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The Journal of the International Organization for Medical Physics

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Medical Physics International (MPI) is the official IOMP journal. The journal provides a new platform for medical physicists to share their experience, ideas and new information generated from their work of scientific, educational and professional nature. The e- journal is available free of charge to IOMP members.

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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.

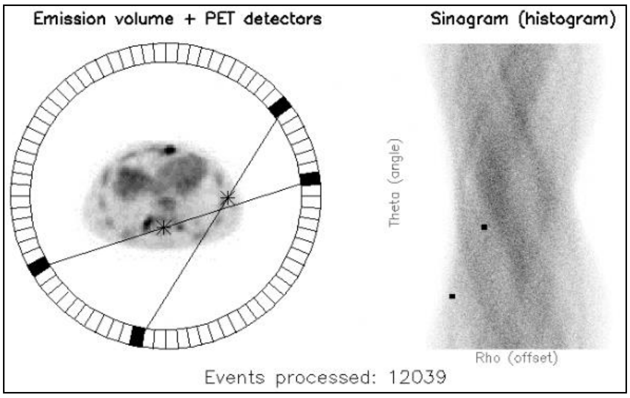

Figure 1. Static frame from one of the gif animations available in the learning content, visualizing the detection of annihilation photons in the PET scanner (left), and how those data are stored in the corresponding sinogram (right).

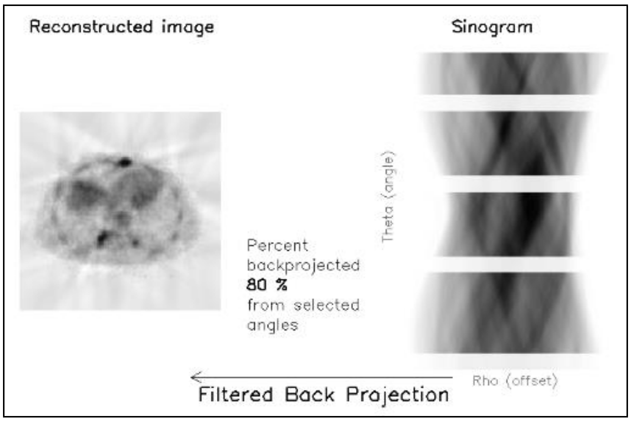

Figure 2. Static frame from one of the gif animations available in the learning content, visualizing the filtered back-projected image (left) resulting from only using a subset of the measured sinogram data (right).

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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[4] ICTP, Trieste, Italy, [5]Florence University, Italy, [6]Azienda Sanitaria Universitaria Integrata di Trieste, Italy

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

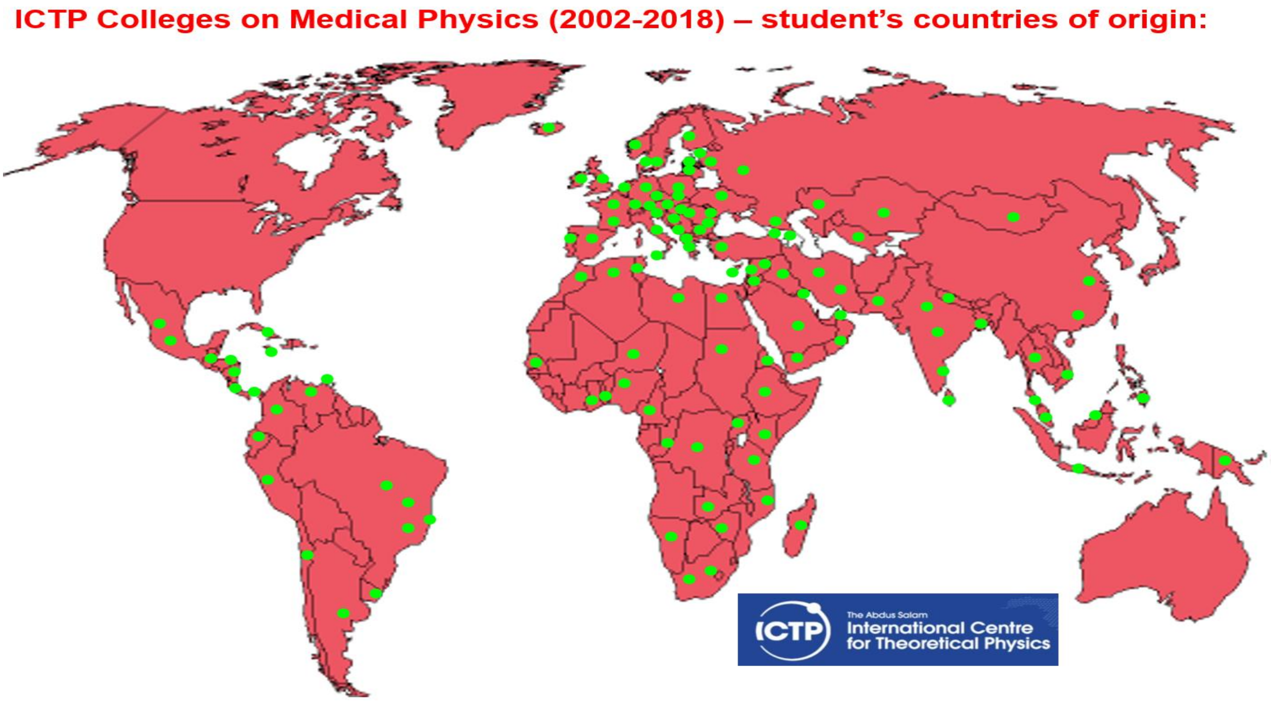

Fig.1 ICTP Colleges on Medical Physics (2002-2018) – students from: Albania, Algeria, Armenia, Argentina, Bangladesh, Belarus, Bosna, Brazil, Brunei, Bulgaria, Burkina Faso, Cameroon, P.R. China, Chili, Croatia, Columbia, Congo, Costa Rica, Cote D'Ivoir, Cuba, Czech Rep., Ecuador, El Salvador, Estonia, 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.

