONVENTIONAL VMAT (RapidArcTM) VERSUS HyperArcTM AUTOMATED PLANNING

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Radiation Oncology –Treatment Planning

Varian Medical Systems recently developed a new feature for Radiosurgery planning.
automated settings for the isocenter location, automated beam arrangement and collimator angles, HyperArcTM generates non-coplanar planes for multiple metastasis. We compared 5 plans generated with conventional VMAT (C-VMAT) approach by an experient planner using the same number of arcs and couch rotations with HyperArcTM plans, but choosing manually the collimator angles and jaw settings, as well as the optimization parameters. We also analyzed the differences using two calculation algorithms, Acuros and AAA. All plans were normalized for the same target coverage, with de prescribed dose of 20Gy covering 99% of the PTV. The CT scans were performed with a 1,25mm slice thickness and the calculation grid was also set to 1,25mm; the TPS was a Varian EclipseTM V15.5. The plans with AAA and Acuros, for C-VMAT, respectively, have reached a mean V10%=643cc (Equivalent Sphere of 10,7), V30%=68cc (5,1) and V50%=29cc (3,8); V10%=578cc (10,3), V30%=64cc (5,0) and V50%=27cc (3,7). The plans generated by HyperArcTM obtained, for AAA and Acuros, V10%=551cc (10,2), V30%=64cc (5,0) and V50%=28cc (3,8); V10%=525cc (10,0), V30%=64cc (5,0) and V50%=28cc (3,8). We note the plans are comparable in terms of volume for the 50% dose level, but HyperArc had some significant advantages specially in the low dose levels. We conclude HyperArcTM is a very easy and time-saver tool for Multiple Metastasis planning. Even in a scenarium where we had an experient planner performing C-VMAT plans, the software achieved comparable and even slightly better results with a minimum workload, creating extremaly good clinical plans in times around 10minutes. We also intend to measure these cases to evaluate the adequacy of the algorithms, since they present different results especially at the 50% dose level.
With a minimal workload including

P-395

DEVELOPMENT OF A NEW ALGORITHM FOR GAMMA EVALUATION IN 2D MEASUREMENTS

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Radiation Oncology –Treatment Planning

Introduction: With the use of intensity modulation radiotherapy treatments, it is necessary to implement patient specific quality controls in order to find differences between measured and calculated dose distributions. When measuring with a 2D planar array, commercial gamma algorithms does not use a volumetric searching range, resulting in a misconsider of the volume average effects, laser thickness and couch precision among others. All these factors might result in a less accurate gamma analysis. Regarding these facts, a new 2D gamma analysis algorithm has been developed, addressing real clinical situations.
Materials and Method: 10 VMAT patients were calculated with Monaco TPS and measured using a MatriXX Evolution detector, which is a planar array by IBA. Seven coronal sections with a thickness of 1 mm were exported from the TPS. An algorithm based on the gamma index was created using Matlab as a programming language, which allows to compare a measured dose plane against a calculated dose volume. results of these calculations were compared with commercial algorithms. Preliminary Results: After comparing three different gamma index calculation algorithms, the algorithm devised in this work shows higher gamma results. The difference between algorithms exceeds 5%, obtaining for several cases 100% of the points achieving the gamma criteria. And for cases that did not accomplish the gamma criteria with commercial algorithms, they now do.
Conclusions: Adding an additional dimension to the gamma analysis increases the possibilities of obtaining points that reach the agreement, in addition, it allows to have uncertainties in all spatial planes, a feature that with other algorithms is not allowed.

