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EDITORIALS

Medical Physicists in all countries of the world advance their professional status along with their scientific and clinical capabilities by connecting with and sharing knowledge, experiences, and ideas with each other. Many other journals provide for publication of peer-reviewed research reports that advance the science, related technology, and clinical applications of the profession. The many other activities within the medical physics profession including educational methods and resources, individual professional development, status of development within the geographical regions, and much more are the subjects for this journal. As a free and open resource publication it is available to all. Readers are encouraged to share and discuss articles with others, especially students and younger physicists to engage them in the world-wide medical physics community.

Perry Sprawls MPI Co-Editor-in-Chief

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This regular issue of the Journal Medical Physics International (MPI, May 2021) continues with the focus on the IOMP Regional Organizations (RO). The focus now is on MEFOMP (Middle East Federation of Organizations for Medical Physics). This issue follows the previous Focused issues related to the South and Central America and the Caribbean Region (May 2019), the African Region (Dec 2019), the South East Asian Region (May 2020) and the Asia-Oceania Federation Region (Dec 2020).

The current issue includes papers tracing the development of our profession in Iraq, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, Yemen, as well as an overall view of MEFOMP and its reaction to the current pandemic. We are grateful to the MEFOMP President and Secretary General - Dr Huda al-Naemi and Dr Mohammad Hassan Kharita - our Contributing Co-Editors of the MPI May 2021 – who solicited papers from the Region. The large Professional section of the Journal also includes information about collaborative activities in Rwanda and Kenya.

The Educational section includes information about the Update of the Scientific Dictionary of Medical Physics (currently cross-translating 4000 medical physics terms in 32 languages), as well as about medical physics education activities during the time of Covid-19.

The How-To part of the Journal includes activities related to the assessment of Patient radiation dose in CT examinations, as well as Quality Control of SPECT Whole body imaging.

Four book reviews are also published, including the current IAEA Guidelines on Certification TCS 71.

We believe that many colleagues will find interesting information in the new issue of the MPI Journal. We are happy to inform our readers that our recent MPI Special Issues related to the Project History of Medical Physics – from January and May 2021 (covering History of Ultrasound in Medicine), have now thousands of downloads. The consistently high number of MPI readers underlines the importance of the aim of our free MPI Journal -supporting of the global development of our profession.

As usual, we welcome papers from our colleagues

Slavik Tabakov, MPI Co-Editor-in-Chief

Web server stats showing the global use of the MPI Journal during May 2021

EDUCATIONAL TOPICS

THE UPDATE OF THE SCIENTIFIC DICTIONARY OF MEDICAL PHYSICS

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Abstract

The paper describes the update of the Scientific Dictionary of Medical Physic with 25% more terms, including new fields (Non-Ionising radiation safety and Clinical Engineering) and increased number of languages (now 32 languages in 11 alphabets). This Dictionary is now a very important part of the educational process in Low and Middle Income (LMI) countries with thousands of users per month. The paper gratefully acknowledges the contribution of over 250 senior colleagues, forming the international network of the Dictionary.

INTRODUCTION

The Scientific Dictionary of Medical Physics is online from 2005 and was merged with the e-Encyclopaedia of Medical Physics in 2010 (at www.emitel2.eu). In previous publications [1,2] we described the first steps of this huge project - the Thesaurus of the Dictionary; the need for it, especially in Low and Middle Income (LMI) countries; our original methodology for Dictionary development, which was further updated for the development of the e-Encyclopaedia; the use of the Dictionary and its place in the process of global development of medical physics.

Here we describe briefly the process and content of the recent significant update of this Scientific Dictionary, and list all colleagues who took part voluntarily in this huge project. The update consists of both inclusion of more languages in the Dictionary (now 32 languages in 11 alphabets), and the update of its Thesaurus with terms from additional fields related to medical physics.

I. THE UPDATE OF THE THESAURUS OF THE SCIENTIFIC DICTIONARY OF MEDICAL PHYSICS TERMS

The initial thesaurus of the Scientific Dictionary was developed as part of our project EMIT (2001-2003) and was released during WC2003 in Sidney, Australia. This thesaurus included terms from the main fields of our profession - Physics of: X-ray Diagnostic radiology, Nuclear Medicine, Radiotherapy, Ultrasound Imaging, Magnetic Resonance Imaging, Radiation Safety [2].

As part of the e-Encyclopaedia project EMITEL, the thesaurus was updated in 2008 with new terms related to new equipment and methods in these fields. This updated Scientific Dictionary was e-published in 2010 on the website www.emitel2.eu (together with the e-Encyclopaedia).

During the following years it was evident that the future updates of the Thesaurus will have to include, additionally to the main fields, the field of Non-ionising radiation safety. The current activities of the IUPESM, related to collaboration of medical physicists and engineers, revealed additionally that including terms from the field of Clinical Engineering will benefit many colleagues from LMI countries, as there they often take part in Clinical engineering activities.

The update of the Thesaurus included mainly the Editorial Team of the Encyclopaedia of Medical Physics (S Tabakov, F Milano, P Sprawls, M Stoeva, S Tipnis, T Underwood) plus F Fedele, E Chaloner, L Pecchia, E Iadanza, P Bregant, K Ng, J Oshinski, A De Stefano, R Longo, J Thurston, E Bezak.

During the process of update some older terms were consolidated with newer ones and 650 new terms were added. Some of these terms are complex (e.g. Laser classification, Laser output mode, Laser protective eyeware, etc). We continued to include common abbreviations of methods, organisations, classifications, etc., hyperlinked with the original term. This way the Thesaurus of the Scientific Dictionary reached almost 4000 terms, what is normal for a dynamic scientific field such as medical physics. In order to facilitate the parallel update of the e-Encyclopaedia of Medical Physics (to be released around the end of 2021) all previously existing Dictionary Identification numbers (ID) were preserved and new IDs were assigned to the new terms.

II. NEW LANGUAGES OF THE SCIENTIFIC DICTIONARY

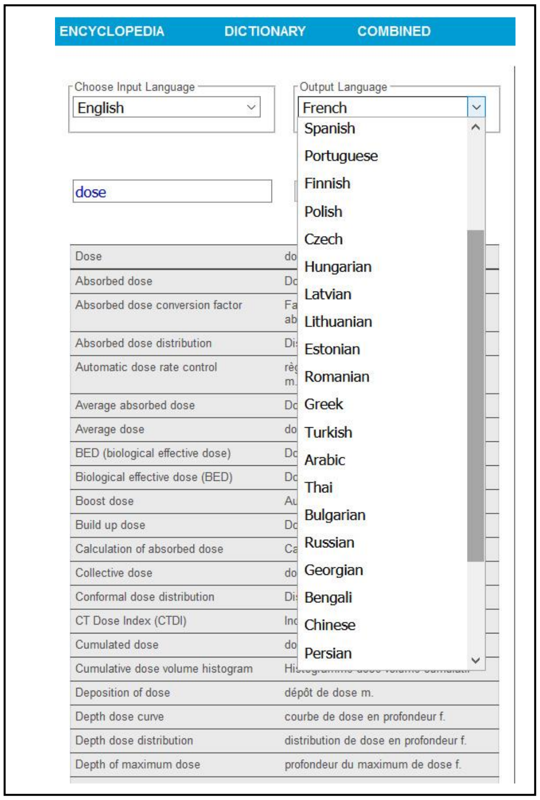
After the online launch of the e-Dictionary in 2010, five more language were included in it: Finnish, Korean, Georgian, Ukrainian and Vietnamese. Also the existing teams of specialists were joined by additional colleagues for the update of the Dictionary (lised in Part III of this paper). Some of those colleagues are associates and attendees of the College on Medical Physics in ICTP, Trieste, Italy.

The development of this huge project took over 20 years. The team of senior colleagues who contributed to the update of the Dictionary included most of the previous members, but some retired and unfortunately some are no longer with us. Additionally new members were included in the Dictionary Network and we hope this will continue in future.

The software of the Website of the Dictionary [3] was also updated by M Stoeva and A Cvetkov to allow faster search with handling of complex terms with many words. All this process was going in parallel with the update of the Encyclopaedia of Medical Physics (to be described in a further paper this year). The Dictionary translates not only from and to English, but between any two of its 32 languages.

The use of the Scientific Dictionary is the same as before

The use of the Dictionary is illustrated on Fig.1 below (English to French) - only part of the images are displayed.



The combined use of the Scientific Dictionary and the Encyclopaedia of Medical Physics is shown on Fig.2 below:

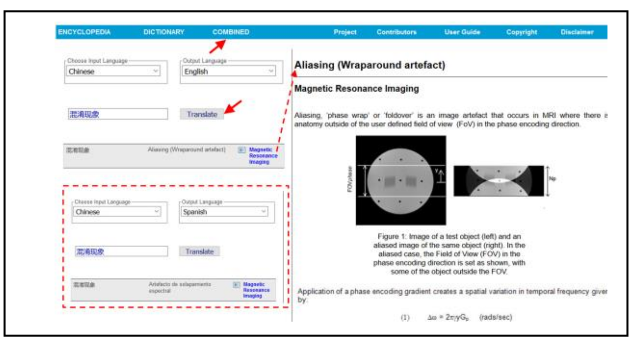


Fig.2 Combined mode (Dictionary+Encyclopaedia): the term *Aliasing* has been included in the local language (e.g. Chinese) and the term entry is displayed in English. Additionally the term name can be translated to any Dictionary language (in the box: second example with translation in Spanish). The term text is displayed in English.

One important moment is that all specialists who took part in the translation of the terms in the Scientific Dictionary contributed voluntarily this activity aiming to support the global development of medical physics. As I developed and coordinated all phases of the Scientific Dictionary plus the Encyclopaedia of Medical Physics, and invited personally most of these colleagues, I am truly grateful to each one.

III. DICTIONARY CONTRIBUTORS

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The current 32 languages in the Scientific Dictionary are: Arabic, Bengal, Bulgarian, Chinese, Croatian, Czech, English, Estonian, Finnish, French, Georgian, German, Greek, Hungarian, Italian, Japanese, Korean, Latvian, Lithuanian, Malaysian, Persian, Polish, Portuguese, Romanian, Russian, Slovenian, Spanish, Swedish, Thai, Turkish, Ukrainian and Vietnamese.

The website www.emitel2.eu (and www.emitel2.net) includes the Multilingual Scientific Dictionary of Medical Physics Terms and the e-Encyclopaedia of Medical Physics.

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Postgraduate education in Medical Physics - Response to COVID-19 restrictions for delivery of radiation physics practicals: A student survey

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Abstract— **Interruptions to in-person delivery of scientific training due to the restrictions imposed by the COVID-19 pandemic have called in most case for lateral development of online modules. Here we consider the impact and potential future use of such online resources and learnt experience developed for radiation physics practicals as part of Medical Physics training. A student questionnaire survey suggests positive benefit to the understanding of concepts and processes with the majority (19 out of 24) indicating *Agree*/or *Strongly Agree* to such improvement in overall understanding and (20 out of 24) knowledge of radiation measurements for Medical Physics. The majority of responses supported the continuing use of resources developed for remote teaching needs of the past academic year (>21 *Agree* or *Strongly Agree*) for preparation or on-going support of on-site lab practicals. However, the consensus (54%) was not in agreements that existing material could solely support student-led study of the subject at local training centres after the pandemic. As result of this feedback, we plan to maintain access to online resources for future students for preparation and support of the on-site practicals. Some occasions where the experience learnt could be taken forward may include a supplementary role of continuing professional development across international networks, especially when close links can be formed with local training centres providing hands-on experience.**

Keywords— **Medical Physics, E-learning, Clinical Scientists Training, COVID-19.**

I. INTRODUCTION

The COVID-19 pandemic demanded significant changes to higher education. Higher Education Institutions (HEIs) had to adapt rapidly in order to continue delivering education during the past academic year (2020-2021), especially in areas of medical practice [1,2]. Medical Physics training was not insular to these changes. In particular, not only delivery of the academic components of training was affected in terms of format shifting to real-time and asynchronous on-line options [3], but often access to the hospital-based training environment was also affected with restrictions imposed by the pandemic [4].

As an example here we are looking at the academic component of medical physics training in one of the largest HEIs in England – King's College London (KCL) – with over 120 part-time students/trainees distributed in 3 academic years. The MSc in clinical science (Medical Physics stream) at KCL provides the academic component for an annual intake cohort of 40 Trainees, approximately half of the Medical Physics Trainees in England under the Scientific Training Program (STP) coordinated by the National School of Healthcare Sciences and Health Education England (HEE). Trainees who attend the Masters course are spread in various geographic locations in the south of England, spanning from Northampton to Brighton and Maidstone to Southampton, over a range of 70 miles radius (or about 2 hours of travel time) from London. There is a small cohort of students outside the STP scheme who attend the full-time course. They are both national and international students, who share some modules with the STP students. The geographical spread of students was an added consideration in adapting to any COVID-19 related measures for academic delivery. As part of the autumn term of this program all students attend radiation physics labs covering essential concepts applied to Medical Imaging and Radiotherapy.

As per governmental regulations during the 2020 autumn period of the pandemic, face-to-face delivery in all UK HEIs was restricted with all group teaching activities replaced by real-time or asynchronous remote learning. As such, practicals were converted within the short interim period preceding final regulatory restrictions, into a format blending pre-recorded material, including on-site recorded video clips of the lab processes, on-line group activities and on-line tutorials leading to a final coursework assessment.

With some distance of time and access to the resources generated from the process, we are now revisiting the teaching of the radiation practicals under COVID-19 restrictions with emphasis on the student learning experience. Although the generation of teaching resources was unplanned and in response to urgent circumstances, it has shown an opportunity potentially applicable to remote support of lab training processes such that may occur in the specialized area of Medical Physics where decentralizing sparse training resources may be desirable. In order to better understand the potential of such opportunities, we developed a questionnaire and conducted a small survey of the student experience from the radiation physics practicals during autumn 2020.

II. PREPARATION FOR THE REMOTE DELIVERY OF RADIATION PRACTCALS

While e-learning (e-L) in medical physics has long history and we have introduced some lectures with e-L since

2001 [5, 6], the delivery of practical labs is challenging and complex.

This practical academic activity could have three main components/steps:

-Preparing specific topical demo of the practical

-Recording a series of video clips demonstrating the practical activity

-Preparing spreadsheets with real data, which will help students calculate relevant parameters.

In our case we prepared three separate radiation physics practicals and all students performed these through on-line delivery at specific times. The subjects of the practicals were:

- *Radionuclide Dose Calibrators*: involving basic measurements for the understanding of quality control and the influence of source positioning and geometry in radionuclide calibrators (fig 1).
- *Half Value Layer (HVL)*: involving measurements of HVL for two different materials using an X-ray unit aiming to the understanding of radiation attenuation and radiation filtration concepts (fig 2).
- *Contamination Monitors*: involving the calibration of different types of contamination monitors aiming to lead to a greater understanding of the workings, limitations and uses of different types of contamination monitors and test sources.

For each of these practicals we prepared the three components:

-Video clips were pre-recorded according to the protocol of the specific lab (with handheld camera, mp4 format). All steps of the measurements were shown and the lecturer guiding the video explained specific steps and possible errors during the process;

-Demos were prepared including clips from specific software, images showing the effect of various radiation levels and spectra on final image quality. Specific equipment and material were shown and explained;

- Data from previous years (from past lab practicals) was used for the preparation of spreadsheets with existing real measurements. The students were asked to use these data to calculate specific parameters, associated with the practical;

-Additional questions were added to each lab protocol, which the students had to discuss as part of their final lab report, thus testing their understanding of the subject.

On the day of the practical the students had a remote session with the lecturer (through MS Teams). They observed the video of the activity and were encouraged to ask questions. Following this they were asked questions related to the lab practical, using the demo material. Finally they were explained how to proceed in using the spreadsheet with data to prepare their practical lab reports.

III. Student survey of remote delivery of radiation practical

The remote Radiation Physics practical were conducted immediately after the remote academic lectures on the subject. After submission of lab reports we conducted a survey. The survey was completed anonymously and attempted to record the level of prior knowledge as the student cohort has a varied academic background (eg undergraduate Physics or Engineering, some with existing MSc or PhD in related or non-related subject). The stream of study i.e. STP or stand-alone full-time student, was also recorded. There were responses from 24 students (18 STP and 6 full-time students). The results of the survey (as per the questionnaire) are presented in detail below.

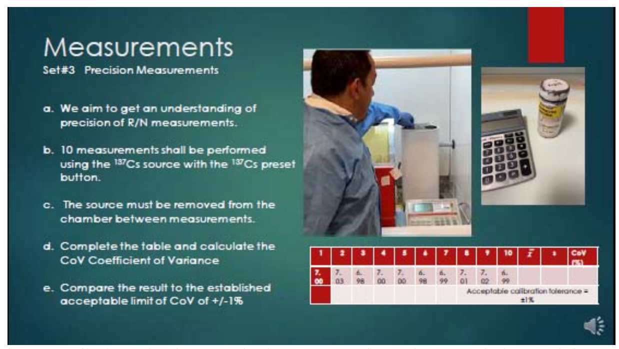

Fig. 1 Radiation Physics practicals – excerpt from the recorded material on radionuclide calibrator measurements.

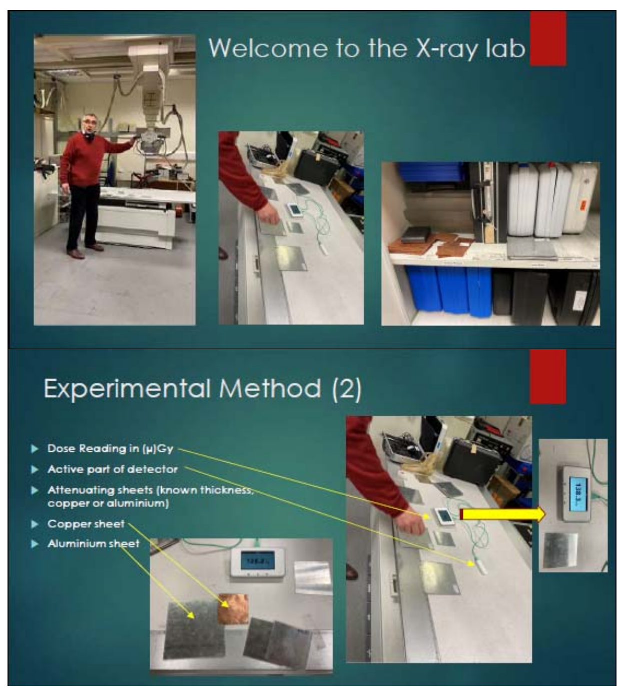

Fig. 2 Radiation Physics practicals – excerpt from the recorded material on Half Value Layer measurements.

Level of prior knowledge: The responses to the relevant question ("*Prior to the sub-module, how would you rate your level of understanding and experience in radiation labs (e.g. from previous studies, practical experience etc)?*") resulted to an average of 2.83±1.3 (on the scale from 1 to 5, 5 being higher level) with 2.5±1.24 and 3.38±1.16 for the STP and full-time cohorts respectively.

Self-appraisal of post-activity knowledge: The responses to the relevant question ("*Following the completion of the sub-module, how would you rate your level of understanding and experience in radiation labs?*") resulted to an average of 3.7±0.8 (on the scale from 1 to 5, 5 being higher level) with 3.55±0.85 and 4.16±0.4for the STP and full-time cohorts respectively.

In more detail, responses indicated positive benefit to the understanding of concepts and processes (fig. 3) with the majority (19 out of 24) indicating *Agree* or *Strongly Agree* to such improvement in overall understanding and (20 out of 24) knowledge of radiation measurements for Medical Physics. In some responses free text feedback indicated praise for the material while in others the varying degree of self-engagement and online-fatigue was flagged up during these times of fully online imposed learning with absence of face-to-face interaction; As an example a comment read:" *The lab groups we were put in were really great … as it forced contact between some otherwise lonely students*". Some free text responses also highlighted varying degree of understanding and engagement among the different elements of the module and on a couple of occasions that associated coursework didn't always seem self-explanatory.

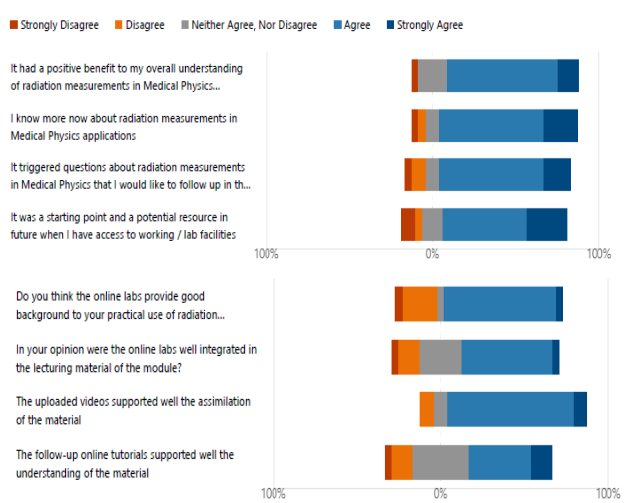

Fig. 3 Radiation Physics practicals – Survey results on online resources evaluation.

Future utilisation of online resources: Additionally to our assessment aim, the survey attempted to probe on the potential value of the developed resources for any future teaching applications looking ahead into a post-COVID-19 restriction era. This may be in the form of support of medical physics academic teaching when face-to-face activities resume as well as support of wider training needs which may span a wider geographical range e.g. for continuing professional development across international networks. To this end, the following question was included: "*Considering the possibility of students being able to access the labs next year, how would you evaluate the use of the existing recorded/online material in radiation labs?*"; Responses are summarised in fig 4. The majority of responses supported the use of resources developed for the remote teaching needs of the past academic year (>21 *Agree* or *Strongly Agree*) for preparation or on-going support of on-site practcal. However, the consensus (54%) was not in agreements (13 *Disagree* or *Strongly Disagree*) that existing material could solely support well student-led study of the subject at local training centres (usually hospitals) thus avoiding visit to the HEI. Free text comments included: "*The online material was good, but I think a physical visit would always be preferable*" and "*in person labs are much better but obviously when this is not allowed the online labs were a good alternative. I think giving next year's students access to the online material before they visit the labs would be really helpful and help alleviate some anxiety students may feel about [performing lab exercises] for the first time*".

As an outcome of this feedback, we plan to maintain access to the online resources for future students as a preparation and support material for the on-site practical sessions. Some of the experience learnt could be taken forward for the preparation of on-line workshops when the geographical spread of participants limits regular face-to-face interaction. Such cases may include continuing professional development across international networks, especially when close links can be formed with local training centres providing hands-on experience to which on-line resources may have a supplementary role.