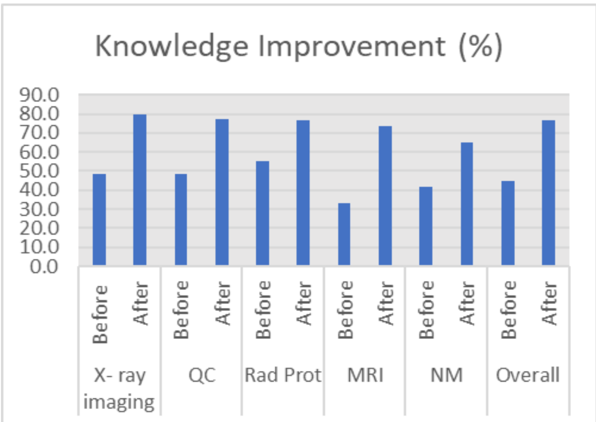

Fig.2 Student's own estimate of their knowledge (in %) before and after completion specific parts of the College curricula (max 100%): X-ray imaging; X-ray Quality Control; Radiation Protection; Magnetic Resonance Imaging, Nuclear Medicine Physics and Overall

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

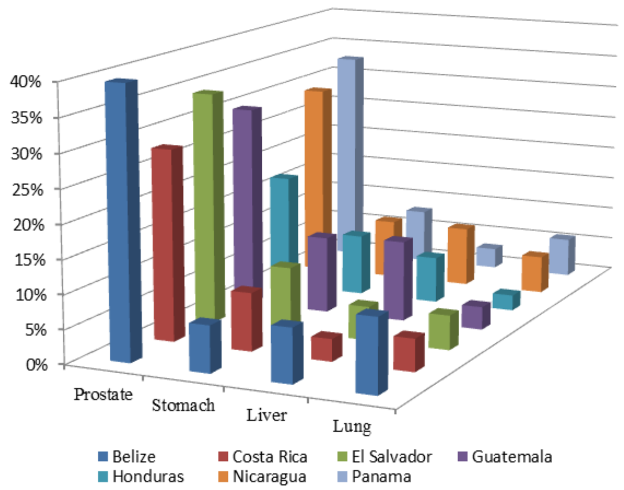

Fig. 1 Percentage of incidence of the most frequent types of cancer in Males in Central America, 2018.

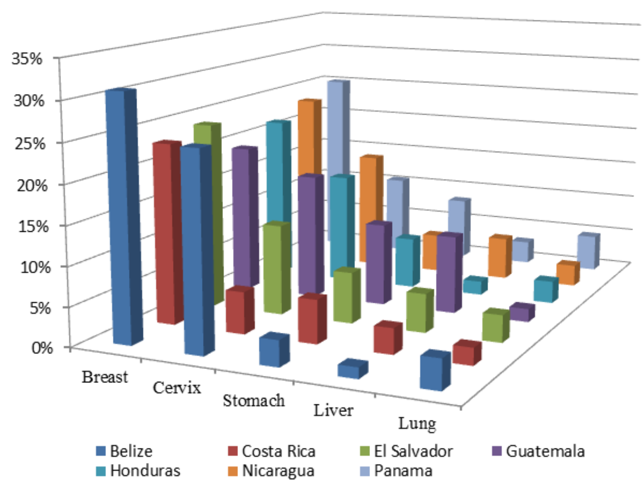

Fig. 2 Percentage of incidence of the most frequent types of cancer in Females in Central America, 2018.

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.

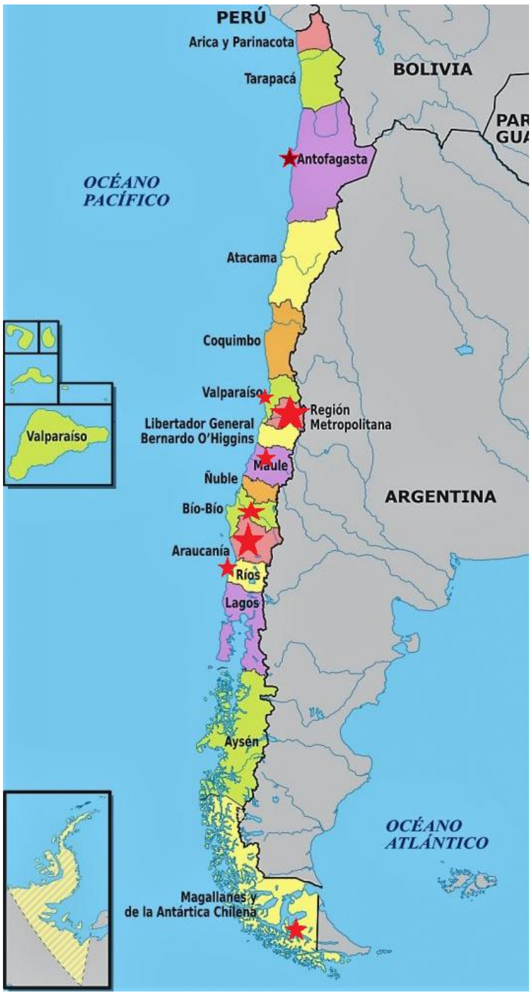

Fig. 1 Medical physicists' distribution throughout Chile. Red stars indicate the places where medical physicists are working in clinical and academic activities.