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EXPERIMENTAL MEASUREMENT OF ENHANCEMENT AND RADIATION SHIELDING EFFECT OF DOSES BY GD USING PAGAT DOSIMETERS IN PHANTOMS IRRADIATED WITH 192IR FOR HIGH DOSE RATE BRACHYTHERAPY TREATMENT

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Radiation Oncology – Dosimetry

The aim of radiotherapy is to give high doses of radiation to the tumor tissue without exceeding surrounding healthy organs, however, there are anatomical areas whose access is difficult for external radiotherapy both by its homogeneous dose delivery and by risk for surrounding volume. For this reason, treatments such as brachytherapy allow a more viable treatment method due to its abrupt dose drop at a distance. Currently several investigations have shown that the injection of a high Z material in tumor volumes subsequently irradiated, generates a dose enhancement due to the increase in photoelectric absorption and the subsequent emission of photoelectrons and Auger electrons that locally deposit their energy in the vicinity of the doping agent. The dosimetric measurement was performed using a set of PAGAT gel dosimeters in the form of 12 cm3 substrates doped with Gd at concentrations of 68 mM and 138 mM, which were inserted into a solid water phantom at a distance of 0.5 cm from a radioactive source of Ir-192, obtaining a thickness of 1.5cm of Gd-PAGAT to measure dose enhancement and 0.5 cm of PAGAT to measure radiation shielding effect, this geometry simulates the irradiation of a tumor doped by high dose rate brachytherapy. Subsequently, they were irradiated with a total dose of 4Gy, obtaining results by optical transmission/absorbance, considering the enhancement at 2 cm from the source, according to the evaluation criteria of the brachytherapy treatments and the radiation shielding produced by this material in the vicinity of the undoped volume. Experimentally, it was possible to check the dose enhancement in agreement with Monte Carlo simulations performed parallel to the experiment with comparing purpose, reporting a dose increase of 10-12% depending on the dopant material concentration and a radiation shielding of the dose proportional to the studied concentration.

P-398

OPTIMIZATION OF NEUTRON CAPTURE THERAPY BY VARYING THE BORON CONCENTRATION WITH THE HELP OF GEANT4

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Radiation Oncology – Dosimetry

There are certain types of cancer that are radioresistant, such as cutaneous malignant melanoma capable of surviving conventional radiotherapy. There are also brain tumors that are impossible to operate due to the high risk of surgery and in which external beam radiation therapy is not a good option since it generates side effects due to the delivery of doses to healthy tissue by radiation. For this reason, neutron capture therapy is used, which allows tumor cell destruction in a selective manner, decreasing the condition to adjacent healthy tissue, since it consists of supplying Boro-10 to the tumor tissue through which a thermal neutron beam passes. is captured by Boron-10 and becomes Boron-11, which in turn fissiones into an alpha particle and a Lithium-7 nucleus, with high LET (linear energy transfer). These particles have a spatial range in the order of the diameter of a cell. The objective of this work is to perform a simulation in GEANT4 by varying the concentration of Boron-10 in a phantom, to verify which is the adequate density for the coverage of the dose at 100% of the PTV. A phantom is taken that possesses the tumor characteristics with Boron uptake with different concentration, immersed in another phantom of water simulating the human body. Which is irradiated with a beam of epithermic neutrons with energy of 0.3 ev (varies with the depth of the tumor). It was found that the optimal concentration for the treatment is between (10-30) mg of boron per gram of tissue. As a conclusion, it is possible to determine the adequate range of boron concentration in the tissue and it is also appreciated that the delivery of doses to adjacent tissue is low.

P-400

INITIAL EXPERIENCE IN GUATEMALA PERFORMING QUALITY CONTROL IN X-RAYS, MAMMOGRAPHY AND TOMOGRAPHY

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Diagnostic and Interventional Radiology – General