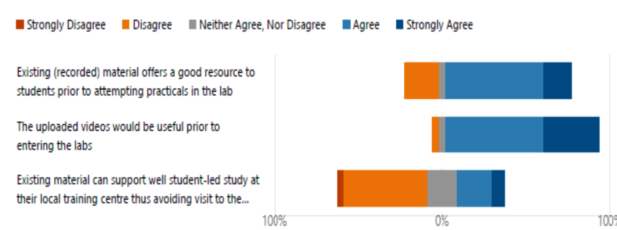

Fig. 4 Radiation Physics practicals – Survey results on future use of resources.

IV. CONCLUSIONS

Online resources developed for the acute demands of remote academic teaching of laboratory components for medical physics during the pandemic, may have a role as supportive framework for future learning activities. The results from the assessment of the practicals reports showed similar level of understanding (similar marks), compared to previous face-to-face lab activities. However, both - the students survey and our own views - indicate that face-to-face practicals should be performed in all cases where the circumstances permit. Another interesting outcome of this remote practicals delivery was that students will benefit from access to such online materials prior to face-to-face lab-based activities.

Acknowledgment

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Online webinars a new learning solution in the pandemic times: An evaluation of AFOMP initiative of monthly webinar series

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Abstract— **The COVID-19 pandemic has been a major challenge in all sectors of our society especially education and training. Regulations related to social distancing and social mobility has led to significant reduction in extracurricular learning and training activities. Learning activities on digital platforms has greatly improved widely accepted as a result. The year 2020 and 2021 has seen testing of new virtual educational approaches in all phases of education worldwide and proved to be effective in the pandemic times. World has seen newer solutions and opportunities. Asia-Oceania Federation of Organizations for Medical Physics (AFOMP) formed on 28th May 2000 with an objective of development of medical physics profession in Asia-Oceania region, to celebrate its 20th anniversary year decided to have a series of monthly webinars on a commercial virtual platform to mark teamwork and cooperation for sustainable growth of medical physics in this region. These webinars were a great success despite the time zone differences for participants from not only the Asia Oceania but also across the globe. Though, it was planned to be organized on every first Thursday of the months of the 20th anniversary year, May 2020- May 2021, considering the enthusiastic responses and eager wish to have more of these from the participants especially the young medical physics professionals AFOMP decided to continue these monthly webinars. The first webinar was on 5th June 2020 and the 13th is scheduled to be on 3rd June 2021. This article discusses in detail about the impact and lessons learned from these monthly webinars at this testing times of COVID-19 pandemic.**

Keywords—**Webinar, Survey, AFOMP, Medical Physics Education, COVID-19 Pandemic.**

I. INTRODUCTION

The impact of COVID-19 is observed in all quarters across the globe. The different sectors of education in all countries of Asia Oceania as well as the rest of the world are severely affected. The worldwide lockdown imparted acute effects on routine life as a whole. Learners stopped to go to schools/ colleges and all physical educational activities halted across the world [1]. The educational institutions were pushed forward to grow and option for methods utilizing advanced new technologies, which have not been used/ popular before. To wash away the serious threat on education, the stake holders in the sector has been fighting to survive the crises with different approaches and digitizing was the answer.

The pandemic COVID-19 has rapidly spread over whole world and urged everyone to maintain social distancing. It disrupted the education sector significantly which is a crucial determinant of any country's economic ensuing. COVID-19 was first reported in Wuhan, China on 11th January 2020 [2]. The name COVID-19 was proposed by the World Health Organization (WHO) on 11th February 2020. The first case of the COVID-19 pandemic in the second largest population in Asia Oceania, India was reported on 30th January 2020 in the State of Kerala and the affected has a travel history from Wuhan, China.

The COVID-19 pandemic has affected countries and territories worldwide with a huge impact on the lives of millions of people. While countries are at different points in their COVID-19 infection rates, education sector is heavily affected by the closure of learning institutions, to slow its spread. The global academic calendar has been in a state of disarray by the pandemic outbreaks [3]. Schools and universities from basic to advanced education halted their regular physical classes and students have return to their natives for social isolation. As a result of this, higher learning institutions have been pushed into experimenting Electronic learning (E–learning) in an unprecedented scale. E-learning is defined as the use of computer network technology, primarily over or through the internet, to deliver information and instructions to individuals [4].

The adoption of digital technology was accelerated by lockdown adopted worldwide. Development of new and improved professional skills/ knowledge resulted through more efficient and productive online learning. It is a fact that technology-based education is more transparent in all respects. The expertise and exposure to information and communications technology of both educators and the learners have significant role in the selection of appropriate pedagogy for online education.

Medical physics uses physics principles, methods and techniques in practice and research for the prevention, diagnosis and treatment of diseases varying from simple physiological or morphological abnormalities to cancer with the specific goal of improving health and well-being. Radiation Oncology Physics, Medical Imaging Physics, Nuclear Medicine Physics Medical Health Physics (Radiation Protection in Medicine), Non-ionizing Medical Radiation Physics, and Physiological Measurements include the vast spectrum of medical physics practice. It is also closely linked to neighboring sciences such as Biophysics, Biological Physics, and Health Physics [5].

Asia-Oceania Federation of Organizations for Medical Physics (AFOMP) was formed on 28th May 2000 with an objective of development of medical physics profession in Asia-Oceania region. AFOMP has made notable milestones such as regularizing annual conference AOCMP, newsletter, journals, oration, awards, and policy statements with support of each member of AFOMP. In two decades, seven teams of AFOMP Executive committees, which include President, Vice President Secretary General, Treasurer, and Committee Chairs have provided leadership, guidance and served for the betterment of organization and profession [6-8].

The co-operation and communication among medical physics organizations in the region, medical physics related activities, status, and standard of practice of the profession were all improved and upheld in the last two decades by means of organization or sponsorship of regional/ international conferences, collaboration/ affiliation with scientific organizations and so on [8].

During the pandemic, the health services needed to be continued and therefore medical physicist also contributed hugely to tackle the pandemic during COVID [9]. The Radiotherapy facility, Radio Diagnosis, Nuclear Medicine, Radiation safety, QA, QC, education, and training continued with greater challenges than usual. AFOMP also took many steps to keep the education training, dissemination of knowledge and the technology has helped in this endeavor [9-11]. AFOMP started monthly virtual webinars for the benefit of medical physicist as most of the conference either are postponed or canceled. However, the 20th AOCMP was held at Phuket Thailand in hybrid mode that is virtual as well as in person.

AFOMP has brought out guidelines for the medical physicist in radiotherapy for the radiotherapy services and guidelines for Radiological imaging for radiological imaging staff and are available on the AFOMP website. To encourage publication of research articles in AFOMP official Journals, AFOMP has started AFOMP best publication award.

II. Materials and methods

Asia-Oceania Federation of Organizations for Medical Physics (AFOMP) was established in 2000 (www.afomp.org) for encouragement of co-operation among national Medical Physicist organization of the IOMP (www.iomp.org).Today AFOMP has 21 countries as members and last 20 years AFOMP has tried to afflict medical physics education and profession in this region. AFOMP has started lifetime achievement award, best publication ward traveling grants to young medical physicist. AFOMP is trying to increase its activities for benefit of young Medical Physicist in the region and planning some more awards like young Medical Physics Innovation Award, Best research award etc. to sustain and to recognize the contribution of medical physics and radiation safety.

The study was a cross-sectional survey based on a web-based questionnaire carried out among medical physicist who attended the AFOMP monthly webinar. The web-based questionnaire was prepared based on the experience of the participants who was attending the AFOMP webinar in COVID-19 pandemic.

The survey comprised a total of 26 questions. The survey was composed of questions adapted to evaluate awareness and understanding level of participants during webinar. We used Google Forms, a web-based survey method to create as well as to distribute the questionnaire. An online Google form questionnaire link was shared with different in various social media platforms (WhatsApp messaging software, AFOMP Website, Face Book, Gmail etc). All the participants and researchers were asked to answer the questionnaire for a survey purpose. Participants were also asked to share the questionnaire link among their colleagues; therefore, the questionnaire could reach many participants. The final questionnaire for this study consisted of 26 questions. The questions include the common problems encountered in the online webinar, and suggestions to improve the online webinar. The questionnaire consisted of 24 multiple-choice questions and two short answer questions.

Consent was obtained from all the 107 participants. No personal or demographic information was collected in the study. Data collection was done using a Spreadsheet linked to the online Google form questionnaire. The responses were collected as Excel sheets and analyzed. Data collection was done during the period 10th February to 31st March 2021.

III. Resuts

A total of 107 responses were obtained. Participants from 28 countries contributed to this survey. 26 participants were from India (24.3%), 11 (10.3%) participants from Malaysia, and 6 (5.6%) from Taiwan. The other countries participated in the AFOMP survey were South Africa, Morocco, Iran, Africa, Sudan, Japan, Nepal, Philippines, Syria, Bangladesh, Philippines, Singapore, Indonesia, Australia, Turkey, México, Thailand, Mongolia, USA, HKSAR, Pakistan, Morocco, France, China, and Ireland (Fig.1).

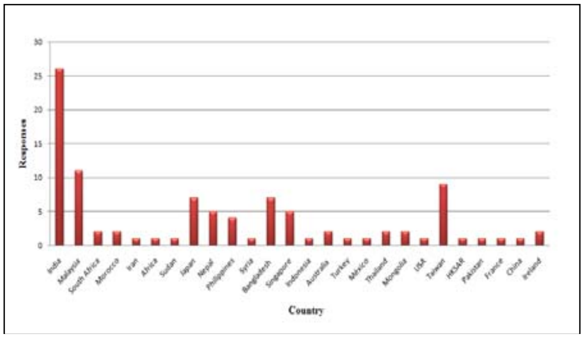

Table 1 Analysis of the questionnaire responses on individual details

Fig.1 Country wise participation in the survey

Out of the 107participants, 63 (59.8%) were males, and 43 (40.2%) were females

Demographic Profile N=107			
		N	%
Gender	Male	63	59.8
	Female	43	40.2
Designation	Student medical physicist	24	23.1
	Clinical medical physicist	39	36.1
	Faculty medical physicist	24	23.1
	other	20	18.7
Specialization	Radio diagnosis	9	8.4
	Nuclear medicine	2	1.9
	Radiotherapy	65	59.8
	All three	19	17.8
	other	13	12.1
How do you come to know about AFOMP Webinar?	AFOMP Website	25	23.4
	IOMP Website	6	5.6
	E-Mail	35	31.8
	Social media	5	4.7
	From colleagues and friends	27	26.2
	others	9	8.4
How many AFOMP webinar you have attended?	All	35	33.3
	Few	69	63.9
	None	3	2.8
How do you find webinar subjects?	Relevant	104	96.3
	Non relevant	4	3.7
Should AFOMP webinars continued after COVID-19?	Continued	92	86
	Discontinued	2	1.9
	Continued with changes	9	8.4
	If continued with changes, please specify	4	3.7

(Table1).

The age of participants ranged from <25 to >45 years. About 13.1% of the participants were aged <25 years, 33.6% were aged 25–35 years, 25.2% were Aged 35–45 years, and 28% were aged >45 (Fig.2).

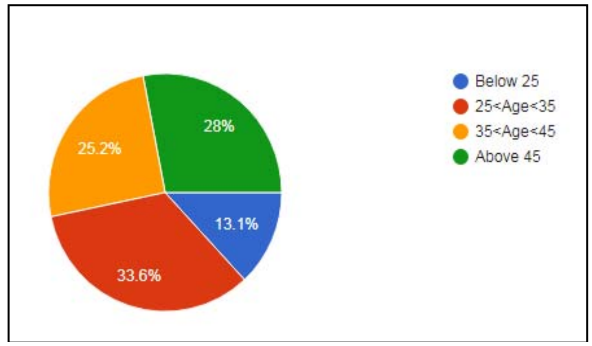

Fig.2 Age group of the participants

Most of the participants were clinical medical physicist (36.1%). About 23.1% of the participants were student medical physicist and faculty medical physicist. The other category includes almost about 18.7 % (Table 1).

It was seen that almost 59.8% of the study participants were from radiation therapy followed by around 8.4% from diagnostic radiology, around 1.9% from nuclear medicine department, 17.8% (18) from all three departments (radiotherapy, radio diagnosis and NM) and 12.1% from other departments (Table 1).

A good number of the participants (31.8%) came to know about AFOMP webinar through email. This was followed by 26.2% from colleagues and friends, 23.4% through AFOMP website, 5.6% from IOMP website, 4.7% from social media and 8.4% from other resources (Table 1)

Out of 107 responses 33.3% participants are attended all the AFOMP Webinar.63.9% attended few of them and rest all are not attended any of them (Table 1).

The study also revealed that 96.3% participants find the AFOMP webinar subjects are relevant and 3.7 % find the subjects are not relevant for them (Table 1).

A total of 86% (92) of participants said that the AFOMP webinar should be continued after COVID-19. 8.4% (9) participants said that continue the webinar with changes. Very few participants said that the AFOMP webinar should discontinue (Table 1).

Half of the participants requested that the subjects of the webinar to be more application based (50.5%). 25.2% of the participants requested that the subjects should be advanced, 15.9 % said that subjects should be researched based and only 8.4% participants responded for basic (Fig 3).

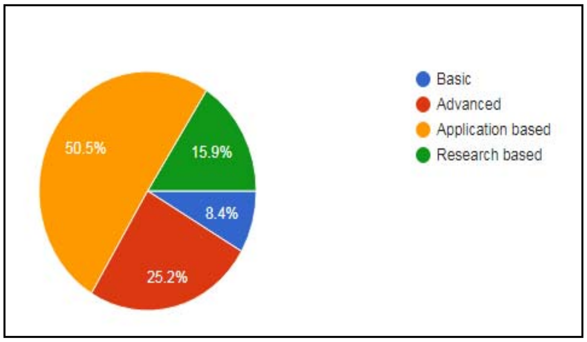

Fig.3 Requirement for the subjects of webinars

Challenges faced during webinar was given internet connectivity, device or equipment, time constraint, demanding workload and other ommitments.30.8% participants said that internet connectivity,28% for demanding workload ,18.7% for time constraint,17.8% for other commitments and 4.7% for device or equipment (Fig 4).

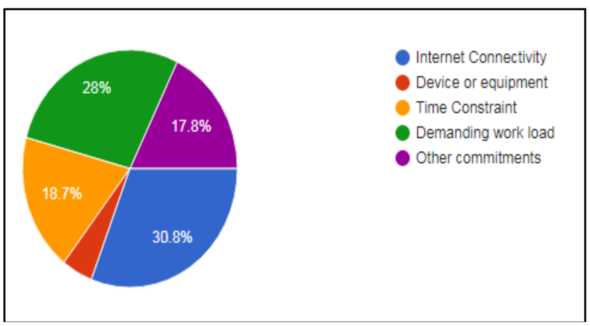

Fig.4 Challenges faced during webinar?

Almost 62.6% participants are requested to add more webinar subjects related to radiotherapy.19.6% for radio diagnosis, 11.2% for nuclear medicine and rest for other topics (Fig.5).

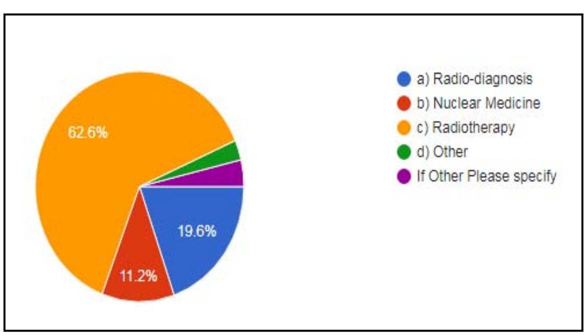

Fig.5 Further requirement of webinar subjects

For the time duration of AFOMP webinar, majority of 72.9% participants responded for remaining same, 22.4% responded for increasing time and 4.7 for decreasing time. (Fig.6)

56.1% of participants said that the frequency of AFOMP monthly webinar should be same, 40.2% said that frequency should be increased and 3.7% responded for decrease (Fig.6).

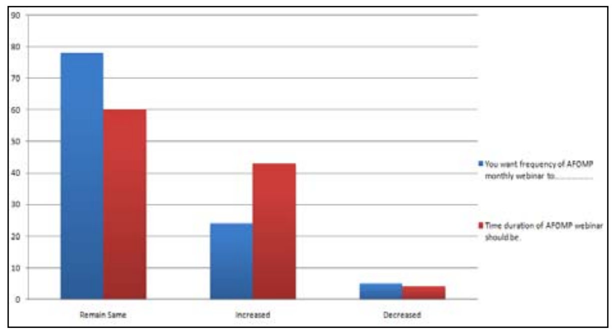

Fig.6 Responses on the time duration and frequency of AFOMP monthly webinar

The majority of the participants said that the AFOMP webinar timing are suitable for their country time zone (88.8%).11.2% responded that the timing is unsuitable for their country time zone. (Table 2)

Almost 72% of the participants found that the video and audio quality of webinar was good, and 28 % participants said that the audio video quality was average. (Table 2)

Table 2 Analysis of the questionnaire responses on webinar details and requirements

Demographic Profile N=107			
		N	%
Suitability of AFOMP webinar timings to your country time zone	Suitable	95	88.8
	Un-suitable	12	11.2
Video and audio quality of webinars	Good	77	72
	Average	30	28
	Below average	0	0
Devices/equipment used for attending webinars.	Laptop	48	44.9
	Smart phone	32	29.9
	Desktop	23	21.5
	Tablet	4	3.7
	Yes	98	90.7

Is recorded AFOMP webinar video on AFOMP website is easily accessible and useful?	No	6	5.6
	If no, specify	0	0

Data showed that participants used several electronic devices to attend webinar. The most used device was the laptop (44.9%) followed by Smartphone (29.9%) and desktop (21.5%), while the least used device (3.7%) was the tablet (Table 2).

A good number of participants (90.7%) were satisfied with the accessibility and use of pre-recorded video on AFOMP website and 5.6% felt that the accessibility and use of pre-recorded video was not good (Table 2).

It was found that the overall rating for the AFOMP webinar series, 51.4% of participants have given excellent, 44.9% has given good and 3.7 responded for average (Fig7).

Our data showed that for 61.3 % of participants are given excellent for the speaker's expertise of subjects and 34% of participants are given well for their subject expertise. Only 4.7% are given average (Fig7).

A good number of participants (47.2%) were satisfied with the Quality and flow of the webinar talks and 48.1 % felt that the clarity and flow of the webinar talks was good.38% responded for average quality (Fig7).

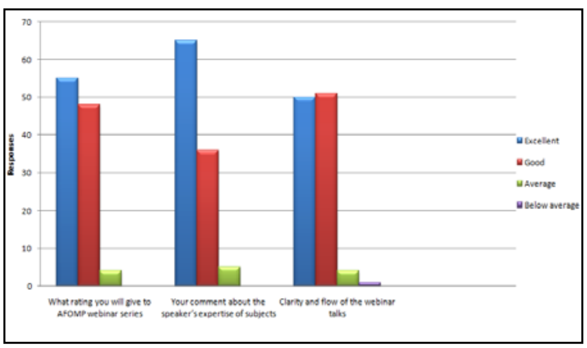

Fig.7 Rating to AFOMP webinar series based on speaker's expertise of subjects, clarity, and flow of the webinar talks.

84.1% of the respondents reported that the question-and-answer time during the webinar was sufficient.15.9% reported that the time was insufficient for them. (Fig.8)

For the use of AFOMP webinar software application, 97.2 % participants responded that application was easy to use, and 2.8% participants said that application was not easy to use. (Fig.8)

Data showed that for 96.3% of participants the AFOMP webinar are helped for knowledge up gradation through e learning duding COVID-19 and 3.7% participants responded no. (Fig.8)

From all 107 responses 69(63.6%) participants are from AFOMP region and 43 (36.4%) participants are from out of AFOMP region. (Fig.8)

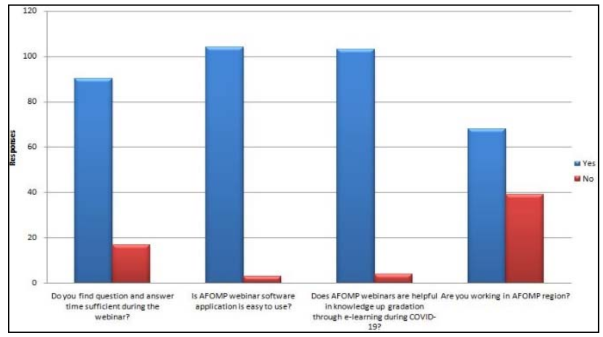

Fig. 8 Responses on ease of accessibility and usefulness of AFOMP webinar video on AFOMP website and AFOMP webinar software

Recommendations to Improve Online Learning in AFOMP webinar.

The participant's recommendations regarding improvement of the online webinar were summarized as change the timing of seminar; continue the excellent work in future, background noise from participants should be addressed before the webinar begins, more free fundamental webinar ,ZOOM Webinar is better than ZOOM meeting, conduct next webinar subject related also to calibration procedure for equipment in diagnostic radiology & nuclear medicine, proton measurement, AAPM TG 43, Low dose radiation effects and LNT hypothesis, good initiative to support medical physics, give sample time for the question and answer portion, organization committee is very cooperative and expert, it is very attractive to provide training from the Asia-Oceania region, focus some course work virtually to students for transfer of knowledge related IMRT, VMAT, Gamma knife and quality assurance and protection, more time for Q&A session since many people join the webinar every time, provide hard copy of lecture , this webinar should continue with more to application and advanced topic on medical physics, the AFOMP should increase the pragmatic and research webinar. Conduct more training programmes in physical as well as virtual modes, reduce the webinar duration to 30 min per session, very nice and should be continued, include more practical based stuff that will help in daily routine, kindly include veracity of topics, continue after COVID-19, please provide some certificate-based lecture where we can give exam after lecture and able to get certificate.

IV. DISCUSSION

Genuine and periodic assessments and feedback are essential components of effective e-learning. Availability of helpful formative assessments and timely feedback are very crucial to the continuous progress of online learners. There are varieties of online infrastructure that have been prepared by many educational firms and made free for learning during this pandemic. The affordability and accessibility to these online infrastructures for all the learners of varied economic backgrounds are still a challenge. COVID-19 has brought many changes to the practice of radiation physics and day to day social life. This pandemic has allowed us the opportunity to reevaluate the way we practice, the way we add value to our field, the way we promote our importance, and the way we adapt using technology in a field that is arguably more comfortable and reliant on cutting edge technological innovation than most fields including those within medicine.

Our data showed that 107 participants from 26 countries answered the questionnaire; Participants were 59.8 % males and 40.2%females, respectively. These findings also show that gender was not a factor about E-learning because both female and male participants were knowledgeable about it. Similar results were found by [1, 12-13] "COVID-19 and E-learning: Perception of Freshmen Level Physics Students at Lusaka Apex Medical University" [1] also indicated that there is no difference between male and female students which each of them is aware of the E-learning system in their study life.