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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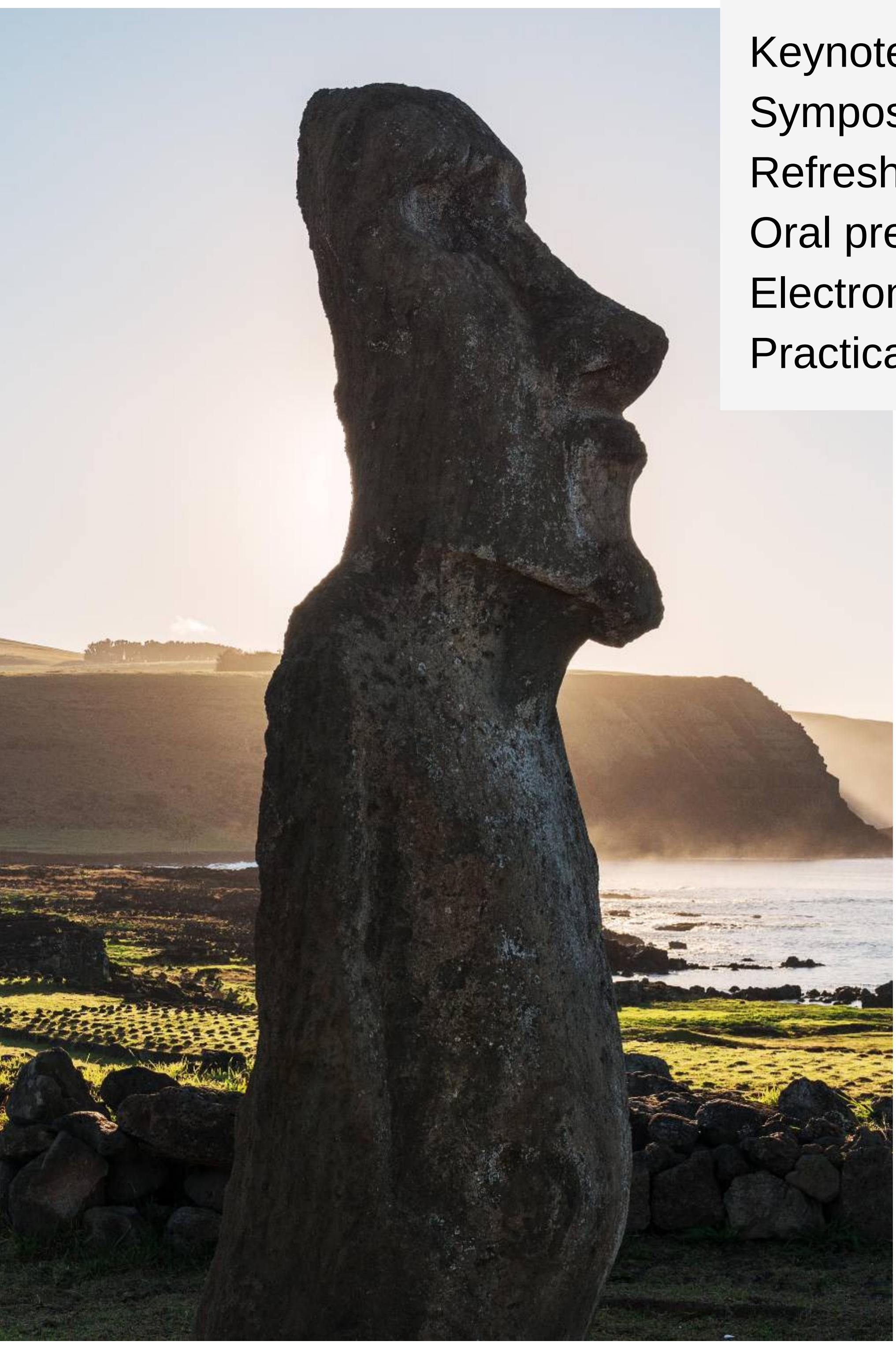

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INVITED PAPER

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].

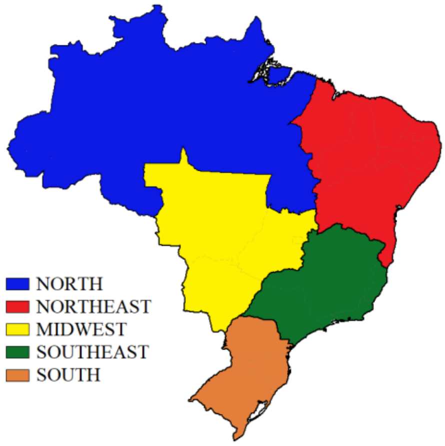

Fig. 1 Map of Brazil divided by regions.