In Guatemala there was no obligation to perform tests of dose controls on equipment that emit ionizing radiation, but just over two years ago the regulatory body started with this requirement. FIXCA is an accredited company in Guatemala to perform these tests through the regulatory body. The tests in X-ray equipment in general was performed without receive the corresponding maintenance service. The tests for the X-rays have been with an average of 7% (absolute dose), accuracy of kV ± 5% (absolute dose), tests of collimation ± 1.4 cm (averaged all directions and field sizes), yield for 80kV (depending on the case three-phase or single-phase) 10% of equipment the result has not been within the acceptable range, filter ± 8%. In the case of fluoroscopy, accuracy of kV ± 4%, automatic exposure control (CAE) ± 3%, filter ± 3%, in the case of performance more than 85% the result has been within the acceptable range. In the case of Mammography, the accuracy of kV ± 9% (absolute dose), glandular dose ± 8% (absolute dose), filter ± 3%, performance for 28kV 12% of equipment has not been within the acceptable range. For the case of Tomography, the accuracy of kV has been an average of ± 3%, the values of dose in air per kV, CTDI for head and body have been evaluated comparing them with the publications of IMPACTSCAN.ORG, which have coincided more 80% of equipment evaluated. In general, only the approved equipment will receive a quality certificate and/or inform. Because all the tests can´t be approved if exist one parameter out of range and this could affect the results of the other parameters.

P-401

SAFETY EVALUATION OF ONE BRACHYTHERAPY INSTALLATION OF HIGH DOSE RATE

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Radiation Protection

The safety evaluation of the Brachytherapy installation of the Elisa Clara Radiology Center RF S.A.S was carried out, in order to determine the level of risk existing in the area. The evaluation was carried out in accordance with the requirements of Resolution 90874-2014 of the Ministry of Mines and Energy of Colombia, in which the criteria for the application of the general principles of control (based on the international recommendations and the International Atomic Energy Agency), with a graded risk approach for the authorizations applicable to the radioactive sources used in any activity, in our case, only the operational and special procedures performed in the facility during the practice of High Dose Rate Brachytherapy (developed with an Ir-192 radioactive source and only for Intracavitary Brachytherapy procedures). The results of the risk profile of the practice were obtained using the software tool SEVRRA 2.0 (online mode); 97 events were analyzed in total, of which 20 were not applicable to the practice. From the evaluation, 74 (76.3%) events evaluated with consequences on the patient were obtained; 16 (16.5%) events with consequences on the occupationally exposed worker and 7 (7.1%) events with consequences on members of the public. A first and second screening was performed; in this last, there was a reduction to the maximum (0%) in the probability of occurrence of incidents with very high and high consequences that could develop during the practice of Brachytherapy; this led to a significant increase in consequences with medium risk 60 (78%) and low risk 17 (22%). The conclusion of the safety assessment shows us, that certain technological barriers, as well as the application of the processes and protocols of protection Radiologic in the area during the practice, help significantly in the control the occurrence of possible potential exposures in the installation.

P-405

OCCUPATIONAL RADIATION DOSE IN MEDICAL WORKERS IN A HIGH COMPLEXITY HOSPITAL

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Radiation Protection

Introduction: Monitoring the results of the personal dosimetry of all Occupationally Exposed Workers (OEW) is the main indicator of the effectiveness of radiological protection in a given institution. The objective of this work was to evaluate the behavior of the effective dose values in medical staff of "Clinica Las Condes" Hospital received for 7 years. Methods: The occupationally exposed workers of the services that use ionizing radiations were taken into account in an important way, the quarterly record was kept for seven years of the doses reported. To optimize the statistical management of the values to be analyzed, a database was created where the demographic, labor and quarterly dose values of each of the workers participating in this study were recorded. The variables that were followed in this study were: The number of workers occupationally exposed by service, the annual average of equivalent dose or Hp(10) per service, the number of workers whose annual dose it did not exceed 0.1 mSv in each service and the totals of the institution for each of the years analyzed. Results: Around 513 workers per year were in the radiological surveillance program with personal dosimetry between 2012 and 2018 with an average dose of 0.13 mSv per year and more than 75 % of doses were registered as lower than the dosimeter recording level (0.1 mSv). Conclusions: Through the results it can be seen that the workers in this hospital work in a safe environment, since in general the average dose was 0.1 mSv, that is 10 times less than the allowable dose for the general public (1 mSv) according to ICRP 103. The implementation of the Radiological Protection Program at Clinica Las Condes Hospital has fulfilled its objective, in the sense of keeping the doses of workers as low as possible.