The current study showed that the most popular device that participants used to access the online webinar was the laptop followed by Smartphone, while the least used tool was the Tablet. This is in agreement with previous studies [4, 14-16]. The most common problems associated with online webinar in general included the availability of internet connectivity, demanding workload, time constraint, device or equipment, and other commitments. A good number of participants (90.7%) were satisfied with the accessibility and use of pre-recorded video on AFOMP website and 5.6% felt that the accessibility and use of pre-recorded video was not good. Similar results were found by [14]. The pre-recorded videos were very clear and helped them in their lessons for about 64% (7/11). The majority of the participants were between 20-24 years old; and the majority of the participants were specialized in radiotherapy followed by specialized in other three departments radiotherapy, radio diagnosis, and nuclear medicine.

Good number of the participants (78.4%) came to know about webinar through email and from colleges and friends. Only 36% of the participants attended all the webinar and almost more than half of them attended few of them.

For most of the participants, the webinar subjects were relevant and help them for up gradation of knowledge through e learning. Majority of the participants said that the timings of the webinar were suitable for their country zone and continue the webinar after the COVID-19 pandemic. Half of the participants want the subjects of the webinar related to radiotherapy and should be more application based. For 97.2% participants, the AFOMP webinar software was easy to use and 84.1% responded that the question answer timings were sufficient during webinar. For more than half of the participants, the time duration of AFOMP webinar was suitable and perfect. Majority of the participants said that the frequency of the monthly webinar should be remaining same after the Covid-19 pandemic. The audio, video quality of the webinar was good for most of the participants and recorded video was easily accessible for them.

To improve online education in general it is recommended to change the timings of the webinar, control the background noise from the participants during the webinar, include the webinar subjects related to calibration procedure for equipment in diagnostic radiology and nuclear medicine, proton measurement, AAPM TG 43, Low dose radiation effects and LNT hypothesis. Also, many participants requested that conduct some course work virtually to students to transfer the knowledge related to IMRT, gamma knife, Quality Assurance, and protection. Also Include more practical based stuff that will help in daily routine and provide some certificate-based lecture where we can give exam after lecture and able to get certificate.

V. Conclusion

The emergence of COVID-19 pushed education to adopt into E-learning. Though the education sector was impacted immensely and created many challenges, various opportunities are also evolved. The academic performances of most participants were affected to varying degrees by the pandemic induced lockdown. An opportunity for self-study is an important advantage of online education. This study has provided a situational analysis of the quality and effectiveness of AFOMP monthly webinar in medical physics due to the impact of the COVID-19. There are minor challenges in implementing E-learning monthly webinar lessons such as access and connectivity of internet, workload etc. However, majority of the participants are satisfied with all AFOMP webinars and they are expecting that the webinar should continue after the pandemic. From 26 countries, almost all of the participants said that the AFOMP monthly webinar performance and coordination is good and webinar subjects were relevant.

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A MEDICAL PHYSICS PEER SUPPORT FORUM FOR MEDICAL PHYSICISTS IN KENYA

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***Abstract*— While many Low-to-Middle-Income-Country (LMIC) focused radiotherapy educational efforts are directed at oncologists, few opportunities exist for medical physicists. To fill this gap in Kenya, a Kenyan Physicists Forum (KPF) was created. The forum is open to physicists at any Kenyan radiation therapy centre with the goal of hosting monthly online meetings to discuss medical physics topics of interest to the participants. Invitations were sent to previously established contacts requesting participation in an informational survey and approval from an immediate supervisor in order to verify alignment with local learning objectives. The survey yielded information about the applicants' backgrounds, work environment and aspirations for the forum. Meetings took place online. Discussion topics were chosen by the Kenyan physicists and sessions were either seminar or discussion based. Eleven meetings were held in the first year, each attended by 4-12 people. Over the year, the forum grew from 12 to 22 members by word of mouth. After one year, a 'Help us improve' survey was sent to all participants and included questions with both rating scale and free text responses. Eight physicists completed the 'Help us Improve' survey. The average score for rating scale questions was 10.4/14. Based on the one year survey responses, the forum is performing reasonably well. Barriers to participation were availability and technology connectivity problems. Meeting discussion choices revealed the diversity of practice, with some centres being ready for IMRT, while others were just embarking on 3D planning. A key positive effect of the forum: increased connections among Kenyan physicists. The survey also highlighted interests in advanced technology, artificial intelligence, and research. The Kenyan Physicists Forum is a useful model for interacting with and assisting LMIC physicists.**

Keywords— **LMIC, Physicists Forum, virtual meetings.**

I. INTRODUCTION

There are many organizations assisting Low-to-Middle-Income-Countries (LMICs) with building their capacity to treat cancer patients[1]. A main contender in this space is the International Atomic Energy Agency (IAEA), which assists countries with their radiation therapy infrastructure from design to staff training[2,3]. Another prominent contributor is Radiating Hope, an organization which helps provide radiation equipment to LMICs and assists with installation and training[4]. EmpowerRT provides an inexpensive alternative to provide IMRT on non-MLC linear accelerators using compensators[5,6]. Rayos Contra Cancer is a United States based organization which offers education and training for radiation oncology professionals in LMICs through multi-institutional collaborations referred to as "Telehealth Brigades"[7,8]. Many other efforts focus on education and are often directed at physicians [9,10,11,12,13]. Even when the audience is a mix of oncologists, medical physicists and therapists, the educational materials focus more on the process of therapy and less on the technology that supports it. Outside of these efforts, there is no clear help for everyday issues for medical physicists in LMICs, who often work with no or few colleagues. In an effort to fill this gap for physicists in Kenya, a solution modeled on oncology rounds was implemented. However, instead of presenting a particular patient treatment challenge, the focus was on challenges related to medical physics. To this end, the Kenyan Physicists Forum (KPF) was created and opened to physicists at any Kenyan radiation therapy centre. The goal of the KPF is to provide a space for Kenyan physicists to meet online on a monthly basis to discuss medical physics topics of interest to the participants.

II. BACKGROUND

Prior to beginning this project, both authors had some initial contact with radiation treatment facilities in Kenya. SP visited Kenyatta National Hospital in Nairobi[14] and MvP visited the Moi Teaching & Referral Hospital in Eldoret. The concept of a forum was conceived by MvP after attending a number of seminars directed at radiation oncology departments in LMICs and observing many interactions between oncologists or surgeons[9] on different continents. During background research, MvP came across an article in the Washington Daily News about SP's visit to a cancer centre in Nairobi in 2017[15]. The authors connected via e-mail to discuss being co-directors of a forum for medical physicists and agreed this was an interesting and feasible idea.

The goal of the forum was to provide an opportunity for Kenyan medical physics trainees and practicing physicists to discuss challenges and solutions related to physics problems encountered in modern radiotherapy techniques. Kenyan physicists would be invited to lead and/or participate in topics most relevant to them. Regularly occurring distance learning web-based sessions were chosen as the platform in order to enable real time interactions.

III. Materials and methods

To begin the forum, formal invitations were sent to contacts requesting both approval from an immediate supervisor and participation in a basic informational survey. The supervisor's approval was meant as assurance that the goals of the forum were in line with the trainee's departmental learning goals and objectives. The survey provided information about the background of the physicists, the environment in which they worked, and their aspirations for the forum. Due to the limited initial contact list, participants were encouraged to distribute the invitation to their interested colleagues.

Beginning in November of 2018, meetings took place online once per month using either Gotomeeting, Skype or WebEx. Each meeting focused on a medical physics topic chosen by the Kenyan physicists. Topics of interest during the first year were CTSim QA, linac commissioning, HDR QA, IMRT H&N planning, IMRT QA and beam modelling for treatment planning systems. For two of the topics, CT Simulation QA and Linear Accelerator Acceptance Testing and Commissioning, pre-meeting surveys were conducted to better assess the current practices and needs of the participants. 1.5 hours were allocated for each session. If a seminar lecture seemed appropriate for a given topic, one of the KPF directors would seek out an expert who was likely to have a presentation available. At the conclusion of the meetings, either slide sets or video recordings were provided to the participants depending on which were available.

After 1 year, participants were asked to evaluate the forum. A questionnaire consisting of both rating scale and free text response questions was distributed to the attendees and used to assess the effectiveness of the meetings, reasons for non-attendance and to request input for improvements. The questionnaire was sent via Google Forms to all forum members with a request to return responses within two weeks. Questions based on a rating scale were set up so that a higher number reflected a better result. The questions addressed scheduling, communication during sessions, time allotted to Q&A, utility of answers, how much was learned during each session, the usefulness of the information shared for each topic, whether participants watched the video recording, and whether access to the video was found to be useful. The latter two were 'yes' or 'no' questions; the others were rating questions with a scale from 1 to 4. Responses to open answer questions were collected and investigated for common themes.

IV. Results

Invitations to join the forum were e-mailed mid-August of 2018. Since the inaugural meeting on November 5, 2018, 10 additional meetings have occurred. Meetings are generally attended by 4 – 12 people, with 6 people attending regularly. The number of sessions per topic ranged from one to four and each session lasted for the full scheduled time of 1.5 hours.

The group has grown by word of mouth from 12 to 22 people and also includes one member from a country other than Kenya. The 22 participants are associated with 12 different institutions that include three public institutions, seven private institutions, one university, one government regulatory agency (See Figure 1) and one non-Kenyan institution not included in the figure. The number of participants per institution range from one to five with one institution having five participants (large public hospital) and seven institutions having one participant (See Figure 2). The technology used by the participants includes Cobalt-60 teletherapy machines, linear accelerators, high dose rate (HDR) brachytherapy units, and CT Simulators. An additional linear accelerator at a public centre is expected to come on-line in by early 2021. The types of treatment planning employed by the facilities range from 2-D manual planning to IMRT and/or VMAT treatment planning. Seven participants reported themselves as students or trainees. The reported years of experience for those working as medical physicists ranged from one to eight with an average experience of 4.5 years.

Fig. 1 Participation in the KPF by number of participants per institution.

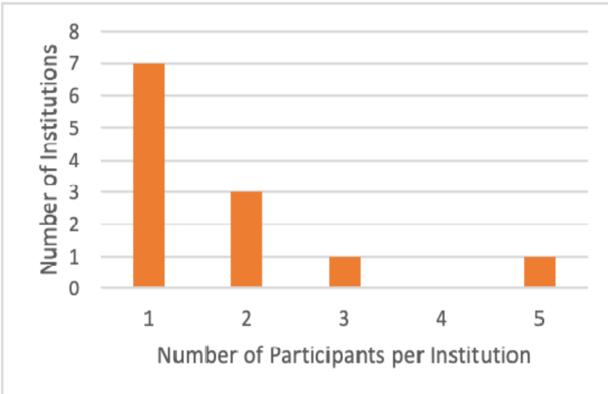
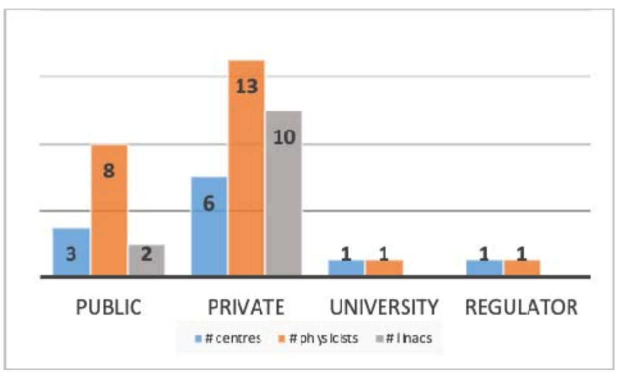


Fig. 2 Participants by institution type and number of external treatment machines per institution.



Four centres responded to the CT Simulation pre-meeting survey. All four centres had access to multi-slice CT simulators (4 – 64 slices), but only three of the four had appropriate accessories for radiation therapy planning such as a flat table-top and lasers for marking isocentre. Two of the centres had a CT simulator in their radiation oncology department, while the other two had access to CT simulators in the diagnostic departments. The physicists were able to do some QA on their scanners, but did not have access to a CTDI phantom and ion chamber, Catphan (or similar) QA phantom or an electron density phantom. None of the physicists reported having access to manuals for their CT Simulators. The results of the survey are listed in Appendix A.

Four centres responded to the pre-meeting survey about linear accelerator details. All centres had at least one linear accelerator and all were expecting new accelerators in the next two years. Vendors of current and future accelerators included Varian, Siemens and Elekta. All centres either have or have access to a beam scanning system, but one centre did not own a calibrated ion chamber. All centres had survey meters and physicists were responsible for performing radiation surveys. The planning systems used included Varian Eclipse, Philips Pinnacle (in near future), Elekta Monaco/Xio and Prowess. One centre started with a remote planning service but switched to local Eclipse planning in 2020. Linear accelerator acceptance and commissioning training ranged from none to attendance of a certificate course. Only one respondent reported having a list of data required to commission a treatment planning system. Further details of the linear accelerator survey have been omitted in order to maintain the anonymity of the respondents.

The response rate to the one-year survey was 8 out of 22 or 36% and did not include responses from members who had not attended any sessions. The overall score was 10.4/14 for the rating scale questions. The survey results are available in Appendix B.

V. DISCUSSION

The inaugural meeting on November 5, 2018 was largely a meet and greet session. Subsequent meetings focused on a medical physics topic chosen by the Kenyan physicists. Inviting other physicists in Canada and the United States to deliver seminar lectures proved effective in that the information provided was not limited to the knowledge of two individuals.

The response rate for the two pre-meeting surveys was low, which may be due partly to the smaller number of centres participating at the time. The information provided in the surveys did provide insight into the participating centers and was considered useful by the KPF directors. However, due to the low response rate relative to the effort involved in creating the surveys, further pre-meeting surveys were not conducted.

The CT Simulation pre-meeting survey revealed a lack of QA phantoms and equipment manuals at the responding centres. During the forum session, alternative QA procedures were discussed and have been implemented by some of the Kenyan physicists. Additionally, links to on-line copies of CT Simulation manuals were shared with the participants.

The linear accelerator pre-meeting survey revealed the broad range of technology and practices among the participants. The access to 3D scanning tanks was encouraging. Points of concern included the lack of training of some of the participants regarding linear accelerator acceptance and commissioning, and that one centre did not own a calibrated ion chamber.

During the forum sessions, online connection problems did exist and typically required 5 – 15 minutes to resolve. Occasionally, connection problems were severe enough to prevent one or two participants from attending a particular session. There were some reports of failed connection attempts and one meeting had to be rescheduled due to software incompatibilities between the host and connecting institutions. Difficulties with establishing connections persisted throughout the year and could take on the order of 15 minutes to resolve. There were also a few times when connections were lost entirely during the session, but these interruptions were brief, with the session continuing after about 5 minutes.

Meeting attendance appears to be topic dependent. The increase in group size over the year and the addition of a physicist from outside Kenya indicates that the attendees feel the forum is useful.

The response rate to the one year survey was 8 out of 22 or 36%. Response rates for surveys that collect data from individuals have been reported to average 52.7% with a standard deviation of 20.4%. [16] The response rate for the one-year survey falls within one standard deviation of this reported average response rate. The survey results showed that the forum is doing a reasonably good job, with an overall score of 10.4/14 on the rating questions. Items highlighted by the survey included the challenge of getting a large number of people from different centres together at the same time and the importance of online meeting etiquette in the form of non-speakers muting their microphones to minimize noise. Comments on the choice of topics showed the diversity of practice at the different centres, with some requesting more advanced topics such as IMRT planning and others wanting to postpone advanced topics to the future. Barriers to participation were largely two-fold: scheduling and technology problems.

The survey results, as well as a number of e-mails on the topic during the year, showed that the forum was much appreciated and reasonably effective in improving practices at Kenyan centres. The responses to “Please provide a brief description of changes to processes as a result of participation in the forum” are copied in Table 1.

The multiple requests about new technology and research opportunities was encouraging and the possibility of starting a research project within this group is under discussion. Potential publications would help Kenyan physicists achieve recognition in the field[17]. Another particularly positive outcome of the forum is the increased communication among physicists at different Kenyan centres, thereby fostering interactions and mutual assistance among them. Even before the forum started, there were some ideas about creating a physics society such as the Canadian COMP (Canadian Organization of Medical Physicists) and AAPM (American Association of Physicists in Medicine). The forum may also be able to assist with the newly created Kenyan Medical Physics Society, which has the potential to help the profession in Africa[17].

Table 1: Responses to “Please provide a brief description of changes to processes as a result of participation in the forum”

Improved my understanding, as such no changes implemented so far
We started doing some CT QA at XXX cancer center
Member mobilization
I would wish we focus more on IMRT,VMAT and Beam modelling since many centres now are planning to role out the technique
Even though we had commenced attempts at CT QA, we did not realize that we didn’t have some phantoms requisite for performance of some of the tests until during the sessions. We’ve since sought alternatives about the CT QA.
We have introduced slice thickness as part of QA in our CT simulator We are doing absolute dose measurement for the CT sim I also learnt tips for planning a good IMRT plan and since then am so happy with my plans
I have been enlightened in all the topics discussed. This has greatly affected my planning especially IMRT and IMRT QA. HDR QA also improved what we have always been doing as a center

Conclusion

A Kenyan Physicists Forum was created with the aim of assisting Kenyan physicists with increasing their access to knowledge on topics related to medical physics. In the first year the forum has grown from 12 to 22 members (excluding the authors) and has received positive feedback with regard to improvement in processes and practices. The main challenges are scheduling and connectivity.

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Appendix A CT Simulation Pre-Meeting Survey

Questions:	**Survey Responses**			
	Respondent 1	**Respondent 2**	**Respondent 3**	**Respondent 4**
Are CT Simulation specific scan protocols used for CT Simulations?	No	Yes	Yes	Yes
What slice thickness is typically used for CT Simulation patients? (Check all that apply)	3 mm	2 mm; 3 mm	3 mm; 5 mm	3 mm; 5 mm
What kV is typically used for CT Simulation scans? (Check all that apply)	120 kV	110 kV	120 kV	100, 110, 120 kV
Is automatic exposure control used on your CT Scanner?	Yes	Yes	Yes	No
Do you currently perform QA on the CT Scanner?	No	Yes	No	Yes
How often is CT Scanner QA performed? (Check all the apply)	We are planning to start performing	Daily	Semi-Annually; Daily warm up	Daily warm up; Annually
Who completes the QA? (Select all that apply)	N/A	Physicist; Radiation Therapist	X-Ray Technologist; Biomedical Engineers	Service provider
Do you have access to CT Simulation QA Equipment?	No	Yes	Yes	Yes
Do you have access to a daily laser QA device or a similar device?	No	Yes	No	Yes
Do you have access to a daily CT scanner QA device or a similar device as shown below?	Yes	Yes	Yes	Yes
Do you have access to a laser QA phantom similar to this one?	Yes	No	Yes	Yes
Do you have access to a Catphan QA phantom?	No	No	No	No
If you have access to a Catphan QA phantom, what model is the phantom?	N/A			
Do you have access to a CTDI phantom and ion chamber?	No	No	No	No
Do you have access to an electron density phantom?	No	No	No	No
Do you have manuals for all of your QA equipment?	No	Yes	No	No
If you are missing any manuals for QA equipment, please list them below.	There is no manual	-	None is available	-

Appendix B. First year 'Help us Improve' survey results from 8 participants

Tables below give the number of responders who responded as given in column heading.
Numerics above tables indicate points system used in assessment.

Please rate the following on a scale from 1 – 4

	1	**2**	**3**	**4**
	Bad	Needs Improvement	Acceptable	Excellent
Scheduling of session	0	0	4	4
Communication during session	0	0	3	5
Time allotted to Q&A	0	2	2	4
Utility of answers to questions	0	0	3	5

Please rate how much your learned during the sessions on each topic

	0	**1**	**2**	**3**	**4**
	Did not attend	Nothing new	Something new	Improved understanding	New full understanding
CTSim QA (4)Dec-Mar	1	0	3	3	1
Linac Commissioning (2) Apr-May	1	0	1	6	0
HDR QA (1) Jun	1	0	1	5	1
IMRT planning (1) Jul	0	1	2	5	0
IMRT QA (1) Sep	1	1	1	4	1
Beam modelling (1) Oct	3	0	2	3	0

How useful was the information shared during the sessions?

	0	**1**	**2**	**3**	**4**
	Did not attend	Not useful	Will affect future process	Improved existing process	Newly implemented in clinic
CTSim QA (4)Dec-Mar	3	0	1	2	2
Linac Commissioning (2) Apr-May	2	0	4	1	1
HDR QA (1) Jun	2	0	2	4	0
IMRT planning (1) Jul	1	0	3	3	1
IMRT QA (1) Sep	0	0	3	5	0
Beam modelling (1) Oct	3	0	2	2	1

If you did not attend the forum online session, did you watch the video recording of the session?

	0	1
	No	Yes
CTSim QA (4)Dec-Mar	3	3
Linac Commissioning (2) Apr-2May	3	3
HDR QA2 (1) Jun	3	3
IMRT planning (1) Jul	2	4
IMRT QA (1) Sep	2	3
Beam modelling (1) Oct	1	4

Regardless of whether or not you attended the online forum session, do you find having access to recordings of the sessions helpful?