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].

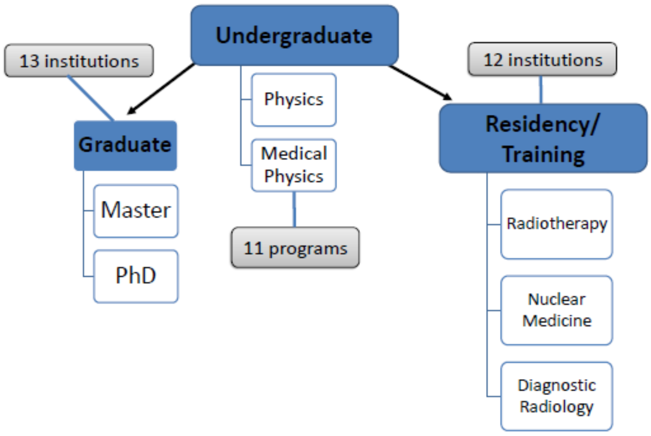

Fig. 2 Diagram of CQMP education in Brazil.

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

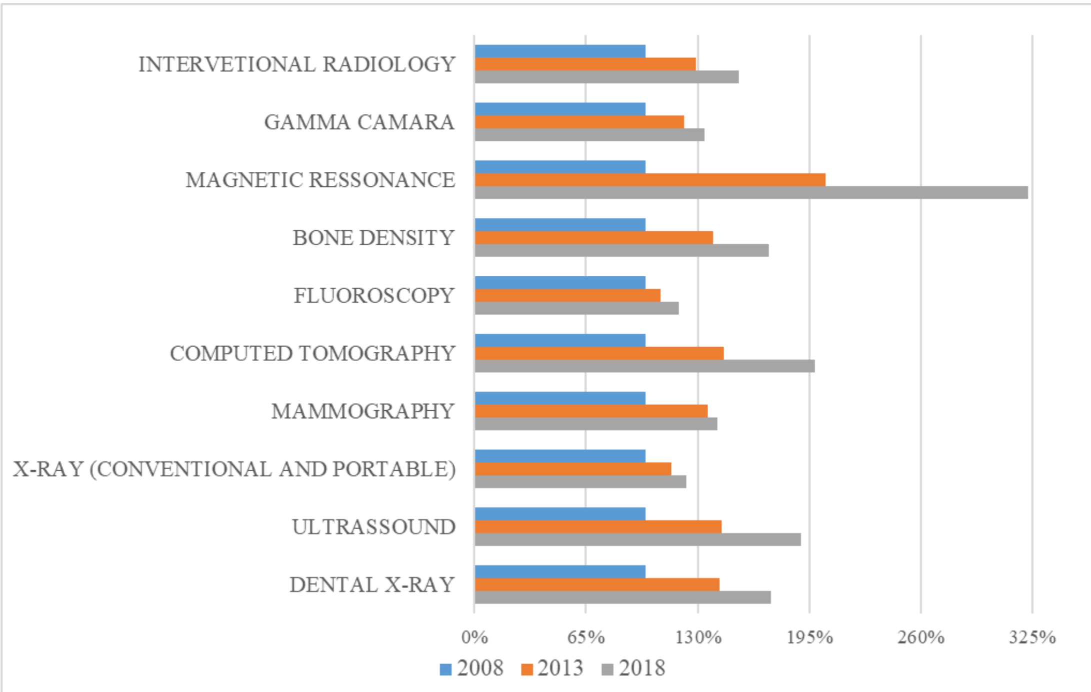

Fig. 3 Increasing of diagnostic imaging equipment in Brazil in 10 years.

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.

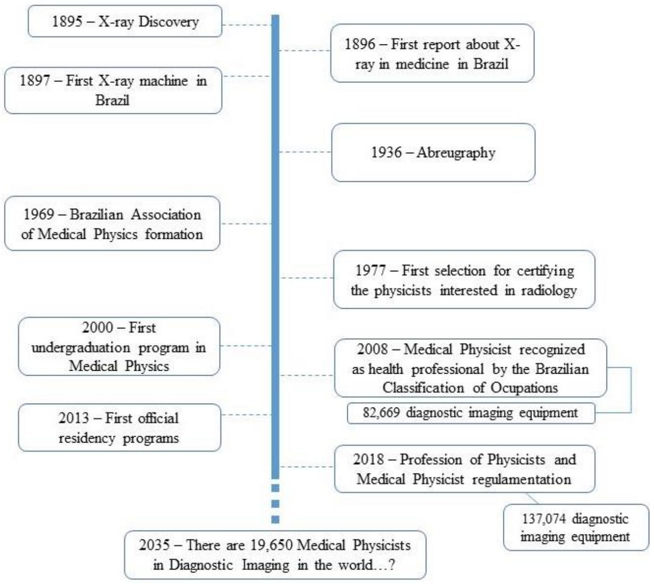

Fig. 4 Chronology of the diagnostic imaging and Medical Physics in Brazil

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.