P-407

A MORE ACCURATE PEAK SKIN DOSE (PSD) ESTIMATE FOR FLUOROSCOPY-GUIDED INTERVENTIONAL PROCEDURES

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Diagnostic Radiology –Dosimetry

A more accurate peak skin dose (PSD) estimate for fluoroscopy-guided interventional procedures (FGI) can be obtained by accounting for X-ray tube angulation, table positions and patient dimensions. An algorithm for calculating and reporting PSD, which includes these factors, is described. Radiation dose management system, RadimetricsTM, is used to query/retrieve the fluoroscopy exam's radiation dose structured report (RDSR) and exports acquisition parameters in a Microsoft Excel format. PSD calculation utilizes parameters within the RDSR including IRP air-kerma, primary and secondary x-ray tube angles, and table coordinates to determine the acquisition-specific source to skin distances (SSD) and skin entrance air-kerma. Field overlap as a function of angulation and patient size is then used to determine the cumulative skin dose from the FGI. Patients are modelled as ellipsoids referring to each patients' dimensions obtained from recent CT scans to the FGI region of interest. Validation testing of the PSD calculation method is done by performing FGI on a phantom, with varying levels of complexity. PSD measurements are obtained using radiation detectors positioned on the phantom's surface. Then, PSD calculations are performed using the new method described above and the traditional “dose-conservative” method. Comparisons between the measured and calculated PSD values determine the level of accuracy the new method provides. Preliminary results suggest that the new method yields a more accurate PSD estimate than the dose-conservative method, with a dose difference of 42%- 53%.

P-410

RESULTS WITH MACACO II: A COMPTON TELESCOPE FOR HADRON THERAPY MONITORING

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Radiation Oncology – Dosimetry

Hadron therapy is a technique used in cancer treatment that consists in the irradiation of tumours using light ions or protons instead of photons. The use of this technique is increasing in the world given its precise energy deposition to the tumors and the dose reduction to healthy tissue as compared to conventional photon radiotherapy. Real-time treatment monitoring is one of the main challenges addressed nowadays.

The IRIS group at IFIC-Valencia is developing a Compton telescope with this purpose. The system is made of three LaBr3 detector planes coupled to silicon photomultipliers (SiPMs). The first MACACO (Medical Applications CompAct COmpton camera) prototype demonstrated the viability of the proposed technology and served to identify its limitations. The second prototype features new detectors and image reconstruction codes, improving significantly the performance in laboratory and accelerator facilities [1,2].

The dimensions of the LaBr3 detectors of a new prototype (MACACO II) are 25.8 x 25.8 x 5 mm3 for the first and second plane and 32 x 36 x 10 mm3 for the third one. The characterization in the laboratory has been performed using Na-22 and Eu-152 radioactive sources while keeping constant temperatures. An energy resolution of the detectors of 5.6 % at 511 keV, an angular resolution of 4.6° and an efficiency of coincidence detection of 1 x 10-3 at 1275 keV were obtained.

To validate the functionality of a second version of MACACO, Monte Carlo simulations were made with GATE V 7.0 (toolkit based on GEANT4) getting a good correlation with the experimental measurements. Through the simulations, the intrinsic spatial resolution of the Compton telescope has been determined (≈ 3mm) using a derenzo phantom.

MACACO II has been characterized in the laboratory and in beam tests. It has been tested at CNA (Sevilla) with 18 MeV proton beams on a graphite target to produce 4.4 MeV gamma rays. Data have been taken with the system in different positions and beam intensities, and the target image has been reconstructed. Further tests have been carried out at KVI-CART (Groningen) with a 150 MeV proton beam impinging a PMMA target and the Bragg peak has been reconstructed in different positions.

In spite of the significant progress, the system does not yet reach the necessary performance for the application and thus, possible improvements are being assessed. Tests include the evaluation of SiPMs of different types and manufacturers to enhance energy resolution and the improvement of the readout electronics. The MADDAQ board currently employed is being replaced by AliVATA, that will allow to operate the three system detectors with just one board and improve the readout speed. In addition, tests are being carried out with the PETsys system, improving significantly the detector timing resolution.

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