0	1
No	Yes
2	6

Short answer questions – answer summaries

1. **What would make it easier for you to participate?**
   Early notice of topic and date
   Resend link to meeting the day before the meeting

2. **What can we do to improve the sessions?**
   Choose topics that are relevant to most centres – leave advanced topics till later
   Keep requesting non-speakers to mute their microphones
   More time for Q&A, at least 30 minutes
   Start focusing on advanced techniques since most centres are switching to IMRT/VMAT

3. **Please describe other barriers to participation in the forum**
   Timing of the meetings; perhaps they should be later in the day
   Technology barriers, malfunction of connectivity, sound quality

4. **Please provide a brief description of changes to processes as a result of participation in the forum**
   Improved QA processes
   Better communication among Kenyan physicists
   Better plans

5. **What would keep you most interested in attending future sessions?**
   Depends on topics discussed
   Workshop of conference

6. **Please suggest topics for future sessions**
   SRS
   SBRT
   LDR brachy (prostate)
   Treatment planning algorithms
   Small field dosimetry

Radiobiology – compensation for missing treatment
MU calculations
Commissioning for IMRT
Beam modelling
QA
3D H&N planning in Eclipse (also other sites)
Commissioning a Truebeam/Vitalbeam
Incident reporting
Monte Carlo in RT
Research openings/collaboration in RT
Technology advances in RT
More IMRT, VMAT and beam modelling
Machine learning, AI in RT
Imaging in RT
Applied nuclear medicine physics
Calculation algorithms
HDR source calibration
IMRT planning review

PROFESSIONAL ISSUES

MEDICAL PHYSICS IN THE MEFOMP REGION: CURRENT STATUS 2021

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Abstract— **Middle East Federation of Organizations of Medical Physics (MEFOMP) was established in 2009 with 12 participating countries: Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen. This wok aims to update the information about medical physics in MEFOMP countries, with limited scope covering education, training, equipment and number of Medical physicists (male/female). The economic diversity and the instability and conflicts in many countries in the MEFOMP region resulted in different tracks of development for medical physics in each country. This implies that enormous efforts must be exerted in order to support the development of the medical physics profession in some of the countries in the region. Medical Physics educational programs offering MSc degrees are currently available in five countries: Iraq, Jordan, Lebanon, Saudi Arabia and Syria. Since, a national or regional certification system does not exist, as interim solution, MEFOMP in collaboration with the International Medical Physics Certification Board (IMPCB) performed certification exams, as some countries in the region started to accept IMCPB certification. The number of Medical Physicists per million ranges between 0.5 in Yemen to over 23 in Bahrain, while the average number for the MEFOMP countries is about 8 medical physicists per million. In MEFOMP countries, the average number of Teletherapy, CT and Nuclear Medicine units are 1, 13.4 and 2.8 units per million population, respectively. MEFOMP has contributed a chapter to a recently published scientific book about medical physics during the COVID-19 pandemic, summarizing the different challenges faced during the outbreak of COVID-19 in MEFOMP countries.**

Keywords— **Medical Physics, Education, Certification, Conference. Middle East and MEFOMP.**

I. INTRODUCTION

The Establishment of Middle East Federation of Organizations of Medical Physics (MEFOMP) in 2009 is part of the effort of the International Organization for Medical Physics (IOMP) to organize societies under its umbrella to further enhance and improve the status of medical physics in all regions across the Globe [1]. MEFOMP includes 12 participating countries: Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen (Figure 1). The mission of MEFOMP is to advance medical physics practice throughout Middle East by disseminating scientific and technical information, fostering the educational and professional development of medical physics, and promoting high quality medical physics services to patients [2]. The mission and the goals of the MEFOMP are planned and executed by the Executive Officers (President, Vice-President, Past President, Secretary-General, and Treasurer) with input from Chairs of Committees (Education & Training, Science, Publications, Professional Relations, Awards & Honors, and Newsletter & Website, while in 2018 elections, the Women's Committee was added).

II. METHODS FOR UPDATING MEDICAL PHYSICS INFORMATION

A comprehensive paper was published in 2017 regarding the status of Medical physics in the Middle East [3]. This work aimed to update information about Middle East countries that are members of MEFOMP. A simple questionnaire was used to collect the information about the status of medical physics in MEFOMP countries, focusing on radiotherapy, nuclear medicine and diagnostic radiology equipment available in each country, the number of available medical physicists, and the education and training programs. Only those countries that have sent their feedback are included in the analysis of this paper.

Figure 1 Countries in the Middle East Region under MEFOM

Table 1 National medical physics societies in MEFOMP including established date, approximate numbers of medical physicists (male and female)

Country	Association / Society	Established (Year)	Population (Million) [5]	Approximate number of Medical Physicists			Number of Medical Physicists per million	Is Medical Physicist recognized as a Health Professional?
				Male	Female	Total		
Bahrain [3]	Bahrain Society of Medical Physics and Bio-Engineering (BSMPBE)	2008	1.7	34	6	40	**23.5**	-
Iraq	Iraqi Medical Physics Society (IMPS)	2011	40.5	30	47	77	**1.9**	Yes
Jordan	Jordanian Association of Physicists in Medicine (JAPM)	2006	10.2	32	56	88	**8.6**	Yes
Kuwait	Kuwait Association of Medical Physics (KAMP)	2016	4.3	25	13	38	**8.8**	No
Lebanon	Lebanese Association of Medical Physics (LAMP)	2005	6.8	12	8	20	**2.9**	Yes
Oman	Oman Medical Physics Society (OMPS)	2018	5.2	7	29	36	**6.9**	Yes
Palestine	Palestine Medical Physics Society (PMPS)	2006	5.1	4	5	9	**1.8**	Yes
Qatar	Qatar Medical Physics Society (QaMPS)	2009	2.9	28	10	38	**13.1**	Yes
Saudi Arabia	Saudi Medical Physics Society (SMPS)	2006	35.0	339	381	720	**20.6**	Yes
Syria	Syrian Medical Physics Association (SyMPA)	2009	17.5	26	11	37	**2.1**	-
UAE [3]	Emirates Medical Physics Society (EMPS)	2005	9.9	7	51	58	**5.9**	-
Yemen	Yemen Medical Physics Association (YMPA)	2013	30.0	15	1	16	**0.5**	Yes
Total (Average)			**169.1**	**559 (47.5%)**	**618 (52.5%)**	**1167**	**(8.0)**	**(75%)**

III. MEFOMP VS NATIONAL SOCIETIES

MEFOMP was established in 2009 with 12 participating countries as shown in Table 1. Although all countries under MEFOM umbrella have similar cultures, speak the same language and have the same religion, due to the economic diversity in the region, the starting point and development of medical physics in each country was quite different. Furthermore, the past and ongoing instability and conflicts in some of these countries imply that enormous efforts must be exerted in order to support the development of the medical physics profession in these countries. It is vital that such efforts be sustained to further accelerate the growth of this field in all MEFOMP countries.

The number of Medical Physicist in the Middle East has been constantly increasing, however, there is a continuous demand for more qualified medical physicists. Table 1 shows the profile of national Medical Physics Societies or Associations in the MEFOMP Countries including established date and approximate numbers of medical physicists (male and female). In Table 1, it is shown that Medical Physics is recognized as a health profession in 75% of these countries. The total number of Medical physicists is about 1180, divided into 560 (47.5%) males and 620 (52.5%) females. As shown, the overall number of female medical physicists in the region is ~16% higher than male. The highest number of medical physicists exists in Saudi Arabia

Table 2 Approximate number of Teletherpay, CT and Nuclear Medicine units in each of the MEFOMP countries (including number of units per million)

Country	Population (Million) [5]	Approximate Number of Teletherapy Equipment		Approximate Number of CT units		Approximate Number of Nuclear Medicine Equipment	
		Number of units	Unit per million	Number of units	Unit per million	Number of units	Unit per million
Iraq	40.5	26	0.6	475	11.7	12	0.3
Jordan	10.2	13	1.3	105	10.3	25	2.5
Kuwait	4.3	4	0.9	45	10.5	49	11.4
Lebanon	6.8	19	2.8	265	39.0	27	4.0
Oman	5.2	5	1.0	28	5.4	10	1.9
Palestine	5.1	3	0.6	10	2.0	3	0.6
Qatar	2.9	3	1.0	60	20.7	10	3.4
Saudi Arabia	35	38	1.1	450	12.9	116	3.3
Syria	17.5	9	0.5	340	19.4	11	0.6
Yemen	30	2	0.1	70	2.3	3	0.1
Total		**122**	**1.0**	**1848**	**13.4**	**266**	**2.8**

(about 720). The number of medical physicists per million population is stretched between 0.5 in Yemen to over 23 in Bahrain. On average, the MEFOMP countries have about 8 medical physicists per million population. This seems a relatively acceptable number, as the average number in the world is about 2.7; 15–20 per million population in the developed countries and 1–5 per million population in developing countries. On the other hand, in many underdeveloped countries this number is close to 0 [4].

IV. Equipment in Each of the MEFOMP Countries

The approximate numbers of teletherapy, CT scanners and nuclear medicine (gamma cameras, SPECT, PET-CT) units in MEFOMP member countries are given in Table 2, as an indication of the level of Radiotherapy, Diagnostic Radiology and Nuclear Medicine services, respectively.

Table 2 shows that the total number of teletherapy units are 122 in the 10 MEFOMP countries that participated in this survey, with the largest number (38) existing in Saudi Arabia. The number of teletherapy units per million population varies from 0.1 in Yemen to 2.8 in Lebanon, with an average for MEFOMP countries of 1 unit per million population. According to the World Health organization (WHO), this number brings MEFOMP countries in the lower limit of the second band of countries (between 1 and 3.33), well below the first band of countries, where Western Europe and North America are classified, where the number of teletherapy units per million population is between 3.33 and 72.81 [6].

In Table 2, it is evident that the number of CT scanners per million population varies greatly across MEFOMP countries: from 2 in Palestine to about 40 in Lebanon. The average number is about 13.4 CT units per million, which is significantly lower than the mean number of CT scanners per million population in the Organization for Economic Co-operation and Development (OECD) countries, which was 22.94 [7].

Table 3 Universities with BSc or Diploma in subjects related to medical physics in the MEFOMP countries.

Country	University	BSc Duration (years)	Annual number (Male/ Female)
Iraq	Al-Karch university for applied sciences	BSc	45
	Al-Elm private University College of Science	BSc	45
	University of Falloja College of Science	BSc	45
	University of Diyala College of Science	BSc	45
	Univ. of Salah Al-Din Education college - Physics	BSc	35
	Al-Mustaqbal private Univ. College of Science	BSc	40
Jordan	Yarmouk University	4 years BSc.	30 (15/15)
Saudi Arabia	Um AlQura University in Mekkah AlMukarramah	4 years BSc	15 (10/5)
	King Abdulaziz University in Jeddah	4 years BSc	40 (20/20)
Syria	Damascus University - Radiation Protection (PGEC)	1 year Diploma after BSc	25 (13/12)
Yemen	IBB University	4 years BSc	26 (12/14)

The approximate numbers of equipment used in the nuclear medicine procedures (including Gamma Cameras, Positron Emission Tomography (PET), Single Photon Emission Computed Tomography (SPECT), PET-CT, SPECT-CT and Cyclotron) are shown in Table 2. It is clear that there are big variations between MEFOMP countries: from 0.1 unit per million population in Yemen to over 11 in Kuwait, with an average number of about 2.8 in the MEFOMP countries. This showed a significant increase from the average of 2.3 per million population in the Middle East Region reported in 2015 [8].

V. Education and Training

The local authorities in MEFOMP counties started to realize the importance of Medical Physicists in the medical practice at a different pace. Therefore, it is still a challenge to acquire qualified medical physicists due the following [9]:

1. limited number of universities offering this specialty.
2. limited awareness about the importance of this profession.
3. absence of recognition of the profession by the some of the local authorities.

Currently the undergraduate Medical Physics (or related subjects) university programs, offering BSc degree or Diploma are available in 5 countries: Iraq, Jordan, Saudi Arabia, Syria and Yemen. Table 3 shows the list the universities with medical physics BSc programs.

Table 4 Universities offering MSc or PhD program in subjects related to medical physics in the MEFOMP countries.

Country	University	MSc Duration (start year)	Annual number (Male/ Female)
Iraq	University of Nahrain Medical college	2 years (2016)	15
	University of Baghdad, Science College (Females)	2 years	50
	University of Baghdad/ Baghdad Medical College	2 years	10
	Univ. of Mustansiriyah Medical College	2 years	10
	University of Hwler Medical college (MSc& PhD)	2 years	30-40
	Univ. of Salah Al-Din/ College of Science Physics	2 years	10
Jordan	Jordanian University	2 years (2007)	16 (10/6)
	Yarmouk University	2 Years (2020)	13 (5/8)
Lebanon	Lebanese University (MSc.& PhD)	2 years (2015)	12
	Beirut Arab University (MSc& PhD)	2 years (2017)	5 (3/2)
Saudi Arabia	King Fahd University	2 years (2002)	3
	Um AlQura University in Mekkah AlMukarramah	2 years (2019)	35 (20/15)
Syria	Damascus University (Rad Prot) (MSc & PhD)	2 years (2006)	16 (8 /8)
	Damascus University (Medical Physics) (MSc & PhD)	2 years (2013)	14 (7 /7)

Post Graduate Medical Physics (or related subjects) educational programs offering MSc and PhD degrees are currently available in 5 countries: Iraq, Jordan, Lebanon, Saudi Arabia, and Syria. Table 4 shows the Universities offering MSc or PhD in subjects related to Medical Physics in the MEFOMP countries.

There is a strong need to establish regulations, guidelines and standards specific to the medical physics profession. This will facilitate the improvement of professional recognition, which would promote interest within the new generation of medical physicists. A formal recognized education system and preferably certification system on a national or at least on the regional level such as a MEFOMP Certification Board, would further promote the Medical Physics field as a well-established profession.

During the last 3 years, as an interim solution, MEFOMP and some National Societies in the region, in collaboration with the International Medical Physics Certification Board

Table 5 International Medical Physics Certification Board Exams in MEFOM region.

Country	IMPCB Exam	Dates
Saudi Arabia	Examination Part I and II	9-10/2/2019
Jordan	Examination Part I and II	24- 25/4/201
Qatar	Examination Part I, II and III	22-24/10/201
Saudi Arabia	Examination Part I, II and III	8-9/2/2020
-	Online exams Part I, II and III	2020 &2021

(IMPCB, website: www.IMPCB.org) started to carry out certification exams in the region as shown in Table 5. Some countries in the region started to accept IMCPB certification for Medical Physics and included it in the job description requirements.

VI. Awards and Honors

Most medical physics societies in MEFOMP countries established their national award system. At the federation level, MEFOMP nominates three candidates every year to the International Organization of Medical Physics (IOMP) – International Day of Medical Physics (IDMP) Award since its start in 2015. The individuals who won this award from MEFOMP till now are: Mr. Ibrahim Duhaini (2015), Dr. Abdalla AlHaj (2016), Dr. Huda AlNaemi (2017), Dr. Jamila Al Suwaidi (2018), Dr. Hanan AlDousari (2019) and Dr. Mohammad Hassan Kharita (2020).

As appreciation for hard work of the medical physicists in the region during the COVID-19 outbreak, MEFOMP decided to give a special MEFOMP award under the title of "MEFOMP Award for Best Medical Physicist during COVID-19". The award was given as a recognition of the total contribution of the winners during this crisis, to highlight those Medical Physics community members who played an important role during this pandemic. This honor was awarded to 14 medical physicists from different MEFOMP countries [10].

VII. Mefomp Contribution during Covid-19

COVID-19 has been spreading worldwide starting at early 2020. MEFOMP has contributed a chapter in a recently published scientific book with title of “Medical Physics during the COVID- 19 pandemic” published by CRC press on 18 March 2021 [11]. The book explores how the COVID-19 pandemic has affected clinical practice, education, and research in medical physics, and how colleagues on the frontline dealt with this unpredictable and unprecedented pandemic. The chapter from MEFOMP summarizes the contribution of the Medical Physics National Societies’ of MEFOMP country members, for better diagnosis and treatment of COVID-19 patients, as well as the challenges faced in order to continue offering the routine medical physics services during the special circumstances which a pandemic. This book addresses the activities related to all aspects of medical physics, health physics and radiation safety in radiology, radiotherapy, and nuclear medicine during the COVID-19 pandemic, with some examples from the different MEFOMP member countries.

MEFOMP has emphasized the role of medical physicists during this pandemic in the diagnosis, and the containment of the virus to prevent its spread by implementing the safety measures to protect themselves, patients and other staff. MEFOMP has also encouraged medical physicists to play a leading role in fighting this pandemic. Through its website [2], newsletter and direct communication with its national counterparts, MEFOMP emphasized the importance of protection of staff and patients in addition to the cooperation with physicians for better diagnosis and treatment for the COVID-19 patients.

MEFOMP Award and Honors Committee’s contribution was to express MEFOMP’s appreciation towards their members in all countries, by giving a special award [10] the "MEFOMP Award for Best Medical Physicist during COVID-19", as a recognition of exceptional performance during this crisis (as mentioned in the previous section). Furthermore, at the peak of the pandemic, several online courses, webinar and conferences on various aspects of medical physics and radiation safety were offered by MEFOMP and different national societies in the Middle East for all medical physicists and health professionals.

MEFOMP in cooperation with International Atomic Energy Agency (IAEA) has recently organized the 2021 Virtual Medical Physics Conference [2, 12]. This event aimed to enhance the knowledge of healthcare professionals in various aspects of medical physics by providing state-of-the-art and up-to-date developments in the profession. The conference attracted over 2,900 individuals from 81 countries. This indicated that this virtual conference has succeeded to spread knowledge and updates, making them accessible to a larger and more diverse audience. The conference has put MEFOMP firmly on the Medical Physics world map. The number of participants competes with the big and established international meetings. The world-class speakers and the excellent IT infrastructure were essentials to the phenomenal success of the conference.

During the COVID-19 pandemic, various international organizations such as IOMP and the IAEA, prepared several online courses on various aspects of medical physics and radiation safety, which were attended also by many medical physicists of MEFOMP countries.

The contribution of MEFOMP Women in Medical Physics Committee in fighting the pandemic focused on medical teams as frontiers in their tireless battle against the infection. The women committee issued a special booklet [13] about the effort and experiences from women medical physicists during COVID-19, which was very challenging for all medical community including medical physicists. Women medical physicists bravely faced the epidemic accepting the risks by taking all precautions to protect themselves and their beloved ones. Women medical physicists exerted extra efforts in the field of awareness and education especially for female patients. The committee participated in the webinar organized by the International Organization for Medical Physics Women Group (IOMP-W) on 24 July 2020 which focused on the role and contributions of women scientists during COVID-19 pandemic.

The medical physics teams played critical role in all MEFOMP countries since the beginning of the pandemic in ensuring that staff are working in a safe environment while following safety protocols to prevent the spread of the virus to patients and other staff across the medical facilities. During the COVID-19 medical physics practices covering different specialties, modalities and services related to all aspects of medical physics, health physics and radiation safety activities in all radiology, radiotherapy and nuclear medicine, were continued despite all the adversities.

In summary, medical physicists in the MEFOMP region played a significant role during this unprecedented time, both in sustaining its essential role to the healthcare system and in optimizing the preventive effort of humankind in the control of this pandemic. Medical physicists is in support of other front-liners and scientists in their effort to enhance diagnostics and therapeutics so that the world will come up with a robust control of the virus and eventually end the COVID-19 pandemic.

VIII. Conclusions

MEFOMP, during those 12 years that have passed since it was established in 2009, has exerted remarkable efforts in order to support the development of the medical physics profession in the region. The average number of Medical Physicists per million in MEFOMP countries is about 8 medical physicists per million. In MEFOMP countries, the average number of Teletherapy, CT and Nuclear Medicine units are 1, 13.4 and 2.8 units per million population, respectively. Medical Physics educational programs offering MSc degrees are available only in five countries in the region. Since currently there are no national or regional certification system, as interim solution, MEFOMP in collaboration with the IMPCB has performed certification exams. Some MEFOMP countries started to request and accept IMCPB certification for medical physics jobs.

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MEDICAL PHYSICS EDUCATION, TRAINING AND PROFESSIONAL RECOGNITION IN IRAQ

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Abstract — **The history of diagnostic and therapeutic radiation services in Iraq dates back to 1920s. The growth of the medical physics specialty in Iraq started with increasing the establishment of new radiotherapy centers in most of the Iraqi governorates and the rapid developed of the radiation therapeutic and diagnostic techniques which requires the presence of qualified clinical medical physicists. Many Iraqi private and governmental universities established BSc, MSc. and PhD programs, which are found in most of the Iraqi provinces. Increasing the capacity of the of radiotherapy units in the governmental hospitals as well the opening of many private centers all over the Iraqi provinces led to increasing the numbers of the radiotherapy devices and the diagnostic radiology techniques. Nowadays, most of the radiation therapy units have LINACs, CT, MRI. Ultrasound, and other advanced techniques like PET/ CT and SPET/CT. The clinical training programs are considered very limited in Iraq, there is a necessity for providing trainings in the fields of quality control and quality assurance. The improvement and the recognition of medical physics specialty in Iraq was greatly supported by the establishment of the Iraqi Medical Physics Society (IMPS), 2011. Currently IMPS have about 120 (70% females and 30% males) medical physicists who are affiliated to different medical and academic institutions of the Iraqi provinces.**

Keywords — **medical physicist, radiotherapy, nuclear medicine, diagnostic radiology, Iraq.**

I. INTRODUCTION

The history of diagnostic and therapeutic radiation services in Iraq dates back to 1920s, when the first Radiology Institute was established in Baghdad. Then the number of the radiology institutions expanded to cover the main Iraqi provinces like Mousel, and Basra. At that time the field of medical physics was not recognized in Iraq, and few numbers of medical physicists who served in these institutions graduated from the medical physics departments of UK and USA universities, where there was no academic program of medical physics found in the Iraqi universities.

The growth of the medical physics specialty in Iraq started with increasing the establishment of new radiotherapy centers in most of the Iraqi governorates. The rapid developed of the radiation therapeutic and diagnostic techniques required the presence of qualified clinical medical physicists to work together with the oncologists to introduce the optimum medical services to the cancer patients. This motivated the academic medical physicists to work on the establishment of postgraduate programs to provide the Iraqi health institutions with medical physicists who are capable of dealing with the advanced therapeutic and diagnostic technologies in the fields of radiotherapy, nuclear medicine, radiation protection, dosimetry, the applications of laser in medicine, and other imaging techniques. For this purpose, in 1989, the first Msc. Program of medical physics in Iraq was found in Mustanisriyah Medical College in Baghdad. Since that time, the medical physics unit of Mustansiriyh medical college received large number of Msc. Students from different regions of Iraq as well from the neighboring countries like Jordan. The medical physics researches varied in terms of subspeciality. Many of these researches had obtained local and international awards. The Iraqi ministries of health and higher education recognized this program and the graduates employed in different health institutions to enhance the quality of the medical services. In 2016, another M.Sc. Medical physics program has been established in Al-Nahrain medical college, and many B.Sc. Medical physics programs have been established in the colleges of science of the Iraqi universities.

The improvement and the recognition of medical physics specialty in Iraq was greatly supported by the establishment of the Iraqi Medical Physics Society (IMPS), 2011. The IMPS works on keeping the medical physics specialty in Iraq within the international standards through the updating of the BSc. And MSc. Curriculums in collaboration with the medical physics departments of the Iraqi universities, and by identifying and implementing of applied research projects that contribute significantly in raising the standards of the medical services which are introduced to the patients not only to the cancer patients but it includes many other fields where the physical aspects can be applied in the medical field. The current dependent MSc. Program's curriculum in both of the medical colleges of Al-Nahrain and Mustansiriyah universities is derived from the AAPM MSc. Curriculum. Currently IMPS have about 120 (70% females and 30% males) medical physicists who are affiliated to different medical and academic institutions of the Iraqi provinces.