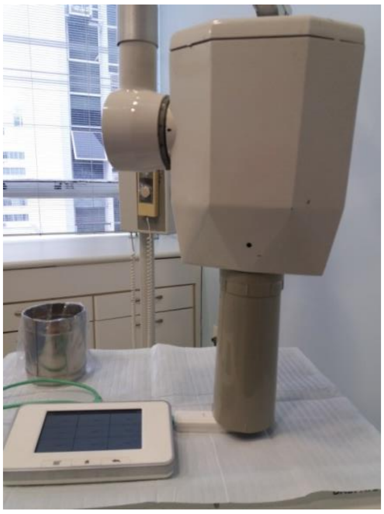

Fig. 2 Experimental arrangement adopted. Solid-state detector positioned at the exit of the X-ray tube.

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.

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

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

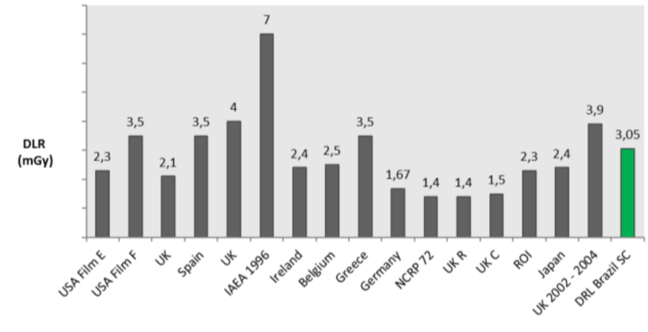

Fig. 2 Comparison between DLRs obtained in Brazil and in other countries.

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.

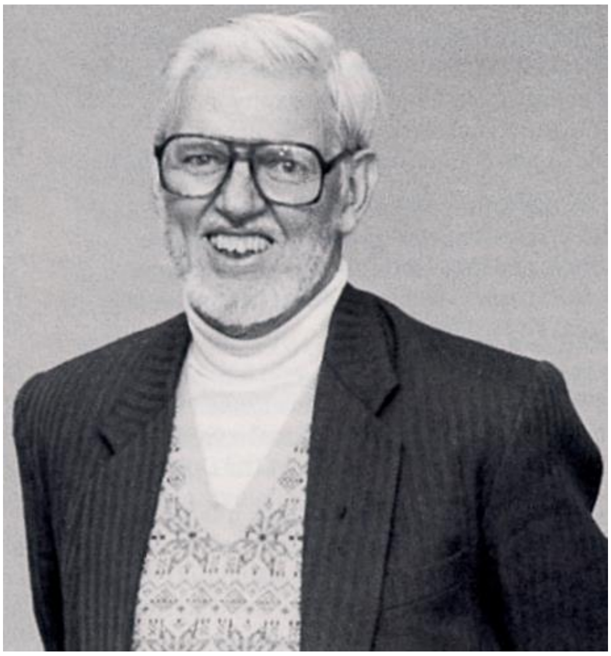


Fig. 1 A classical photo of Prof. John Cameron.

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.

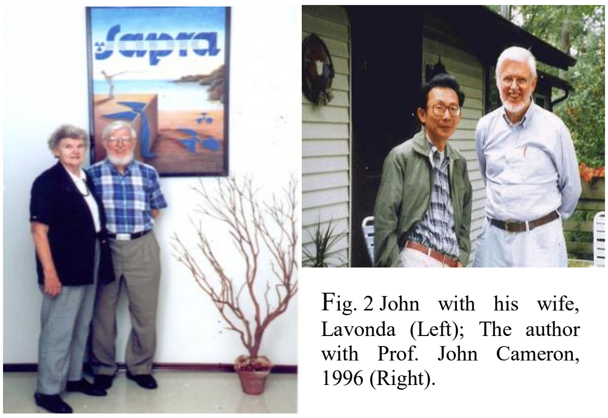


Fig. 2 John with his wife, Lavonda (Left); The author with Prof. John Cameron, 1996 (Right).

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

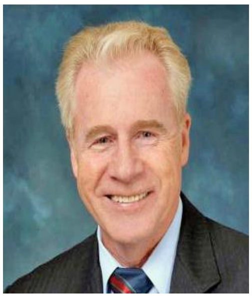
Whole body scanning within a breath hold period and truly isotropic high-resolution CT have become routinely available with the latest multi-slice spiral CT (MSCT) scanners. What is the state of the art? What are the challenges for future developments? The talk shall focus on two core issues: on scanner 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.

4th 2009 7th 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.

5th 2010 8th 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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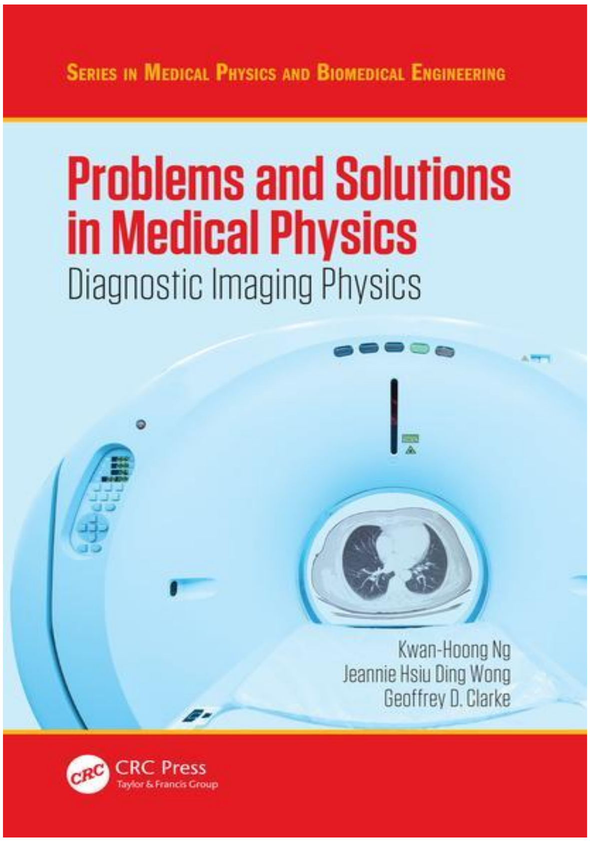
BOOK REVIEWS