II. ACADEMIC PROGRAMS

Teaching of medical physics subject was limited during the last few years. It was only included within the curriculums of the first-grade medical college students. All of the medical colleges in Iraq have about 40 hours for the theory part of this subject and about 60 hours for the practical part where the physical principals of the medical diagnostic and therapeutic devices introduced to the first-grade medical students as experiments in the medical physics laboratories. These universities are located in Baghdad, Basra, Mousel, Erbil. Sulaymania, Duhok, Babil, Missan, Al-Qadisiyah, Thi-Qar, Al-Kufa, Al-Anbar, Karbala'a and Diyala. After 2014, the academic programs of medical physics in Iraq have witnessed great expansion, where many governmental and private universities established BSc. Medical physics programs, these newly opened departments receive annually students from all over the country, the matter which led to increase the postgraduate students who shows their interest in obtaining MSc. Degree in medical physics. So that, the ministry of higher education and scientific research increases annually the number of seats in the universities that offer MSc, programs to receive larger number of the applicants. Moreover, the establishment of new radiotherapy centers in the capital "Baghdad" and the other provinces requires more medical physicists to be employed. Table 1. shows the number of the governmental and private universities that offer BSc, MSc, and Ph.D medical physics programs in each Iraqi province.

Table 1 The number of the governmental and private universities that offer BSc, MSc, and PhD medical physics programs in each Iraqi province

Province	University	Academic Program	Annual no. of graduates
Baghdad	University of Baghdad/ College of Science (females)	BSc. & MSc.	50 females
	Al-Karch university for applied sciences	BSc.	45
	Al-Elm private University/ College of Science	BSc.	45
	Al-Nahrain University/ Al-Nahrain Medical College	MSc.	15
	University of Baghdad/ Baghdad Medical College	MSc.	10
	University of Mustansiriyah/ Mustansiriyah Medical College	MSc.	10
Al-Anbar	University of Falloja/ College of Sceince	BSc.	45
Diyala	University of Diyala/ College of Science	BSc.	45
Erbil	University of Hwler/ Hwler Medical college	MSc. & PhD.	30-40
	University of Salah Al-Din/ Education college/ Physics Dept.	BSc.	35
	University of Salah Al-Din/ college of science/ Physics Dept.	MSc.&PhD	10
Sulaymania	University of Sulaymania	MSc.	10
Babil	Al-Mustaqbal private University/ College of Science	BSc.	40

For the time being, there is limited Ph.D programs of medical physics in Iraq, it is only offered by two universities in Erbil province/ Kurdistan region, the universities of Erbil and Salah Al-Din in Kurdistan as mentioned in Table 1. The reason behind the limited number of the Ph.D programs is the shortage in the research institutions that can support the research projects. Adding to that, the working load on the therapeutic and diagnostic devices in the health institutions which obstacle the research process and real data obtaining.

III. Training programs

The clinical training programs are considered very limited in Iraq. The number of the trainings that were introduced to the physicists and medical physicists of the radiotherapy centers don't cover the needs of the trainees for the advanced technical information of the modern therapeutic and diagnostic devices such as the IMRT, and VMAT techniques, as well the necessity of providing trainings in the fields of quality control and quality assurance. The period of each offered training differs according to the contract with the medical institutions that received the Iraqi medical physicists' trainees. Some of these trainings took place outside Iraq such in American University of Lebanon (AUB), the Turkish radiotherapy centers, and the radiotherapy centers of UK, while some other trainings were taken place in the radiotherapy center of Baghdad and the other Iraqi provinces, Table 2 shows the radiotherapy centers where the Iraqi medical physicists had trainings on the advanced radiotherapy techniques. These trainings were under the supervision of qualified Turkish, Egyptian and Lebanese medical physicists.

Table 2 The distribution of radiotherapy centers in Iraq and the number of medical physicists trainees.

Province	Institution	No. of medical physics trainees
Baghdad	Al-Jawad Radiotherapy Center	4
	Baghdad radiotherapy and nuclear medicine hospital/ Baghdad Medical City	15
	Al-Amel radiotherapy center	14
Najaf	The Middle Euphrates radiotherapy center	9
Erbil	Rezgary radiotherapy center	4
	Hwler radiotherapy center	4
Sulaymania	Zynawa radiotherapy center	5
Basra	The radiotherapy center of Basra hospital	5
Mousel	The radiotherapy center of Al-Mousel teaching hospital	4
Babil	Al-Marjan radiotherapy center	7

IV. Regulation of medical physics

There is no recognized residency program for the Iraqi medical physicists. The IMPS made communications with the ministry of health through its representation in the Iraqi Cancer Board (ICB) to explain the necessity of establishing clinical training program which is recognized by both of the ministries of health and higher education. The role of IAEA is of great importance in improving the field of medical physics in Iraq, but there is no noticeable and known projects for the IAEA in this regard. The IMPS aims to cooperate with the IAEA to benefit from the educational and training programs through the IAEA representatives in the ministry of higher education. There is a real need to evaluate the needs of the medical physicists especially in the clinical field and, especially those that contribute in improving the skills of the medical physicists. IMPS is looking for the cooperation of the other medical physics societies in the region to exchange experiences. IMPS is going to revise the medical physics curriculums of the BSc. Programs due to the defects in some of these curricula, which affect the quality of the medical physicists' graduates. The poorly equipped laboratories of some newly established departments has a negative impact on the graduates. So that, IMPS consider this issue as a priority point that should be discussed with the ministry of higher education which should have a control on the quality of the BS, programs.

The lack of a clear and detailed described job description for the Iraqi medical physicist is considered as one of the most important issues. There isn't any document that stated the duties of the sub-specialized medical physicists, where many of them are working in different specialty of their experience or academic qualifications. IMPS highlights this point and tried to discuss it with the ministry of health in order to write new job descriptions that matches the sub-specialty of each employed medical physicists.

IV. The role of IMPS in improving the medical physics in Iraq

The IMPS aims to raise the standards of medical physics specialty in the Iraqi academic and health institutions through gathering the medical physicists in one society. Since its establishment, the IMPS administrative board built the links among the Iraqi physics and medical physicists to share the experiences and to get new idea that contribute in improving the qualifications of its members and to spread the advances of medical physics to the largest number of beneficiaries.

The IMPS targeted the junior medical physicists in the newly opened medical physics departments to make them aware of the importance of this field in the quality of the medical care. This is achieved by conducting seminars, workshops and conferences in these newly established departments. The IMPS contributed positively with head of departments to assure that the curriculums cover all the aspects of medical physics. The IMPS provides trainings in the physics principals of the radiotherapy and nuclear medicine techniques.

The goals of the IMPS extended to the implementation of applicable projects which are based on the available materials in the Iraqi markets to manufacture materials with new physical and chemical properties to be used as shielding materials by the staff of the radiation units of the hospitals. Some of these developed materials are currently under the examination of the laboratories of the quality control institution in the ministry of science and technology.

Moreover, the IMPS keen on creating a generation of medical physicists who have excellent experience in the medical physics subspecialties through involving them in MSc. Or Ph.D research projects in the fields of radiotherapy, dosimetry, radiation protection and the techniques of diagnostic radiology. This step enables the Iraqi medical physicists from the participation the IMPCB examination to get the Board of medical physics and be certified as qualified clinical medical physicists, because the current number of the sub-specialized medical physicists is considered very low as compared to the actual need of the radiotherapy centers, especially in the field of nuclear medicine. Table 3. shows the certified sub-specialized medical physicists in Iraq.

The IMPS members have an important role in identifying and implementing projects that support the community assistance through the financial help for the cancer patients' kids by the volunteering activities of the members.

Table 3 Number of the sub-specialized medical physicists in Iraq

Medical physics Subspecialty	Number of certified medical physicists (registered in IMPS)	The total number of medical physicists
Radiotherapy Dosimetry	12	15
Radiation protection	9	12
Diagnostic radiology	10	14
Audiology	4	6
Applications of laser in medicine	10	30

Increasing the capacity of the of radiotherapy units in the governmental hospitals as well the opening of many private centers all over the Iraqi provinces led to increasing the numbers of the radiotherapy devices and the diagnostic radiology techniques. Nowadays, most of the radiation therapy units have LINACs, CT, MRI. Ultrasound, and other advanced techniques like PET/ CT and SPET/CT, while the last two techniques are limited or not available in some Iraqi provinces. Table 4 shows the approximate numbers of the diagnostic and radiotherapy equipment's in the country. The increment in the number of devices and the usage of the modern techniques requires increasing the number of the qualified clinical medical physicists to be able to manage these devices efficiently in order to provide the optimum health services to the cancer patients. In this regard, the IMPS focused on the type of the research projects and support the clinically applied projects by making collaborative work with the Iraqi National Center of Cancer and Medical Genetics, the Iraqi National Center of Radiation Protection and the radiotherapy units of the Iraqi health institutions in order to identify projects that help in finding applicable solutions for any problem that face the medical physicists and the oncologist during the routine clinical work.

Table 4 The approximate numbers of the diagnostic and radiotherapy equipment in the country.

Equipment	Total
LINAC	26
PET/CT	6
SPECT/CT	1
Gamma Camera	5
Gamma Knife	3
Dose calibrators	23
CT	400-550
MRI	250-300
Ultrasound	900-1000
Mammography	200-300

V. Conclusion

There is no designed plan or strategy by the Ministry of Health or the Ministry of Higher Education regarding finding employment to the increased numbers of graduates of medical physicists, especially those who have postgraduate degrees. In addition to the absence of a clear job description for the medical physicists which reflects negatively on the standards of the health care. Most of the medical physics departments of the Iraqi universities are not equipped with research laboratories. The poorly equipped ones have difficulty performing research especially in the field of nuclear medicine. The participation of the Iraqi medical physicists in the IMPCB exam is still limited because of the lack of clinical trainings that enable them from having good clinical experience, many of the Iraqi medical physicists are academic staff and they do not have continuous clinical attachment with the radiotherapy units of the hospitals, the experience that they have is limited to only the MSc. or BSc. research works. The number of the register medical physicists as IMPS members is still low in comparison with the number of students and staff of the medical physics departments.

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MEDICAL PHYSICS EDUCATION, TRAINING AND REGULATION IN JORDAN

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Abstract— **Cancer is a major problem in Jordan and is the second leading cause of deaths in the country. Successful cancer treatment involves an advanced team that consists of oncologists, medical physicists, dosimetrists, and others. Medical physicists play a pivotal role in the accurate diagnosis and treatment of cancer. Over the last twenty years, medical physics in Jordan has seen an expansion in academic programs which include clinical training in the fields of medical imaging, nuclear medicine, and radiotherapy. This was accompanied by expansion in medical centers for cancer treatment with state-of-the-art diagnostic and treatment equipment. Medical physics education is currently offered through one BSc. program in biomedical physics and two MSc. programs in medical physics. The recognition of Medical Physics as a profession with proper licensing and certification is still a work in progress but there is an optimistic hope of accomplishing this in the near future.**

Keywords— **Medical Physics, Education, Radiotherapy, Nuclear Medicine, Jordan.**

I. INTRODUCTION

Jordan is a Middle Eastern country which is classified as an upper middle-income country (UMIC) by the World Bank classification [1]. The country though has limited resources and faces some economic challenges. It occupies an area of 89,000 km2 with an estimated population of 10 million in 2018 [2]. Cancer is a major problem in Jordan and is the second leading cause of death, after cardiovascular disease [3]. The number of cancer cases in Jordan has risen from 8,400 in 2015, according to Jordan Cancer registry (JCR) [4], to 11,559 in 2020, according to the Global Cancer Observatory (GCO) [5]. This is an increase of about 5.3% per year which is almost twice the average annual population growth rate (~2.5%) during the same period [2]. Globally, in middle-income countries, it has been estimated that the number of cancer incidents would rise by 80% from 2012 to 2035 (3.5% per year) [6]. Thus, the cases in Jordan seem to follow this trend and are expected to increase in the future. Moreover, the World Health Organization stated that in 2020, cancer will cause the death of more than 10 million people annually around the world [7]. The organization has also warned that some countries do not have any infrastructure for cancer treatment at all, some have the infrastructure but without systems that enable them to provide comprehensive cancer care, and some lack the human resources and knowledge to provide effective treatment.

There is a lack of knowledge with regard to the importance of radiotherapy treatment of cancer in middle-income countries, and thus, medical physics. Radiotherapy now plays a vital role in providing effective cancer treatment. It was estimated that about 6.5 million new cases of cancer in middle-income countries would benefit from radiotherapy at least once during their illness [8]. Despite these facts, studies have shown that developing countries have not benefited from this type of treatment to the same level as Western Europe and North America. The challenge facing developing countries is to establish the required infrastructure, acquire equipment, attract highly qualified professionals, develop education and training programs and adopt policies to provide effective and accessible care for all [9]. These are the challenges that Jordan is currently facing.

The feasibility of medical physics as a unique discipline in Jordan began when a private university (Applied Science Private University) started offering a BSc. Degree in medical physics in 1992. However, that program was not sustained due to string constraints imposed by the Ministry of Higher Education in Jordan that were placed on the acceptance policy of new students and was later terminated. A new attempt to offer a BSc. program in medical physics started at another private university in 1994 (Zarqa Private University) which lasted longer but again that program was not maintained due to similar reasons and was terminated almost 10 years later. It was not until 2004 that a public university, Yarmouk University (YU), started a BSc. program in biomedical physics which attracted students and qualified faculty members. The BSc. Program at YU is still active and strong 17 years later and additionally there are currently two graduate programs offering MSc. degrees in medical physics and a residency program is expected to start very soon in Jordan. This seemed to start a new era for medical physics in Jordan and medical physics started to attract the attention of the public. Furthermore, in 2006, the Jordanian Association for Physicists in Medicine (JAPM) was established with efforts from the limited number of medical physicists working in government agencies, hospitals, and of course academia with leading faculty members from YU University. Currently the society has almost 80 registered and active members. Consequently, the number of centers offering radiotherapy treatments and medical imaging equipment which require medical physicists have expanded during this time as well.

However, despite these improvements, challenges facing medical physicists remain, particularly with professional recognition and certification. The paper will present the infrastructure currently available in the medical physics field, the educational and training programs as well as the current regulations regarding medical physics in Jordan.

II. INFRASTRUCTURE

The facilities available for training of medical physicists in Jordan are those that have medical diagnostic tools and provide cancer treatment. Currently, there are five centers that have radiotherapy units in Jordan. These are Al Basheer Hospital, King Hussein Cancer Center (KHCC), Al-Afia Radiotherapy and Nuclear Medicine Center, Queen Alia Hospital, and King Abdullah University Hospital (KAUH). In addition, Ibn AI Haytham Hospital has within it a gamma knife center which is a private center offering specialized multi-beam teletherapy. It is worth noting that the KHCC is considered the premier cancer treatment center in Jordan and it attracts the top medical physicists in the country and that the center at KAUH has just started recently in late 2020. The typical treatment techniques and other technical information regarding these centers are listed in Table 1 [10].

Table 1 List of the centers that have radiotherapy units in Jordan, along with the sector, starting date, main treatment techniques and the number of available medical physics [10]

Institution	Starting Date	Treatment Technique	Brachy-therapy System	Medical Physicsits	Nuclear Medicine
Al Basheer	1987	3D CRT	No	4	Yes
KHCC	1997	3D CRT IMRT VMAT	HDR LDR	14	Yes
Al-Afia	2006	3D CRT IMRT	No	3	Yes
Queen Alia	2012	3D CRT	HDR	9	Yes
KAUH	2020	3D CRT	HDR	4	Yes

For medical imaging and nuclear medicine units, there are currently 11 nuclear medicine centers and many medical imaging units available throughout public and private hospitals and centers. Table 2 shows a list of an estimate number of these units from a recent survey [11]. The table also compares the status of Jordan with its peers in Upper Middle-Income Countries (UMIC) and with the High-Income Countries (HIC) [12].

As can be seen from Table 2, Jordan has made good progress in keeping pace with upper middle-income countries, however, the gap with the high-income countries is still very wide

Table 2: Number of radiology equipment available in Jordan as reported in a recent survey [11] and the amount of equipment per 1 million as reported by the IMAGINE project [12] and compared to UMIC and HIC.

Unit	No. in Jordan	No. in Jordan per 1 mil	No. in UMIC per 1 mil	No. in HIC per 1 mil
CT scanner	100	10-15	11.99	37.77
MRI units	55	5-7.5	5.36	26.53
PET	9	0-1	0.30	3.52
SPECT	1	0-2.5	1.57	17.65
Mammography	>50	0-5	5	30
Fluoroscopy	60	-	-	-
Ultrasound	600	-	-	-
Gamma Camera	15	-	-	-
Gamma knife	2	-	-	-

III. EDUCATIONAL PROGRAMS AND TRAINING

At the undergraduate level, there is currently one active program in Jordan offering a BSc. degree in Biomedical Physics. The program is offered by the physics department at Yarmouk University (YU), Irbid. The program offers students advanced senior-level courses in radiation physics, radiobiology, health physics, medical imaging, and radiotherapy. In addition, the students are required to spend 12 weeks of practical training in a hospital as part of the graduation requirements (2 full days of training per week). The training is paid for by YU and available at King Abdullah University Hospital (KAUH). The students also have the option to train at other facilities with the approval of the department but in that case, they must cover their own cost. The program started in 2004 and has graduated almost 600 students since its inception. Currently, the graduates of the YU program make up most of the workforce in radiotherapy, radiation protection and nuclear medicine in Jordan. Many have also gone to neighboring countries to seek job opportunities and others have entered the education sector in the country.

At the graduate level, there are two programs offering a MSc. Degree in medical physics. The first one started in 2007 by the University of Jordan in Amman and is a non-thesis program. The program offers two credit-hours of training at local hospitals. The other program offering a MSc. Degree recently started in 2020 at Yarmouk University in collaboration with the King Hussein Cancer Center. This program offers both a thesis and non-thesis track which are technically research-based and clinical-based tracks respectively. The non-thesis track at YU requires the students to go through clinical training for a full semester (4 months) as full-time trainees which is worth 9 credit hours (36 hours per week). The training will be made available at KHCC as part of the agreement between YU and KHCC. All of the above-mentioned programs are accredited locally by the Jordanian Accreditation and Quality Assurance Commission for Higher Education Institutions (AQACHEI), as required by law. This means that the programs must have a curriculum which provides the students with the competencies required by the AQACHEI. They include competencies in radiation physics, radiotherapy, radiobiology, and medical imaging. We should add that neither of the graduate programs is accredited by an international accreditation body although both have a curriculum that fulfill the IAEA guidelines [13]. Table 3 provides a list of the academic programs and related information.

Table 3 List of the available academic medical physics programs in Jordan and their related information.

Program	BSc.	MSc.	
University	YU	JU	YU
Starting year	2004	2007	2020
Department	Physics	Physics	Physics
Track	-	Non-Thesis	Thesis, Non-thesis
Faculty members (medical physics)	6	3	6
Training	3 credit hours	2 credit hours	9 credit hours
Annual enrollment	50-80	10-12	10-12
Accreditation	Local	Local	local

YU: Yarmouk University, Irbid.
UJ: University of Jordan, Amman

It is worth mentioning here that a residency program is expected to start very soon at KHCC in collaboration with YU and IAEA. In addition to the clinical training offered through the BSc and MSc programs, many independent centers offer additional training for a limited number of qualified candidates, mostly in nuclear medicine.

IV. Regulations

Regulations of medical physics in Jordan is not fully developed. The educational programs, by law, follow the regulations of the Ministry of Higher Education and Scientific Research (MHESR) and The Jordanian Accreditation and Quality Assurance Commission for Higher Education Institutions (AQACHEI). All the educational programs mentioned earlier are accredited by AQACHEI. On the other hand, monitoring of various facilities that use radiation equipment has gone through various changes in the past few years as part of the country's effort to reorganize its nuclear and atomic agencies. In 2008, the Jordan Nuclear Regulatory Commission (JNRC) was established as a successor to the Nuclear Safety and Radiation Protection Department. Recently, in 2014, a new law was issued to merge the Jordan Nuclear Regulatory Commission, the regulatory activities of the Natural Resources Authority and Electricity Regulatory Commission and is now the Energy and Minerals Regulatory Commission (EMRC). By the new law, EMRC is the body responsible for regulating the use of nuclear energy and ionizing radiation in Jordan. Its responsibilities include:

- Ensuring the availability of the radiation protection requirements for x-ray, radiotherapy, or nuclear medicine departments.
- Authorization of permits and licenses for institutions and workers in the field in compliance with pertinent rules and regulations.
- Controlling and monitoring the implementation of pertinent rules through inspection.

While the role of EMRC includes the licensing of workers in radiation, it is not responsible for certification of medical physicists in Jordan. The Ministry of Health is yet to play a major role in regulating and recognizing medical physics as a profession and it does not play any role in establishing board exams or certificates for the profession as it does with other allied health. The role of the Jordanian Association for Physicists in Medicine (JAPM) has been to try to moderate efforts to regulate the profession by communicating with the different parties involved in recognizing medical physics as a profession. There has been some progress in this regard which includes:

- A radiation officer is now recognized and is required in hospitals that have facilities using ionizing radiation, as required by MERC regulations.
- The Civil Service Bureau (CSB) now recognizes job calls for medical physicists, when requested by public sectors and administers competitive exams for applicant's selection.

Despite these improvements, much still needs to be done in order to achieve full recognition of the profession. Particularly, the Ministry of Health must have a specific body responsible for recognizing the medical physics profession. We are optimistically hoping that in the next few years, a full recognition and regulation of the profession in Jordan will be achieved.

V. Conclusions

In recent years, Jordan has seen progress in medical physics teaching and training. Since the BSc. program in biomedical physics started 17 years ago, there are now two MSc. programs, with the recent one having just started in 2020. Moreover, a residency program is expected to start very soon. All academic programs are accredited locally the AQACHEI and follow a curriculum in accordance with the IAEA guidelines. Students in these programs achieve almost all the competences in all areas specified by the IAEA recommendations. The facilities for cancer treatment have expanded as well to include five centers. These centers, along with other nuclear medicine and radiology facilities, provide medical physics students with the needed clinical training using the latest state of the art medical related technologies.

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MEDICAL PHYSICS IN KUWAIT

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Abstract — **Medical Physics is a branch of applied of physics in science concerned with the application of the concepts and methods of physics to assist the diagnosis and treatment of human disease. It is allied with medical electronics engineering, instrumentation and bioengineering. An access to the quality and affordable health care is one of the priority areas of the government. For decades, the biggest user of nuclear and radiation technology in Kuwait has been the health sector. Unfortunately Medical Physics training programs are currently not available in Kuwait. All local medical physicists obtained medical physics degrees from abroad.**

Keywords — **medical physicist, radiotherapy, nuclear medicine, Kuwait, KCCC.**

I. INTRODUCTION

There is a growing incidence of cancer especially in the developing world as clearly outlined in the Kuwait cancer registry. The estimated cancer incidence in Kuwait was 2,467 new cases of cancer in Kuwait in 2020.This is expected to increase to 4440 by 2035, i.e., an 80% increase. It was estimated that 41% of these cases will benefit from having radiation therapy thus at the present time at least 1776 patients have been receiving radiation therapy.