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

Tabakov, S.[1,2],

[1] King's College London, UK, [2] Immediate Past President IOMP (International Organization of Medical Physics)

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.

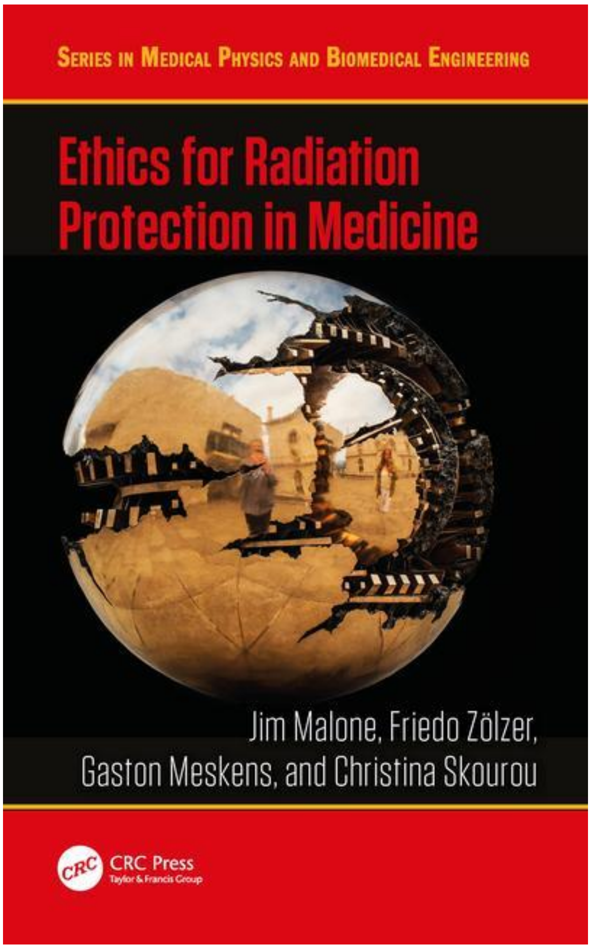
This is a typical book to support the medical physics teaching process (as well as this of related specialties). The book could have significant number of readers from Universities – it will be very useful for lecturers and students in Diagnostic Radiology. One can expect that the sequel of three books, 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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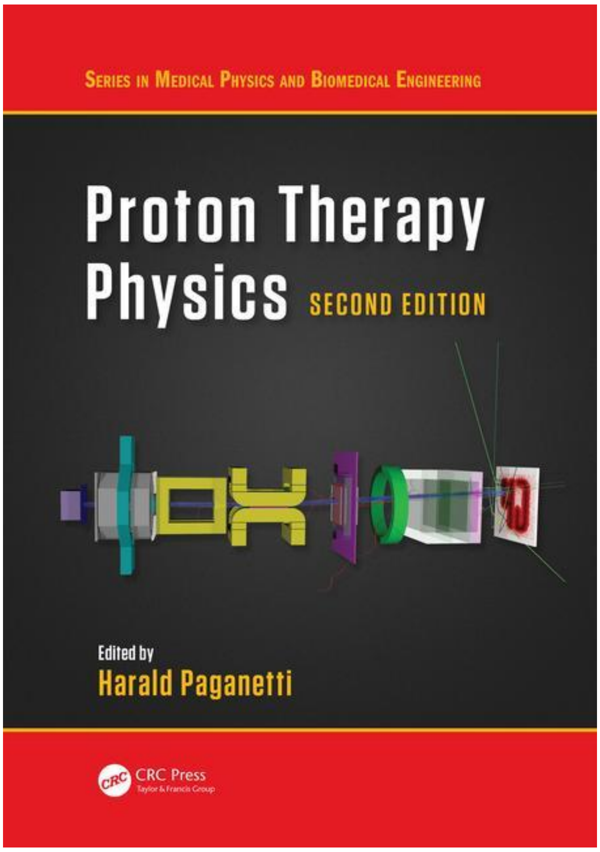
Abstract— **This article is a brief review of the CRC textbook "Proton Therapy Physics – Second Edition" Edited by Harald Paganetti, 2018, CRC Press (Series in Medical Physics and Biomedical Engineering), ISBN-9781138626508**



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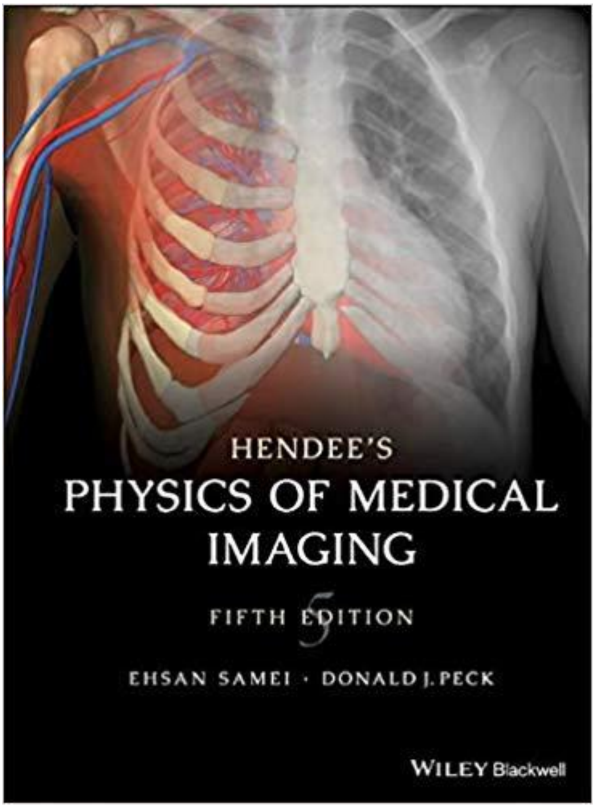
Abstract— **This article is a brief review of the textbook "Hendee's Physics of Medical Imaging" 5th Edition, by Ehsan Samei and Donald J Peck, 2019, Wiley-Blackwell, USA, ISBN-13 9780470552209**



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.

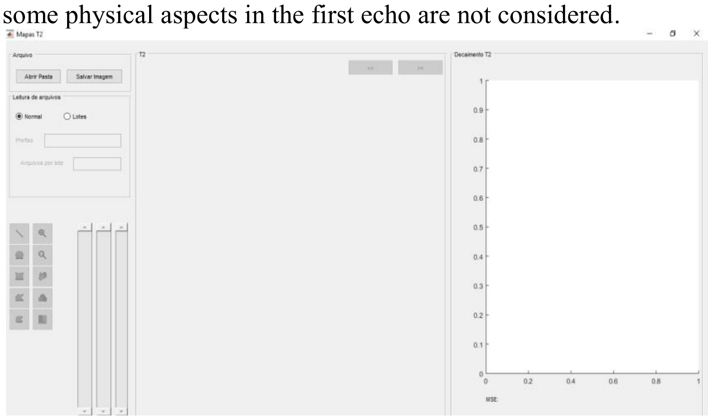

Fig. 1. Interface of the Mapas T2 application. Once the files containing the images are selected, the processed T2 map is displayed in the viewer and, after selection of an ROI, the decay curve is displayed.

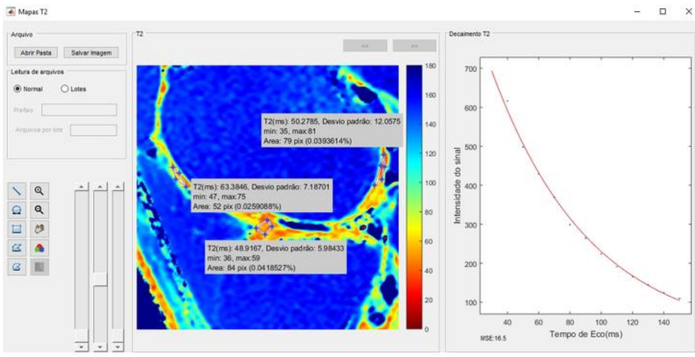

Fig. 2. Simultaneous visualization of three ROIs on a single T2 map

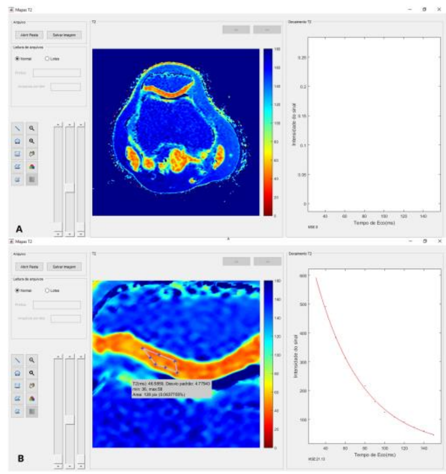

Fig. 3. A) T2 map obtained with 14 echoes. B) The zoom function was used to aid in the visualization and to obtain an ROI in the cartilage.

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).

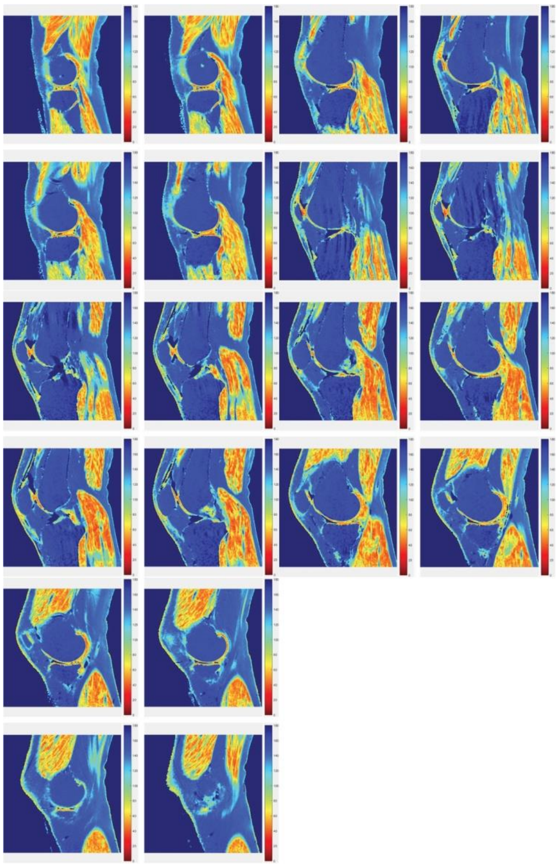

Fig. 4. Simultaneous post-processing procedure of 280 MR images.