The Kuwait Cancer Control Center (KCCC) is a governmental center affiliated to the Ministry of Health (MOH) of the State of Kuwait. KCCC is a comprehensive center dedicated entirely to provide cancer care across the Arab States of Gulf Cooperation Council (Kuwait, Saudi Arabia, the United Arab Emirates, Qatar, Bahrain, and Oman). The center utilizes all available resources to serve cancer patients with a wide number of competent medical staff and several available treatment modalities.

KCCC is primarily made up of 4 specialized buildings; Hussain Makki Juma building for Specialized Surgery, Sheikha Badriya Al Sabah Medical Oncology Building, Faisal Sultan Ibn Issa Diagnostic Imaging building, and Bahbahani building for hematology and stem cell transplantation. It is a 200-bed hospital complex located in Shuwaikh that treats over 3000 new cancer patients each year. The center has all areas of cancer management, the surgical oncology, the medical oncology, hemato-oncology, and the radiation oncology.

Medical physics contributions and supports to both nuclear medicine and radiotherapy are well-established disciplines in the country with the availability of competent professionals and technical staff performing advanced medical imaging systems and procedures. KCCC's nuclear medicine department is currently equipped with one cyclotron facility for the production of short-lived radioisotopes associated to two Positron Emission Tomography – Computed Tomography (PET/CT) scanners, four Single-Photon Emission Computed Tomography (SPECT/CT) scanners, and a radionuclide therapy suite for treatment with I-131, Lu-177, Ac-225. Its central radio-pharmacy unit supplies on a daily basis all nuclear medicine services in Kuwait with ready-to-use radiopharmaceuticals, starting materials for compounding radiopharmaceuticals locally and PET radiopharmaceuticals.

The KCCC is dedicated entirely to the purpose of providing cancer care across the State of Kuwait and hosts the country's only radiation oncology facility. Currently, the KCCC's radiotherapy department has four linear accelerators, three of which are modern linacs with 0.5cm MLCs and CBCT capabilities. The fourth one has 1cm MLC and portal imaging, this linac is dedicated to electron treatments and palliative cases. The department provides High Dose Rate (HDR) brachytherapy services with an after-loader machine (Ir-192 source) for gynecological applications. The department also has a CT simulator and a traditional simulator. The department offers radiotherapy, paediatric oncology and palliative treatment services. Most cases are treated with 3D conformal radiotherapy. Intensity modulated radiotherapy (IMRT) services started ~~in~~ at the department in 2016, and currently head and neck, and prostate cancer patients are treated with this technique. Volumetric arc therapy was introduced in 2018. MOH is currently constructing a new cancer center which will have six bunkers for linacs and a bunker for brachytherapy. The new center would also be equipped with 2 CT simulators and an MRI simulator.

In addition, the IAEA have recently honored KCCC in recognition of its distinguished efforts in nuclear medicine by an official ceremony held at its headquarters in Vienna, the agency lauded the KCCC as an outstanding regional training center. Honoring the center is an evidence of several experiments and progresses made by Kuwait is this field. This honoring establishes a start of a key scientific cooperation between the institutions and the centers of nuclear medicine in Asia through the current cooperation between Kuwait and the IAEA.

For any expansion to take place to meet the growing needs to fight against cancer, trained professionals including medical physicists will be required. Currently, all local medical physicists joined the service after obtaining MSc or PhD degree from overseas universities.

In order to address the shortage of medical physicists and the lack of taught medical physics degree in Kuwait extensive training were provided for local staff with the assistance of the IAEA. In addition, the government recruited a number of experienced medical physicists from abroad to assist in training medical physicists locally. A summary of medical equipment for medical imaging and radiation therapy is shown in Table 1.

II. INFRASTRUCTURE

Kuwait, with a population of approximately 4.27 million people, has one radiotherapy and 11 nuclear medicine facilities providing clinical services including imaging and non-imaging studies. Table 1 shows a summary of equipment for medical imaging and radiation therapy available in Kuwait.

Table 1 Medical equipment for medical imaging and radiation therapy

Equipment	Total
Cyclotron	2
PET/CT	14
SPECT	33
Dose calibrators	22
Accelerator	4
MRI	23
CT	45
Mammography	15
Standard Radiology	208
Interventional	40

III. REGULATION OF MEDICAL PHYSICS

In the regulatory framework of Kuwait, the presence of a medical physicist is mainly for Radiation therapy and Nuclear Medicine centers. Currently, the MOH are reviewing the structure and organization of medical physics profession in the country. Distribution of Medical Physicists in the country is given in Table 2.

Table 2 Distribution of medical physicists in Kuwait

Medical Physicists	Total
Radiotherapy	10
Nuclear Medicine	18
Radiology	4
Health physics	6
Total	38

IV. EDUCATION AND TRAINING

Medical physics education and training in Kuwait has traditionally been completion of a BSc degree in Physics or Allied health science followed by a postgraduate degree abroad. At the moment, no proper medical physics academic education and training program available at national level. After completion of the degree program, graduates would be allowed to work as Medical Physicists for two years under the supervision of Clinically Qualified Medical Physicists, after which they would be allowed to carry out independent clinical work as Medical Physicists.

V. CONCLUSION

The Ministry of Health is currently constructing a new cancer center which will have six bunkers for linear accelerators, or LINACs, a machine used to deliver radiotherapy in cancer treatment. It will also provide services in brachytherapy. The new center would also be equipped with two computed tomography simulators and a magnetic resonance imaging simulator. In addition, two PET/CT and a PET/MRI will be installed in the new center. Therefore, there an ever-increasing demand of qualified medical physicists in the country. In addition, a proper medical physics educational and training program is a priority that have been taken into account within the MOH strategic plan.

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MEDICAL PHYSICS STATUS AND CHALLENGES IN LEBANON

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Abstract — **A steady and notable increase in cancer incidence was observed in Lebanon since 1998 that exceeded in 2020 all rates shown in the neighboring Arab countries. Radiotherapy is important for managing most cancers especially breast, lung, prostate and bladder cancer which account for more than two-fifths of cases worldwide. Trained Professionals like qualified medical physicists are at the front line in the fight against cancer. Medical physicists in Lebanon are mostly employed in hospitals and provide a wide range of services to radiation oncology, radiation safety and a variety of other areas including academia. Two universities offer a master's program in medical physics and related field. However, challenges remain with professional recognition, especially the importance of their presence in diagnostic radiology and nuclear medicine departments.**

The present paper is based on an online study that was conducted on all medical physicists practicing in Lebanon (23 medical physicists: 13 Qualified Medical Physicists and 10 Assistant Medical Physicists). An online questionnaire was used to collect data. The data collected was analyzed to identify infrastructure, therapy machines and challenges faced by medical physicists. Challenges are listed, their relation to education is detailed and based on a description of academic education and clinical training as it was developed over the last year. Finally, a list of recommendations is addressed to Lebanese authorities (government, ministry of public health and the Lebanese Atomic Energy Commission) in order to support financially, train and employ more medical physicists to handle all radiation safety issues in nuclear medicine and radiology departments.

Keywords — **Qualified Medical Physicist, Radiotherapy, Education, Lebanon.**

I. INTRODUCTION

Cancer is the second leading cause of death with 13% of worldwide mortalities[1]. Increasing access to radiotherapy worldwide through greater investment could save millions of lives, according to The Lancet Oncology Commission's report presented at the 2015 European Cancer Congress in Vienna, Austria[2]. Radiotherapy is important for managing most cancers, such as breast, lung, prostate, head and neck, and cervical cancers, which account for more than two-fifths of cases worldwide.

Lebanon is a small country in the Middle East with one of the highest levels of Human Development Index. The population of this country reached 6.8 Million in 2020 while the number of cancer cases reached 11,589 cases[3]. A steady and notable increase in breast, prostate and bladder cancer incidence was observed in Lebanon since 1998, this number exceeds all rates shown in the neighboring Arab countries[4]. Lung cancer incidence rates are among the highest in the region as well for both males and females; these are consistent with the smoking habits in the Lebanese population compared to neighboring countries.

Trained professionals including radiation oncologists and medical physicists are in demand to deal with the increase of cancer incidence in this country.

According to the definition of the International Basic Safety Standards (BSS)[5], a medical physicist is: "a health professional, with specialist education and training in the concepts and techniques of applying physics in medicine, and competent to practice independently in one or more of the specialties of medical physics."

The present paper is based on an online study that was conducted on all medical physicists working in Lebanon. An online questionnaire was used to collect data. The data collected are presented and analyzed in order to identify infrastructure, therapy machines, therapy techniques and challenges faced by clinical medical physicists.

II. REGULATION OF MEDICAL PHYSICS

The employment of a qualified medical physicist in radiotherapy departments is a national legal requirement in Lebanon. His/her main role is to establish and maintain a quality assurance program. Every year, the Lebanese Atomic Energy Commission (LAEC) send their external auditors to check the presence of a qualified medical physicist in each radiotherapy department and the implementation of quality assurance program as well as a radiation safety program for all staff engaged in the use of radiation. Treatment license permit cannot be given to any radiotherapy department without a certified or qualified medical physicist supervising radiation treatment planning and delivery.

Unlike in radiotherapy, the presence of a medical physicist in radiology and nuclear medicine departments is not yet a national legal requirement while the presence of a radiation safety officer is mandatory.

III. EDUCATION AND CLINICAL TRAINING

In order to address the shortage of certified medical physicists and taking into account the limited number of medical centers dedicated for training of certified medical physicist, two universities (Table 1) introduced different MSc Degree in Medical Physics and alternative programs in Radiation safety to fulfill the academic requirements for training "assistant medical physicists". The curriculum for the programs was developed with support of the LAEC and under the supervision of qualified medical physicists. In addition to teaching and training, Medical Physicists are often involved in research and technical development in most academic settings.

The initial enrolment in the program was 12 students at the Lebanese University in September 2015. The program is composed of two years with the second year dedicated to a research project or clinical placements. "Basic physics and radiobiology, physics of non-ionising radiations, radiotherapy physics, nuclear medicine physics, dosimetry and instrumentation, medical imaging physics and safety and quality management" are the main elements of the curriculum.

After completion of the MSc degree program, graduates are allowed to work as Assistant Medical Physicist under the supervision of a Clinically Qualified Medical Physicist. Until this date, ten graduated students of these MSc degrees were hired in different radiotherapy centers in order to support qualified medical physicists in their daily work.

In order to continue and pursue a PhD degree in the Medical Physics field, three universities (Lebanese University, Saint Joseph University and Beirut Arab University) conduct research in collaboration with French universities and European institutions. While the type of research conducted in most universities and institutions varies, research in radiation dosimetry is the most common one in the three main subspecialties of the Medical Physics: therapy, radiology, and nuclear medicine. Though research is required from all the PhD students, students in MSc programs are also encouraged to have optional research projects.

Table 1: *Different MSc Degrees in Medical Physics and alternative programs in Radiation safety to fulfill the academic requirements for training "assistant medical physicists".*

Specialty	**University**	**Opening**	**Number of students**
M1&2- Medical Physics (Professional)	Beirut Arab University	2017	5
M2- Medical Physics and Imaging Technologies (Professional)	Lebanese University	2015	12
M2- Medical Physics and Life Imaging (Research)	Lebanese University	2015	12
M1&2 - Lasers and Ionizing Radiations : Safety and Protection (Professional)	Lebanese University	2017	9

IV. METHODS

A study was carried out to identify the challenges faced by medical physicists in Lebanon and the objectives of the study were to identify the number of qualified medical physicists and their work experience/conditions in hospitals and to identify the challenges faced by medical physicists in the country. The study was conducted on 23 medical physicists (13 Qualified Medical Physicists and 10 Assistant Medical Physicists). An online questionnaire was used to collect data. The data collected was analyzed to identify challenges faced by medical physicists.

V. RESULTS

For all the reasons listed above, the practice of medical physicist in Lebanon is limited till now to radiation therapy. Thirteen certified medical physicists are employed in 12 radiation therapy departments. The number of certified medical physicist per million of population decreased to 1.9 in 2021 against 2.6 in 2017[6], which remains among the lowest in the region. The economic crisis hitting the country since the end of 2019 and the depreciation of the local currency pushed 20% of the medical physicists to migrate towards developed countries searching for better work opportunities.

Although an evolution of technology was observed between 2016 and 2020, where a significant number of fully equipped linear accelerators was installed in the country, the number of operational therapy units per million of population decreased to 2.5 against 2.8 in 2017[6].

It should also be noted that this actual number of operational therapy units per million remains the highest in the Arab region.

Table 2: Distribution of radiotherapy centers, number of linear accelerators per institution, the presence of IGRT and gating respiratory systems as well as the techniques of treatments and number of patients treated per day.

Hospital	Number of accelerators	Machine	Imaging systems	Gating respiratory	MLC	Techniques of treatments	Number of patients / day
A	1	Elekta	EPID	No	80	3DCRT	20
B	1	Truebeam	IGRT	yes	120	3DCRT, IMRT	45
C	2	Truebeam	IGRT	yes	120	3DCRT, IMRT	30
		Truebeam	IGRT	yes	120	3DCRT, IMRT, SRT, SRS, SBRT	30
D	3	Truebeam	IGRT	yes	120	3DCRT, IMRT, SRT, SRS, SBRT	50
		Clinac 2300	IGRT	No	120	3DCRT, IMRT	50
		Halcyon	IGRT	No	120	IMRT	50
E	1	Elekta Synergy	EPID	No	120	3DCRT, IMRT	25
F	1	ARTISTE, Siemens	IGRT	No	160	3DCRT, IMRT	50
G	1	Versa HD	IGRT	Yes	160	3DCRT, IMRT, VMAT	15
H	1	Versa HD	IGRT	Yes	160	3DCRT, IMRT, VMAT	20
I	2	ARTISTE, Siemens	IGRT	No	160	3DCRT, IMRT	35
		Mevatron	Portal Film	No	No	3DCRT	10
J	1	Truebeam	IGRT	No	120	3DCRT, IMRT	35
K	1	Oncor Impression	EPID	No	120	3DCRT, IMRT	22
L	2	ARTISTE, Siemens	IGRT	Yes	160	3DCRT, IMRT, SRT, SRS, SBRT, TBI	30
		ARTISTE, Siemens	IGRT	yes	160	3DCRT, IMRT, SRT, SRS, SBRT, TBI	30

Table 3: Distribution of brachytherapy units, number of HDR afterloaders per institution as well as the techniques of treatments and number of patients treated per year.

Hospital	Afterloader	Treatment techniques	Number of patients / year	Localization
A	Varian, Gammamed	3D	80	Cervix, Vaginal vault
B	Varian, Gammamed	3D	50	Cervix, Vaginal vault, Prostate, Breast, keloids, Cholangiomas
C	Varian, Gammamed	3D	70	Cervix, Vaginal vault

Table 2 shows the distribution of radiotherapy centers, number of linear accelerators per institution, the presence of image guided radiotherapy ‘IGRT’ and gating respiratory systems as well as the techniques of treatments and number of patients treated per day. The average number of patients treated per day for all departments is 32 patients on 17 operational linear accelerators. All the centers have computerized treatment planning systems and a comprehensive information management system. Complex treatments such as intensity modulated radiotherapy, Stereotactic radiotherapy treatments, stereotactic radiosurgery and stereotactic body radiotherapy (IMRT, SRT, SRS and SBRT) are done on 15 of 17 radiotherapy linacs.

Table 3 shows the distribution of brachytherapy units, number of high dose rate afterloaders per institution as well as the techniques used for treatments and number of patients treated per year. 3D planning based on CT scans and MRI images is used for all kind of treatments in brachytherapy. Brachytherapy is not only used for gynecological treatments (cervix, vaginal vault) but also used for prostate, breast, keloids and cholangiomas as well.

Results indicate that most medical physicists are working in Radiotherapy and practicing mainly in this area. The level of involvement of medical physicists in Radiology and Nuclear Medicine is minimal.

The law governing the use of ionizing radiation in Nuclear Medicine and Radiology is still not implemented in the country, and there is a need to employ qualified medical physicists in these fields. Nonetheless, there is no full recognition of the role of medical physicists from the hospital managers and health ministry.

All Assistant Medical physicists complained of the lack of national board examination or certification program.

Twenty per cent of the participants working in governmental hospitals suffered from the lack of equipment that has limited the performance of their duties especially in areas of dosimetry and dose assessment. This has minimized their participation in research, publication and implementing complex treatments such as Intensity Modulated Radiotherapy or Stereotactic treatments.

Seventy five per cent of radiotherapy centers have no budget for continuous education to fund conferences or congress attendance.

Finally, all medical physicists admit their salaries are very low taking into account their daily duties and responsibilities.

VI. Conclusion

The number of Medical Physicists per million of the population is projected to triple by 2035 Worldwide. As a result, this may cause significant problems to healthcare providers in the Middle East - especially in the fields of Radiotherapy, Medical Imaging and Nuclear Medicine. The challenges identified in this study can be resolved by the Lebanese authorities; effective communication between Lebanese medical physicists and the government authorities can help improve work conditions and provide better future prospects.

The Lebanese government, ministry of public health and the LAEC should support financially continuous education, training, further employment of medical physicists to handle all radiation dose safety issues pertaining to all departments using ionizing radiation in medicine especially in nuclear medicine and radiology departments.

The presence of medical physicists in Medical Imaging and Nuclear Medicine departments should be mandatory in order to guarantee quality imaging procedures with less dose to the patients.

There is a need for a national board examination to certify medical physicists and to ascertain their role in the clinical settings. National universities should work in collaboration with private hospitals to implement an accredited Medical Physics program and establish the needed laboratories and validate training centers.

Increasing the number of qualified medical physicists should be accompanied by opening new job opportunities in diagnostic departments. Eventually, this will lead to the foundation of a medical physicist's syndicate which will look after the welfare of its members.

Finally, more effective communication among the members of the Lebanese medical physicists' community is needed to face the challenges facing and that lie ahead of us.

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MEDICAL PHYSICS STATUS IN SULTANATE OF OMAN

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Abstract — **Medical physics is a relatively young profession in Oman, but we have seen encouraging development in the last decade. There are currently 36 medical physicists in Oman, making a ratio of 6.6 medical physicists per a million population. Oman currently has one medical physics professional organization named Oman Medical Physics society under the umbrella of the Middle East Federation of Organizations for Medical Physics (MEFOMP) and the International Organization for Medical Physics (IOMP). Since 2004, Oman offers a Medical Physics program as a minor within the Physics program at a BSc. Level at Sultan Qaboos University. Training and educating Omani medical physicists, with a pathway to a career in radiation oncology, diagnostic imaging and nuclear medicine, has been witnessed over the years. This is to provide highest international standards of patient care, radiation safety and clinical practice.**

Keywords — **Medical Physicist, Oman Medical Physics Society, Education and Training**

I. INTRODUCTION

One of Oman's vision for the future, "Oman 2040", is "A Leading Healthcare System with International Standards". Its strategic plan aspires for qualified national talents and capabilities leading scientific research and innovation in healthcare [1].

Oman's healthcare sector continues to grow and advances with diagnostic imaging services and therapeutic procedures with state of art equipment including a recently installed Cyber knife at Sultan Qaboos Comprehensive Cancer Center- Research Centre (SQCCC-RC), which is expected to start its services by the end of 2021. In addition to SQCCC-RC, Oman has a National Oncology Center at the Royal Hospital which started treating its first patients in 2003. Table 1. reflects equipment from Sultan Qaboos University Hospital (SQUH), The Ministry of Health (MOH) and SQCCC-RC where all comprehensive, state-of-the-art diagnostic radiology, image-guided interventional services, and nuclear medicine services are offered. However, medical physics services are further extended to other government and private hospitals and centers in the country.

For occupational radiation safety, there are two Personnel Thermo-luminescence dosimetry laboratories in Oman in Sultan Qaboos University (SQU) and in Ministry of Health. Both laboratories are run by medical physicists.

Table 1 Medical equipment for medical imaging, nuclear medicine and radiation therapy (as of April 2021) in SQUH, MOH and SQCCC-RC, **excluding other government and private hospitals and centers.**

Equipment	Total
Radiation Oncology	
LINAC	4
Cyberknife	1
Brachytherapy	1
Nuclear Medicine	
Gamma Camera	1
SPECT	3
SPECT/CT	3
PET/CT scanner	3
Medical Cyclotron	1
Diagnostic Radiology	
MRI systems	8
CT scanner	28
Mammography	14
Standard Radiology	200
Fluoroscopy and angiography systems	80
Bone Densitometry	3

Abbreviations:
LINAC: Linear accelerator
SPECT: Single photon emission computed tomography
CT: Computed tomography
PET: Positron emission tomography
MRI: Magnetic resonance imaging

II. MEDICAL PHYSICISTS

Medical physics is a relatively young profession in Oman, but has seen encouraging development in the last decade. As of 1st April 2021, there are 36 medical physicists in the country in which 32 are Omani nationals. The population of Oman is approximately 5.2 million people. This makes a fair ratio of 6.6 medical physicists per a million population.

Medical physicists in Oman are mostly employed in hospitals and provide a wide range of services to radiation oncology, diagnostic radiology and nuclear medicine. Ministry of Health has a Medical Physics department and an Occupational Health department where s ome of our medical physicists are employed as well.

There are a number of medical physicists at Sultan Qaboos University and Sultan Qaboos University Hospital in the medical physics unit, where teaching, personnel dosimetry, gamma spectroscopy analysis and cross calibration of survey meters take place. Academic and clinical medical physicists at Sultan Qaboos University contribute in research, mainly in the topics of patient dose optimization, imaging related projects and radiation protection [2]. A number of research papers and outcomes were presented at scientific meetings and international conferences and published in local and international journals.

To meet the increased demand in radiotherapy services and the need for more qualified medical physicists in the diagnostic departments of radiology and nuclear medicine, there are currently 4 PhD holders, one currently pursuing a doctorate degree and 11 MSc. holders. Table 2. demonstrates the current distribution of medical physicists in Oman in Medical Physics sub-fields.

The proportion of female physicists has been growing since 2003 presenting 82% of the workforce in all medical physics disciplines. This trend is expected to continue, supported by the number of women enrolled in Medical Physics program in Sultan Qaboos University each year.

Table 2. Distribution of Medical Physicists in Medical Physics sub-fields as of April 2021 (Including 4 PhD. 11 MSc.).

Specialty	Number of Medical Physicist	Female	Male
Diagnostic radiology	11	8 (73 %)	3 (27 %)
Radiation oncology	7	6 (86 %)	1 (14 %)
Nuclear medicine	10	10 (100 %)	0 (00 %)
Health Physics	3	2 (67 %)	1 (33 %)
Academia	3	1 (33%)	2(67 %)
Research assistance	2	2 (100%)	0
Total	36	29	7

III. Graduate Training

For PhD. and MSc. degrees in medical physics, we currently depend on external academic Medical Physics programs. However, since 2004, Sultan Qaboos University in Oman offered Medical Physics program as a minor within the Physics program at a BSc. Level. A three semester medical physics program is designed and taught in the Medical Physics Unit, Department of Radiology and Molecular Imaging at College of Medicine and Health Sciences. The program covers mainly the following topics: Physics of ionizing and non-ionizing radiation of diagnostic imaging modalities and nuclear medicine, radiobiology and radiation protection. Practical sessions and research projects of the program are conducted within Sultan Qaboos University and Sultan Qaboos University Hospital with the supervision of senior staff and qualified medical physicists. Two weeks of hospital based training is included as well within the syllabus. Since 2004 to date, an average of 10 candidates graduate every year.

IV. Clinical Training

Currently, there is no medical physics residency program in Oman. However, two of our radiotherapy medical physicists underwent an accredited residency program abroad and one is yet to complete the program. Some of our nuclear medicine physicists underwent specialized training programs at certified centers abroad. In addition, most of our medical physicists are trained on-the-job after obtaining their undergraduate and postgraduate degrees.

Moreover, our medical physicists are encouraged to obtain the International Medical Physics Board Certificate (IMPBC) where one of our diagnostic medical physicist has been certified in 2019 and one of our radiotherapy medical physicist passed the first two phases.

The Peaceful Nuclear Technology Office in Oman in collaboration with the International Atomic Energy Agency (IAEA) further support Omani medical physicists on strengthening their education and clinical training through Technical Cooperation (TC) programs, national, regional and international workshops and fellowships.

IAEA is also supporting Omani candidates to join the Post Graduate course on Advanced studies in medical physics program from International Center for Theoretical Physics (ICTP), Trieste, Italy, where one of our diagnostic medical physicist has graduated in 2019.

As part of the radiology residency program at Oman Medical Specialty Board (OMSB), a comprehensive radiation physics program is taught covering all aspects of physical principles of diagnostic imaging equipment, nuclear medicine, radiotherapy, radiobiology, and radiation protection. This program is delivered by our trained medical physicists to first year radiology residents.

For continuous education and self- development, the Medical Physics Unit at Sultan Qaboos University, Ministry of Health and Oman Medical Physics Society play an important role in delivering lecture based and hands-on workshops.

Similar to many other countries in the region, our main challenge in Oman is the lack of a certified residency program on medical physics and lack of academic programs for MSc. and PhD. levels.

V. Oman Medical Physics Society (OMPS)

Oman currently has one medical physics professional organization, Oman Medical Physics Society (OMPS), under the umbrella of the Middle East Federation of Organizations for Medical Physics (MEFOMP) and the International Organization for Medical Physics (IOMP).

OMPS was founded in 2011 with more than 40 members up to date. The main goals of the OMPS are: To promote cooperation and communication between medical physicists locally and between medical physics organizations in the region. To promote medical physics and related activities in the country and to promote the standard of practice of the medical physics profession through conferences, workshops and seminars. In addition, OMPS seeks to create public awareness of the Medical Physics profession in Oman and to encourage research, training and education in the field.

The society is also responsible for the annual celebration of the International Day of Medical Physics (IDMP) and International Medical Physics Week (IMPW).

On September 2019, the society was delighted to host the 1st MEFOMP workshop in Oman and on 7th of November 2019 organized the 1st gathering of Medical Physicists in Oman with a local Radiation Protection workshop. Most recent, the OMPS participated in the 2021 Virtual MEFOMP Medical Physics Conference.

VI. Conclusion

The demand for training medical physicists in Oman increased by year in line with the rapid development in the healthcare services, which aims to operate at the highest international standards of patient care, radiation safety and clinical practice.

This is a result of the improving recognition of the important role of medical physicists in Oman, especially in areas of Radiotherapy, Nuclear Medicine and Diagnostic Radiology.

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Status of Medical Physics in Palestine

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Abstract— **Medical Physics is a branch of Applied Physics, pursued by medical physicists. It uses physics concepts and procedures in the prevention, diagnosis, and treatment of disease. Medical physics is classified into a number of sub-fields, including Radiation Oncology Physics, Medical Imaging Physics, Nuclear Medicine Physics, Medical Health Physics, and Non-ionizing Medical Radiation Physics. Medical Physics fulfils an important role in medicine, in biological and medical research, and in the optimization of certain health related activities. The activities in Medical Physics can be classified into three areas: research and development, clinical service and consultation, and teaching. In Palestine, Medical physicists are trained under the umbrella of Augusta Victoria Hospital (AVH) and the Palestinian Ministry of Health.**

Keywords— **Medical Physics, Radiotherapy, Training, Palestine.**

I. Introduction

Radiotherapy, surgery, and chemotherapy are the main therapies against cancer. Often various treatment possibilities are combined. The choice of treatment depends on cancer type, location, stage of the disease, and the general state of the patient. At present, in industrialized countries, about 70% of cancer patients are referred to a radiation therapy department for at least part of the treatment [1].

According to estimates by the world health organization (WHO), the number of new cancer patients in 2012 is about 14 million worldwide, which is expected to increase to 22 million by the year 2030. This represents an increase of 75% compared with 2008. As a result, cancer will then be the main cause of death [2-3]. In Palestine, the estimated cancer incidence was 1600 cases in 2012. This is expected to increase to 7000 by 2030, where it is estimated that 60% of these cases will benefit from having radiation therapy [4].

Palestine is a country in the Middle East and it is under the control of Israel. The resulting political conditions make it difficult to evaluate the status of medical physics in the country. Medical physics is one of the main themes that is required to improve healthcare in the country. Palestine makes great efforts to organize its national medical physics society to further enhance and improve the status of medical physics across the country. Palestine faces many obstacles to expand the level of medical physics knowledge due to political reasons. The main obstacles are: building the required infrastructures, buying the required equipment, and upgrading of qualified professionals.

For any expansion to take place to meet the growing needs to fight against cancer, trained professionals including Medical Physicists and Oncologists will be required. In order to increase the level of medical physics knowledge in Palestine, the Hebron University introduced a BSc Degree in Medical Physics in 2019 to fulfil the academic requirements for training medical physicists. The Program has been approved by the Ministry of Higher Education and accepted by the Ministry of Health as fulfilling the academic requirements of medical physicists. The program is structured to take four years with the last year dedicated to a research project and training at one or more of the centers across the country, with the possibility to receive a training abroad. The taught courses include: General Physics, Medical Physics, Radiation Physics, Accelerator Physics (including X-ray Machines), Nuclear Medicine & Medical Imaging (e.g CT Scan, MRI, PET Scan), Radiation Therapy (e.g X-rays & Protons), Radiation Protection Methods, Particle Physics, Nuclear Physics, Atomic Physics, Modern Physics, Mathematical Physics, Computational Physics, among others.

The BSc Degree in Medical Physics program at Hebron University faces some obstacles including lack of qualified lecturers to cover teaching of all courses and limited funding which is needed to establish a medical physics laboratory and to buy the required computing systems to support computer simulations and image processing.

II. Infrastructure

The Cancer Care Center at AVH, located in Jerusalem, is the only center offering radiation therapy services for all Palestinian People. This center has one CT simulator and three LINACs capable of producing 6, 10, 15 MeV X-ray beams, and 6, 9, 12 MeV electron beams. There is a plan to have one brachytherapy unit in the close future. The Augusta Victoria radiotherapy division handles about 110 patients daily. There are many conventional X-ray scanners in both public and private institutions as well as CT scanners, mammography units and interventional radiology units. Table 1 summarizes medical equipment for medical imaging and radiation therapy in Palestine.

Although the qualified medical physicists in Palestine are rare, the presence of a medical physicist is mandatory for all Radiation therapy and Nuclear Medicine centers according the regulatory framework. Table 2 shows the distribution of Medical Physicists in Palestine.

Table 1 Palestinian Medical equipment for medical imaging and radiation therapy.

Equipment	Total
SPECT	1
Dose calibrators	1
Accelerator	3
MRI	6
CT	30
Mammography	10
Standard Radiology	350
Interventional	10

Table 2 Distribution of medical physicists in Palestine

Medical Physicists	Total
Radiotherapy	5
Nuclear Medicine	3
Radiology	1
Total	9

III. Education and training

In Palestine, medical physics education and training usually takes place after completion of a BSc degree in Physics or Applied Physics at one the University is the country, with the possibility to receive training abroad. The four-year BSc program at the Hebron University offers an excellent education in a thriving field of science and engineering. The foundation in core physics together with the major areas of physics applied to medicine prepare physicists for a wide variety of careers inside medical physics, including those in scientific research and industry. Due to the lack of clinical training in medical physics, all currently available medical physicists had their clinical training abroad. In addition, Palestine as a member of Middle East Federation of Medical Physics (MEFOMP) and International Atomic Energy Agency (IAEA) receives some funds to support Palestinian Medical Physicists in order to attend training schools and workshops in several areas of Medical Physics.

IV. Conclusion

In Palestine, it is necessary to develop a long-term policy that achieves the objectives of medical physics support in healthcare institutions. Development of medical physics in Palestine faces some challenges, including: encouraging universities to open departments of medical physics or at least start to teach some courses which is related to medical physics and encouraging decision-makers to support medical physics society. Medical physicists in Palestine follow a curriculum training syllabus for Medical Physicists which was derived from IAEA training publications [5-8].

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THE EVOLUTION OF QUALITY CONTROL SERVICES FOR RADIOLOGY EQUIPMENT OF HAMAD MEDICAL CORPORATION IN QATAR FROM 2005 TO 2021

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Abstract— **Hamad Medical Corporation (HMC) is the public health provider in the state of Qatar with 15 hospitals spread around the country. The Medical Physics Section (MPS) of HMC is the sole quality control (QC) service provider for all diagnostic equipment installed in HMC hospitals. In this article, the evolution of the MPS during the last 17 years of its operation is presented.**

Archives and QC reports from 2005 and onwards, were revisited to create an inventory of radiology equipment present in all HMC hospitals, QC control equipment present in MPS and QC protocols and methods used for acceptance and routine QC for radiology equipment.

The work was divided in four different periods 2005-2009, 2010-2014, 2015-2019 and 2020-2021, since the significant changes that took place during 2009, 2015 and 2000 are considered turning points for the evolution of MPS QC services. Emphasis is given in those changes in QC protocols and radiology and QC equipment which advanced the potential and efficiency of MPS in a higher level, leading to the official accreditation of MPS as a QC provider from MEFOMP organization.

The story of MPS is presented as a paradigm of the challenges that medical physicists worldwide, have faced in the past and will face in the future, to achieve the goals that promote both the essence and the appearances of the clinical medical physicist profession in radiological imaging: being knowledgeable, visible, useful and indispensable.

Keywords— **Medical Physics, Diagnostic Radiology, Quality Control, Accreditation.**

I. Introduction

Hamad Medical Corporation (HMC) is a governmental organization which constitutes the major health service provider in the state of Qatar. Starting from with three hospitals in the early 1980's, HMC gradually grew to 15 hospitals in 2020, which cover the whole range of medical specialties, medical personnel and medical equipment required to fulfill the health service needs of people residing in or visiting Qatar.

HMC has invested greatly on the radiology equipment since medical imaging is essential for diagnosis of a wide spectrum of pathological conditions. Apart from ultrasound and magnetic resonance imaging (MRI) equipment, the rest radiology equipment uses ionizing radiation, and therefore involves a certain risk, not only for the examined patients but also for the medical personnel using this equipment.

Due to the adverse effects of ionizing radiation which manifest mainly in high doses but may also appear in low doses (though the probability of occurrence is much lower), the operation of equipment using ionizing radiation should comply with certain requirements that have been issued by specialized international organizations, like ICRP and IAEA. These requirements are reflected in the national radiation protection laws and regulations of each country and Qatar is not an exception (Qatar Radiation Protection Law, Decree Number 31 of 2002 and Minister of Municipality and Environment Decree Number 4 of 2003 on the Executive Regulations for Law No.31).

In response to these requirements, the radiation safety services of HMC grew from a small Radiation Protection Unit at the Radiology (the name changed to Clinical Imaging) Department in 2000, to a fully functioning Radiation Safety Section within the Occupational Health and Safety Department in 2010, which was recently renamed to Medical Physics Section (MPS). MPS oversees the operation of all medical equipment using ionizing radiation in all HMC hospitals, while the last few years has extended its application field to lasers, MRI and ultrasound equipment as well.

The main purpose of MPS is to ensure that the operation of radiology equipment complies with national and international regulations. That is, in all radiology examinations the irradiation of the patient should be minimized as much as possible, while maintaining the image quality to the level required for the radiologist to perform a reliable diagnosis.

For this purpose, the MPS has developed a quality assurance (QA) program that is comprised by an initial extensive quality control (QC) test performed in every radiology equipment installed in HMC hospitals (acceptance/commissioning QC) and periodical QC tests carried out thereafter (routine QC), during the whole time that this equipment is operational. The commissioning QC is very important to certify that the installed equipment is operating within specifications and that also meets the respective national and international requirements regarding safety and performance standards [1,2]. This means that several parameters must be directly measured or indirectly calculated, to ensure that they are within certain limits [3,4].

Additionally, some other parameters must be measured, the values of which will serve as baseline (where specific limits do not apply), to monitor in subsequent QC tests the performance of the radiology equipment and detect any significant deviations from its baseline performance [2,4]. It is well established that regular service and QC testing is the only way to assure that the radiology equipment is operating properly during its whole lifetime [5]. While regular service may prevent but cannot eliminate the occurrence of occasional malfunctions, routine QC is the only way to document that the performance of the radiology equipment adheres to the criteria related to both patient safety and image quality [6,7].

In this study the evolution of QC services in the radiology equipment of HMC during the period 2005-2021 is presented. The changes in X-ray equipment, QC equipment, personnel, QC protocols and QC methods are highlighted, along with the outcome of these QC services. The difficulties encountered during all these years, solutions applied, as well as, future challenges are discussed, from the aspect of Medical Physicists focused in the field of radiology.

II. Materials and methods

The evolution of QC services of the MPS to the various HMC hospitals, can be roughly categorized in 4 different periods: 1st) 2005- 2009, 2nd) 2010-2014, 3rd) 2015-2019 and 4th) 2020- 2021. This evolution was driven by two major factors. The first was the rapid increase in the number of radiology equipment installed in HMC hospitals, which was combined with the establishment of many new hospitals. The second was the gradual replacement of analogue radiology equipment by digital in the existing hospitals and the installation of digital units of advanced technology, like angiography units, CTs and digital mammography systems in the new hospitals, right from the start.

The replacement of film/screen systems by digital detectors in both general and dental X-ray systems had a large impact on our QC program. Some QC tests were abolished, like dark room and wet-processor tests requiring the use of sensitometer and densitometer [2,8]. Others like Automatic Exposure Control (AEC) tests, which were mostly based on measurement of optical density (OD) of processed films with the densitometer, had to fully reshaped since OD of digital printed films was no longer associated with incident air-kerma [4,9]. The installation of advanced technology radiology equipment in HMC hospitals had also a big impact on QC services. The establishment of a QA program for these systems, required additional training of Medical Physicists and new QC equipment, and introduced a whole new chapter of QC tests regarding the evaluation of image quality. In the following sections are presented some informative data on the X-ray equipment installed in HMC hospitals and the QC services offered by the MPS of HMC during these four periods.

III. Results

1st period: 2005 - 2009

During this period, only 5 hospitals established up to that time under HMC: Rumailah Hospital (RH) established in 1957, Hamad General Hospital (HGH) established in 1982, Women's Hospital (WH) established in 1988m, National Center for Cancer Care and Research (NCCCR) established in 2004 and Al Khor Hospital (AKH) established in 2005. Most of the radiology imaging equipment installed in these five hospitals was analogue, using screen/film systems as image receptors. The type and number of units installed and overseen by the MPS are shown in Figure 1. QC was performed every six months in 56 out of 93 units (60%), and it was limited to general radiography systems, mobile X-ray units and dental periapical units. Regrettably, no acceptance or routine QC tests were performed in CT, fluoroscopy systems (stationary or mobile C-arms) and mammography units, due to lack of staff, training, and appropriate QC equipment. During this period, the available staff for performing QC tests was 2 medical physicists (MPs).

As can be seen in **Table 1**, during this period the available equipment was rudimentary; just two multifunction meters for measuring high potential (kVp), dose and dose rate (i.e. air-kerma and air-kerma rate) and exposure time, one set of aluminum filters for determining X-ray beam quality via the half-value layer (HVL), and one set of tools for checking the light and radiation field coincidence and the beam verticality. Two more instruments were available, a sensitometer and densitometer for QC tests related to dark rooms and wet film processors (e.g. film sensitometry, dark room light isolation, safelight evaluation etc.). The number of wet processors and dry printers that were under surveillance during this period can be seen in **Table 2**, while the available staff for performing QC tests is shown in **Table 3.** The QC tests performed during the period 2005-2009 [10-14] are listed in **Table 4** in comparison with the QC test performed in the period 2010-2014 [15-17]. Despite the shortage of staff, 112 QC tests per year were performed in X-ray units plus the QC tests in 10 wet processors that were performed daily. It must be mentioned that after 2010, the printer QC tests were gradually reduced, since diagnosis was shifted from view boxes and films to diagnostic monitors, and currently QC is performed in only one dry printer, monthly.

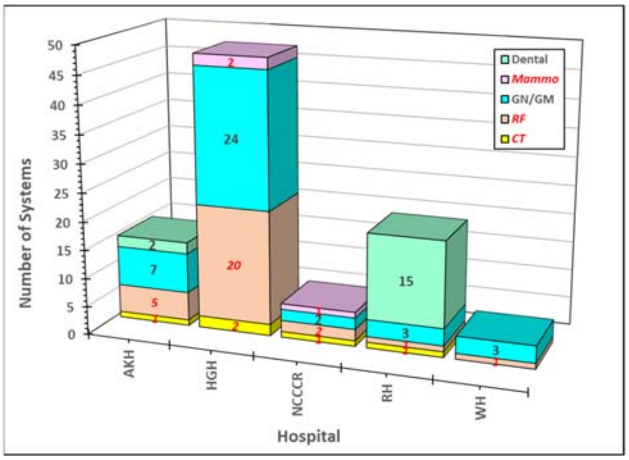

Figure 1 The type and number of the various X-ray modalities distributed in the Clinical Imaging Departments of the 5 HMC hospitals during the period 2005-2009. Units that are not included in QA program have their labels shown in *red italics.*

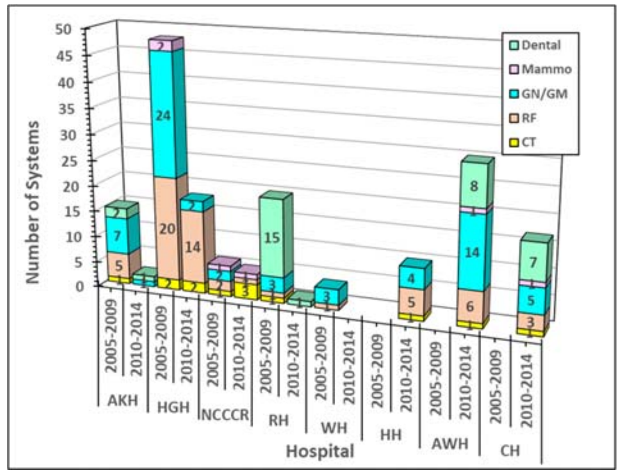

Figure 2 The type and number of new X-ray modalities distributed in the Clinical Imaging Departments of the 8 HMC hospitals during the period 2010 – 2014.

2nd period: 2010-2014

With the inauguration of new HMC hospitals and the installation of new modalities in the existing hospitals, the need to improve and advance the MPS services to meet the international standards became a necessity. As shown in **Figure 2**, during this period three new hospitals were added: Heart Hospital (HH) in 2011, Al Wakra Hospital (AWH) in 2012 and the Cuban Hospital (CH) in 2012, where additional cardiology and mammography departments were created.

Furthermore, a total of 83 new X-ray units of various types were added: 57 in the new hospitals and 26 in the existing ones and the equipment installed in all new hospitals and departments was fully digital, in view of the substantial image quality improvements that digital flat panel detectors offer. However, in most of the existing HMC clinical imaging facilities, the transition from analogue to fully digital occurred gradually. Due to the larger inventory of general and mobile radiography equipment, many of these systems were still being used during this period, but screen/film images receptors and wet chemical processors were replaced by computed radiography (CR) systems and dry printers, that allowed images to be digitized without having to replace the X-ray units.

During this period a significant increase in staff number took place with an increase in number of MPs to 5 (see **Table 3**) while new QC equipment was also made available (see **Table 1**). Both Barracuda and RaySafe Xi were procured as complete systems for multiparameter measurements on all X-ray modalities, capable of simultaneous measurement of tube potential (kVp), incident air kerma (IAK) and incident air-kerma rate (IAKR) per second or per pulse, exposure time for radiographic, fluoroscopic and mammographic systems in addition to measurement of HVL (not applicable for mammography) and recording waveforms. Both sets of instruments were also equipped with software to record the measurements and extract them in worksheets. Cu sheets were used for simulating the X-ray beam attenuation from thin (1 mm Cu), medium (2 mm) and large (3 mm Cu) patients in both radiography and fluoroscopy, while the Leeds TOR CDR phantom which was added last in the equipment, could be used for image quality assessment in both radiography and fluoroscopy.

At the beginning of this period, new QC protocols, shown in **Table 4**, were applied for general radiography, mobile radiography and dental intraoral equipment. Regarding the general X-ray systems, it can be seen in **Table 4** that the basic addition was the automatic exposure control (AEC) QC tests. While image quality was still not monitored (it was added in the 3rd period), the functionality of the AEC in terms of incident air kerma to the image receptor was the first step for connecting QC tests with clinical practice, as far as the dose to the patient is concerned.

It must be stressed, that with screen/film image receptors, high or low patient doses would manifest as over- or under-exposed films respectively, something that was no longer valid with digital image receptors, either flat panels or CR cassettes. In digital systems due to the wider dynamic range and auto-adjusting of window width and level, the IAK to the image receptor does not affect the image "blackening" but only the noise.