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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Clinical Supervisors:
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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

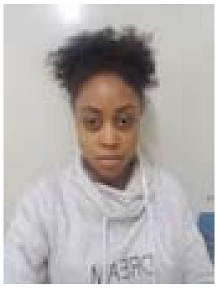
Prospective/Objective. The goals of this work are to characterize new Synthetic Single Crystal Diamond Detector (SCDD) for the dose measurements in the radiation therapy photon beams, in order to use safety it to check the accuracy of TPS modeling for the dose calculation in small field size, penumbra 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 $R^2 = 1$. Constancy checks also indicate positive linearity with $R^2 = 0.999$ 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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Azienda Ospedaliero - Universitaria di Modena

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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Clinical Supervisor:
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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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Clinical Supervisor:
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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:
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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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INFORMATION FOR AUTHORS

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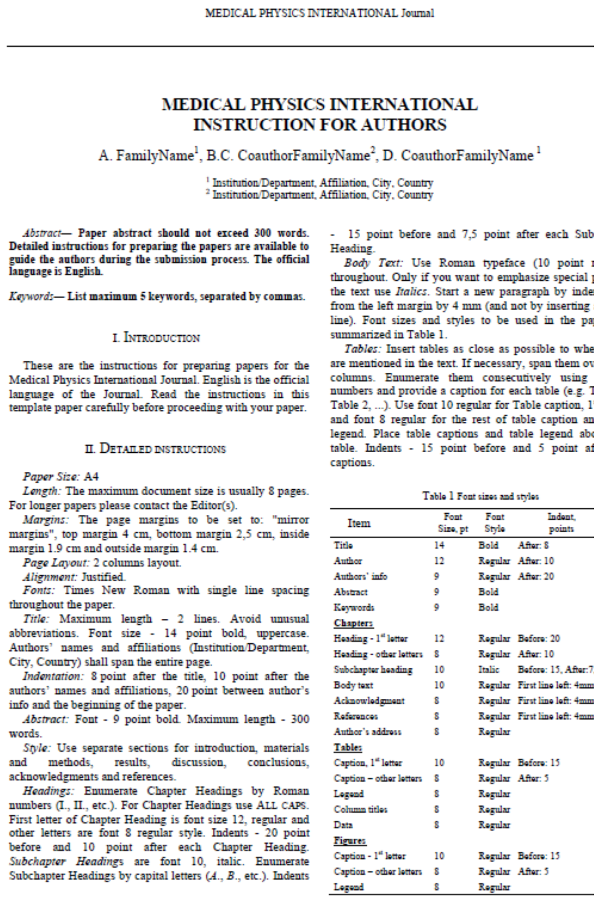

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Author	12	Regular	After: 10
Authors' info	9	Regular	After: 20
Abstract	9	Bold	
Keywords	9	Bold	
Chapters			
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Heading - other letters	8	Regular	After: 10
Subchapter heading	10	Italic	Before: 15, After:7
Body text	10	Regular	First line left: 4mm
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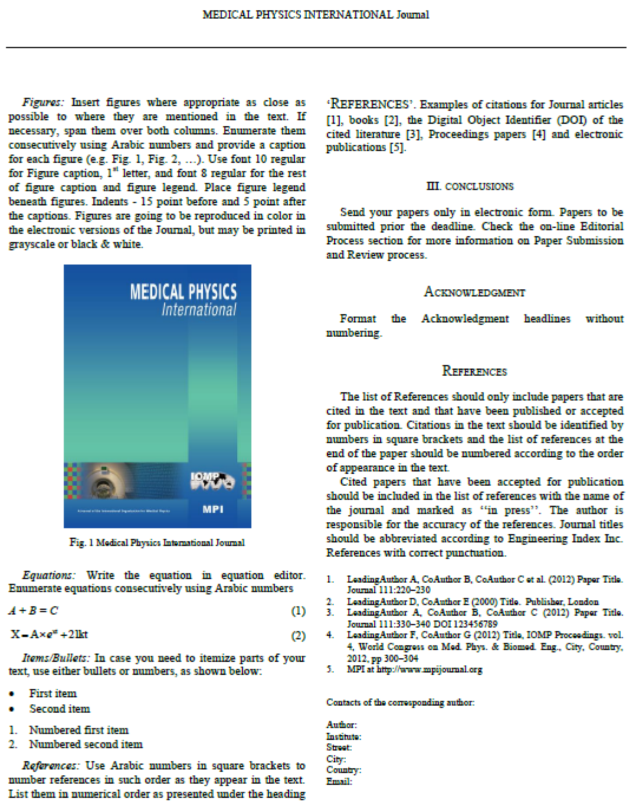

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