Table 1 Equipment available for QC measurements over the years

1st period: 2005-2009	2nd period: 2010-2014	3rd period: 2015-2019	4th period: 2020-2021
Victoreen X-Ray Test Device, Model 4000M+, Fluke	RTI Barracuda multi-function meter	Fluke RaySafe X2 X-ray Measurement System: CTDI, kVp, Dose & Time	Fluke RaySafe DXR+ Tool: X-ray/Light field alignment
Gammex 330 Digital: kVp, Dose & Time Meter	Fluke RaySafe Xi X-ray: kVp, Dose & Time measurement System	Nested CT Dose Phantom Kit for Pediatric/Adult Head and Body Model 76-424-4156: CTDI measurments	Gammex-Sun Nuclear Modular DBT™ Phantom: image quality evaluation in 2D mammography and tomosynthesis
Gammex Model 115A / 115H: Half Value Layer Attenuator Set	Cu sheets (3 × 1 mm) for simulating patient attenuation	18-220 ACR Mammography Accreditation Phantom: image quality evaluation in 2D mammography	Leeds CBCT-161 Phantom: image quality evaluation in Dental CBCT (including automatic evaluation software)
Gammex Model 161B / 162A: Collimator and Beam Alignment Test Tools	Leeds test objects, TOR CDR, contrast-detail phantom	Leeds test objects, TO CDRH: R/F & X-ray image quality evaluation	Leeds PIX 13 phantom: beam alignment and image quality R/F testing
X-Rite 331C: Portable Transmission Densitometer			Iba Primus A Phantom: beam alignment and image quality R/F testing
X-Rite 334 Battery Operated Dual Color Sensitometer			Leeds TOR DEN digital Phantom; dental intra oral and panoramic image quality evaluation
			Gammex Mercury 4.0 phantom; QC for CT AEC
			* Quart Nonius Digital Electronic Ruler; measuring radiation beam slice-width and field edges
			* Gafchromic films XR-M2 and CT2: measuring radiation beam slice-width
			* Software for automatic evaluation of CT ACR, Leeds and iba Primus A phantoms

* Denotes equipment that has been ordered but has not been yet made available due to delays in tenders.

Table 2 Number of medical image printers installed in HMC hospital over the years

Type	1st period: 2005-2009	2nd period: 2010-2014	3rd period: 2015-2019	4th period: 2020-2021
Wet processors	5	-	-	-
Laser Printers (dry)	-	10	22	10

Table 3 Number of Diagnostic Radiology Medical Physicists and Assistants over the years

Staff	1st period: 2005-2009	2nd period: 2010-2014	3rd period: 2015-2019	4th period: 2020-2021
Medical Physicist	2	5	7	10
Assistants	2	3	3	5

The higher the IAK the lower the noise and the better the image quality, something which means that the radiologist would never complain but rather prefer “over-exposed” images [1, 2, 9]. On the other hand, radiologist would complain in the case that the noise was too high, something that would force the radiation technologist to increase exposure factors to an extent that could not be predicted. This was the reason why the addition of AEC tests was considered mandatory.

The new QC procedure not only enabled an indirect way of routine and systematic monitoring of radiation dose to the patient but also helped in the implementation of follow-up actions when IAK values to the image receptor were too high (i.e. > 5μGy on the image receptor and/or >10 μGy on table) or too low (i.e. < 2μGy on the image receptor and/or < 4μGy on table). Since most of the AEC systems had not been adjusted or have been adjusted for use with screen/film systems, the AEC function of most of the general X-ray machines initially failed in one or more of the AEC QC tests. These problems were rectified soon by informing the respective clinical imaging departments and contacting the company responsible for the service. The next most often failures observed were those regarding the exposure time accuracy, which were also corrected without any delay by the servicing company.

At the beginning of this period QC was still limited in X-ray and dental units. However, gradually fluoroscopy systems were incorporated in the QA program. Fluoroscopy is a modality used for dynamic examinations and can be found in various configurations, like over-couch and under-couch systems with radiographic capability or in C-arm configuration, stationary or mobile, like angiographic systems used for complex interventional procedures. Fluoroscopy systems are mainly used by radiologists, but also by cardiologists specialized in interventional cardiology procedures and by many other medical practitioners, such as gastroenterologists, orthopedicians, urologists and neurosurgeons, performing a wide range of diagnostic or therapeutic fluoroscopy guided procedures. Due to the dynamic nature and the complexity of some of these procedures, fluoroscopy can result in relatively high radiation doses which may lead to the occurrence of deterministic effects, like temporary or permanent skin injuries [5, 6]. For this reason, initially the focus of the fluoroscopic QC protocol was on the operational characteristics related to patient exposure.

In analogy to IAK on image receptor in radiography, when the IAK rate (IAKR) in fluoroscopy drops below a certain point, the radiologist will notice that the fluoroscopic images will become excessively noisy and this will hinder diagnosis. To increase the IAKR, an increase in exposure factors is required, which inevitably will result to an increase in the patient dose. So, it is essential to adjust and maintain the IAKR at such a level, that diagnosis is feasible and a further increase in IAKR will provide little improvement in image quality which is disproportional and does not justify the increase in patient dose. The inclusion of image quality tests in the fluoroscopy QC protocol (and later in the radiography QC protocol) was made feasible around 2013, when the Leeds TOR CDR contrast/detail phantom was added in the QC equipment. By the end of this period the QC protocol for fluoroscopy systems and mobile C-arm units - briefly described in **Table 5-** had been formulated [30].

By the end of the 2nd period 157 (99 X-ray and dental, and 58 fluoroscopy units) out of 176 systems (90%) were included in the QA program. During this period, the focus was on setting acceptable performance limits based on the existing international QC protocols [15-17,30], while on the practical side, any failed QC test identified was communicated to the service engineers along with the suggested course of actions that was expected to resolve the problem. The success of every repair performed by the service personnel was documented by follow-up QC tests.

3rd period: 2015-2019

By the end of the previous period, a 90% of the radiology equipment installed in HMC hospitals was included in the QA program. However, this was not satisfactory since two crucial modalities had been still ignored: CT and mammography! Justifiably and undoubtably CT is considered the flagship of the diagnostic equipment involving ionizing radiation. Currently, CT examinations are responsible for more than half of the collective population dose due to medical exposures. Therefore, though image quality is always of primary concern, the patient dose in CT has come in focus during the last years. The QC protocol for CT scanners is described in **Table 6** and as can be seen the QC tests are focused on both image quality and patient doses, though only a limited number of clinical protocols are evaluated (adult & pediatric head, adult and pediatric abdomen & adult HR chest) [8,31,32].

Table 4 QC tests performed in general radiology (GN), mobile (GM) and dental intraoral (DI) units during the periods 2005-2009 and 2010-2014 [11,12,18-20].

Period	2005-2009			2010-2014		
PERFORMED QC TESTS \ Equipment type	**GN**	**GM**	**DI**	**GN**	**GM**	**DI**
1. Beam Geometry Evaluation						
1.1. Source-to-image distance indicator accuracy	×	×	×	✓	✓	×
1.2. X-ray & collimator light field alignment	✓	✓	×	✓	✓	×
1.3. Alignment of image and X-ray field center	×	×	×	✓	✓	×
1.4. X-ray beam perpendicularity	✓	✓	×	✓	✓	×
2. Generator and tube QC tests						
2.1. kVp accuracy	✓	✓	✓	✓	✓	✓
2.2. kVp reproducibility	✓	✓	✓	✓	✓	✓
2.3. kVp independence of mAs selection	×	×	×	✓	✓	×
2.4. Tube output (O/P) vs kVp	×	×	n/a	✓	✓	n/a
2.4. Tube O/P linearity	✓	✓	✓	✓	✓	✓
2.5. Tube O/P reproducibility	✓	✓	✓	✓	✓	✓
2.6. Tube O/P comparison large & small focus	×	n/a	n/a	✓	n/a	n/a
2.7. Exposure time accuracy	✓	n/a	✓	✓	n/a	✓
2.8. Exposure time reproducibility	✓	n/a	✓	✓	n/a	✓
2.9. Half Value Layer	✓	✓	✓	✓	✓	✓
3. Automatic exposure control (AEC) QC tests						
3.1. Relative response of AEC chambers	×	n/a	n/a	✓	n/a	n/a
3.2. AEC reproducibility	×	n/a	n/a	✓	n/a	n/a
3.3. AEC response (image receptor dose)	×	n/a	n/a	✓	n/a	n/a
3.4. AEC density control evaluation	×	n/a	n/a	✓	n/a	n/a
3.5. AEC kVp selection compensation*	×	n/a	n/a	✓	n/a	n/a
3.6. AEC thickness compensation*	×	n/a	n/a	✓	n/a	n/a

✓: Acceptance and routine QC tests, ×: QC tests not performed, n/a: not applicable

* In the 2020 revision these tests were merged to one, as the kV are adjusted according to the phantom thickness. Image quality QC tests (Low contrast sensitivity and spatial resolution) and display monitor QC tests were added for all modalities. KAP meter and exposure index accuracy test were also added for GN and GM units, as well as, the review of average KAP values in comparison to DRLs for GN.

Table 5 The fluoroscopy QC protocol established and applied during the 3rd period and differences with the latest protocol. The tests that refer to the radiographic capabilities of these systems have been omitted, as they are described in **Table 4** [21-29].

PERFORMED QC TESTS \ Period	**2015-2019**	**2020-2021**
1. Beam Geometry Evaluation		
1.1. Field size indicators versus actual exposed area	×	✓
1.2. Alignment of tube to image receptor	×	✓
2. Generator and tube QC tests		
2.1. kVp accuracy	✓	✓
2.2. Tube output (O/P) vs kVp	×	✓
2.3. Half Value Layer	✓	✓
3. Automatic exposure control (AEC) QC tests		
3.1. IAKR to image receptor	✓	☑
3.2. ESAKR* to standard patient** for all FOVs§	✓	✓
3.3. ESAKR to thin (1 mm Cu) and thick patients (3 mm Cu) for all FOVs§	×	✓
3.4. Maximum patient Entrance Surface Air-Kerma rate	✓	✓
4. Image quality		
4.1. Low Contrast Resolution	✓	✓
4.2. Limiting Spatial Resolution	✓	✓
5. Dosimetry		
5.1. KAP meter accuracy & Reference Air-Kerma accuracy	×	✓
5.2. Average Examination Doses	×	✓
6. Display monitor performance	×	✓

☑: QC tests performed in acceptance only, ✓: Acceptance and routine QC tests, ×: QC tests not performed, n/a: not applicable

* ESAKR is the entrance surface air kerma rate at the patient entrance surface and is equal to the IAKR multiplied by the backscatter factor (BSF) which increases with field size and beam HVL

** 2 mm Cu are used to simulate the average patient attenuation

§ In the latest QC protocol routine tests are limited to a maximum of the 4 largest FOV selections

On the other hand, mammography is a very specialized and crucial examination for the early detection of breast cancer, and it is the first radiology examination that is performed in asymptomatic women in the context of screening programs [5,6]. Due to the low energy spectrum required to achieve the image quality necessary for confident diagnosis of subtle differences in breast structure associated with breast cancer, radiation dose to the breast is an issue. This fact combined with the radiosensitivity of the breast have set very high standards for the equipment and techniques that should be used to obtain optimum conditions in breast imaging. In view of these requirements, the QC tests should be thorough and focused on both breast dose and image quality and assure that all components of the imaging chain are operating properly. The QC protocol for mammography systems is described in **Table 7** [31]. It must be noted that the diagnostic workstations used in mammography have usually two medical grade high resolution monitors (of 5 megapixels or more) and their QC testing is most demanding compared to all other modalities.

Table 6 The CT QC protocol established and applied during the 3rd period and differences with the latest protocol [32,33].

PERFORMED QC TESTS \ Period	**2015-2019**	**2020-2021**
1. Technical and geometrical assessment		
1.1. Scout prescription and alignment lights accuracy	✓	✓
1.2. Table Travel Accuracy	✓	✓
1.3. Radiation Beam Width	×	✓
2. Generator and tube QC tests		
2.1. kVp Accuracy	×	☑
2.2. Exposure Time Accuracy	×	☑
2.3. Reproducibility (kVp, Time, Radiation output)	×	☑
2.4. Radiation Output Linearity	×	☑
2.5. Beam Quality (HVL)	×	☑
3. Image quality		
3.1. Artifact Evaluation	✓	✓
3.2. Water CT# accuracy and image noise	✓	✓
3.3. CT# Uniformity	✓	✓
3.4. CT# Accuracy		✓
3.5. Spatial Resolution	✓	✓
3.6. Low-Contrast Performance	✓	✓
4. Dosimetry		
4.1. Displayed CTDI value accuracy	✓	✓
4.2. Average Examination Doses	×	✓
5. Display monitor performance	×	✓
5.1. Visual analysis (Acquisition and diagnostic workstation monitors)	×	✓
5.2. Luminance checks (Acquisition and diagnostic workstation monitors)	×	✓

✓: Acceptance and routine QC tests, ×: QC tests not performed ☑ QC tests performed in acceptance only

To apply these protocols, specialized equipment for CT and mammography QC tests (for image quality and dosimetry) was supplied, as can be seen in **Table 1**. Additional experienced personnel were hired (number of MPs have increase to 7) and training of the existing personnel on the new modalities was also performed.

Table 7 The mammography QC protocol established and applied during the 3rd period and differences with the latest protocol [31,34].

PERFORMED QC TESTS \ Period	2015-2019	2020-2021
1. Beam Geometry Evaluation		
1.1. X-ray beam and light field alignment	✓	✓
1.2. Alignment of X-ray field with image receptor	✓	✓
1.3. Alignment of compression paddle at chest wall edge with image receptor	✓	✓
1.4. Accuracy of displayed compression force value	✓	✓
2. Generator and tube QC tests		
2.1. kVp accuracy and reproducibility	✓	✓
2.2. Tube output (O/P) reproducibility*	✓	✓
2.3. Tube output (O/P) linearity	✓	☑
2.4. Half Value Layer*	✓	✓
3. AEC tests		
3.1. AEC repeatability	✓	☑
3.2. AEC "black level" compensation	✓	☑
3.3. AEC thickness compensation	✓	✓
3.4. SNR variation with thickness	×	✓
4. Image quality		
4.1 ACR DM phantom score (fibers, microcalcifications, masses, SNR etc)	✓	✓
4.2 Limiting Spatial Resolution	✓	✓
5. Dosimetry		
5.1. IAK measurement and AGD calculation for the ACR phantom	✓	×
5.2. Displayed AGD accuracy for ACR**	✓	✓
5.3. Average Examination Doses	×	✓
6. Display monitor performance	×	✓
6.1. Visual analysis (Acquisition and diagnostic workstation monitors)	×	✓
6.2. Luminance checks (Acquisition and diagnostic workstation monitors)	×	✓
7. Manufacturer proposed tests (e.g. Image receptor uniformity, MTF, etc.)	×	✓

☑: QC tests performed in acceptance only, ✓: Acceptance and routine QC tests, ×: QC tests not performed

* In the software accompanying that latest QC protocol, the normalized O/P variation (in μGy/mAs at a reference distance) and HVL versus kVp selection dependence is fitted by a second order polynomial for all anode/filter combinations used, so that the IAK and AGD for any exposure can be automatically calculated from exposure factors and phantom thickness.

** In the software accompanying that latest QC protocol, the displayed AGD accuracy is extended not only to the ACR phantom but all other thicknesses, and furthermore to tomosynthesis acquisitions.

Further increase was observed in the number of the X-ray equipment as described in **Figure 3** as 5 new hospitals were added during this period: the Communicable Disease Center (CDC) in 2016, the Ambulatory Care Center (ACC) in 2017, the Women's Wellness and Research Center (WWRC) in 2017, the Qatar Rehabilitation Institute (QRI) in 2017 and the Hazm Mebaireek General Hospital in 2018 (HMGH). By the end of this period QC tests were performed for 242 out of 251 machines, covering all modalities except panoramic, dental cone beam CT (CBCT, 3D-Dental) and DEXA units.

These changes in the number and the complexity of the equipment and the required QC tests, triggered a change in the routine QC test frequency, which was reduced from twice to once a year. Apart from QC phantoms, 3 new sets of multifunction meters (Fluke RaySafe X2 X-ray Measurement System) were added in the QC equipment. These new systems have all the favorable characteristics of the older model and additionally have more beam calibrations and automatic HVL calculations for mammography. Also, these sets have pencil type ionization chambers for CTDI measurements required for CT (currently the available sets in the MPS are 11 such sets).

It must be noted that in **Table 4, 5, 6 and 7** are not included QC tests regarding personnel safety assessment (shielding assessment which is carried out for all X-ray installations during acceptance and periodically ever after). These tests for the case of CT are more demanding in view of the high workload involved, something which is also valid for fluoroscopic installations. The presence of protective equipment for personnel and patients (like lead aprons and collars) is also recorded and periodically checked for wear and tear, while personnel dosimetry services are also offered by a subsection of the MPS.

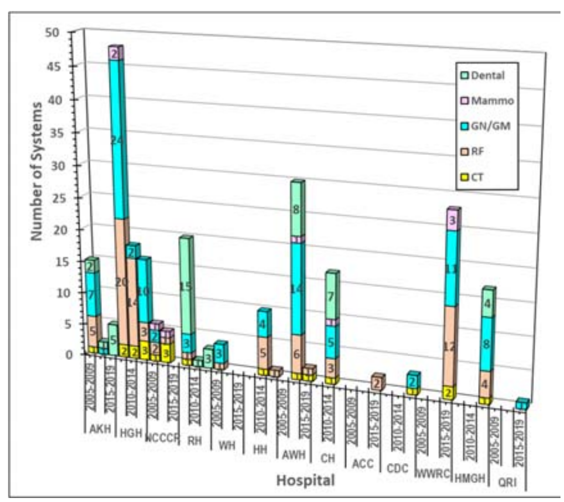

Figure 3 The types and numbers of new X-ray modalities distributed in the Clinical Imaging Departments of the 13 HMC hospitals during the period 2015-2019.

4th period: 2020 – 2021

By the end of the 3rd period QC protocols for all modality types have been established and applied for five years. Medical physicists have gained significant experience in QC procedures and in the use of all new electronic equipment and phantoms required for performing QC tests. Furthermore, the proper procedures for communicating the problems found in any of the X-ray modalities to the respective servicing companies, in order to resolve the problems and restore the operation of the X-ray modalities back to normal, had also being established. As a highlight of the end of this period came the accreditation of our QC services by the MEFOMP (Middle East Federation of Organizations of Medical Physics) in January 2020. In other words, MEFOMP certified that the MPS has implemented and maintained the Quality Control Service Provider (QCSP) requirements according to MEFOMP accreditation program for quality control service provider of X-ray medical equipment for the following X-ray units: CT, fluoroscopy units, general radiography and mobile X-Ray, mammography (2D and DBT), dental units (intra oral, panoramic, cephalometric and CBCT), bone densitometer (DEXA or DXA) and EOS-biplanar Bone Scan. This accreditation was granted after comprehensive audit by external auditors of the QCSP procedures that verified compliance with the MEFOMP requirements. The accreditation is valid until 26-01-2023 (https://www.mefomp.com/CERTIFICATE-OF-ACCREDITATION-001_a6988.html).

During the accreditation process that was finalized just at the beginning of the 4th period, a task group was created within the MPS to prepare the transition to a new era. The first step was to review all the latest international QC protocols from United States and Europe, to search for any changes and additions in the QC procedures, operational limits and QC equipment used. Using as a base the QC procedures already applied in the Department and incorporating all new information found in the reviewed literature, a book entitled "Quality Control Procedures for diagnostic X-ray equipment" was finalized and will be published soon by HMC (henceforth referred to as QC Procedures Handbook). The idea that came into play was that all QC tests should be homogenized, that is to be performed in exactly the same way by all MPS personnel, so as to mitigate any differences in the QC results that may arise from slight variations in the geometrical set-up or equipment used. The QC Procedures Handbook was reviewed by all experienced medical physicists of the MPS until it was finalized. These QC tests are described in **Tables 5-7** for fluoroscopy, mammography and CT modalities respectively. The QC tests for X-ray systems and mobile units are basically those described in **Table 4** for the period 2015-2019. Modified and added QC tests are described in the respective footnotes. The literature used for describing the QC procedures and setting the pass/fail limits are given in the *References* section [35].

Something new in this QC Procedures Handbook was the classification of QC tests in two different priority categories. Those that it is imperative to be performed in every routine QC test and those that can be postponed for a later time or even until the next QC. Given the fact that time is an issue in busy Clinical Imaging Departments and that sometimes the available time is not enough to complete all QC tests, it was accepted that QC tests of parameters that are known to be fairly constant or are of secondary importance were assigned to the second category.

To obtain complete homogenization, it was understood that it was not enough for the QC tests to be performed in the same way. It was also necessary that all measurements would be processed in the same way and the results would be reported in the same way, leaving as possible no space for errors in calculations or deviations in the QC report format. For this purpose, electronic QC forms (eQC-forms) were prepared using Microsoft Excel for all modalities that had some unique characteristics. First, only those cells that were designated for data input were unlocked. All the rest cells that were used to perform calculations or report the QC results were locked to prevent accidental modifications that could alter the calculations and results. Secondly, in these eQC-forms, limits were stored in a specific worksheet (to be able to change them in case that a limit is revised in the future) and along with the baseline values were appearing in the 1st page of the QC report. In this way, all performed QC tests, the pass/fail limits and the QC results (pass/fail) were shown in a single page. Distinct colored symbols were used to denote Pass/Fail and QC tests that were not performed were clearly shown, since all the cells assigned to report the QC results, the pass/fail limits and the pass/fail QC result were automatically blanked out. To accept a QC report as adequate, only QC tests of secondary priority are allowed to be blank. Each QC report before being uploaded to the portal and being officially available, it must be reviewed and approved by the assigned qualified clinical medical physicist.

Another interesting characteristic was that every data input in these forms were compared with the baseline QC results or/and the QC limits where applicable. Using conditional formatting, every time that a data input deviated by 5% or 10% (depending on the case) from the baseline, taking into account possible differences that could exist between these QC tests (e.g. a different mAs value or source-to-detector distance), the input value was turned into red color or was assigned with a pass, fail (depending on the case) to alert the medical physicist that special care should be taken to check if the measurement has been done in the proper way or a typing error was made. It must be noted that while these forms are designed in such a way that eventually all measurements from the multifunction meter can be automatically fed into the appropriate cells, there are always cells were values had to be manually typed or selected from a drop-down list of selections. Similarly, cells containing calculations may become red or be assigned with a pass, fail or in some cases a warning symbol when they deviate from limits, baseline values, previous measurement or desired values. Special techniques to avoid error signals or collapse of graphical representations in case that one or two values are omitted (e.g. if 5 instead of 6 measurements for reproducibility are performed) were used, though the completeness of QC tests is always pursued. Finally, it should be mentioned that these forms are made in a way so that the QC report page and all measurement and calculation pages to be printed easily and seamlessly in a PDF formatted file, for electronical archiving or/and hard copy printing.

Regarding QC equipment, during 2020 new QC equipment that has been ordered since 2019 was received (Leeds PIX 13, CBCT-161, Coarto Force Gauge, Gammex Modular DBT™ Phantom, RaySafe DXR+, iba Primus A Phantom, Leeds TOR DEN digital, Gammex Mercury 4.0 phantom) while tenders for the supply of software for image analysis of ACR CT phantom, and Leeds Phantoms Gafchromic XR-M2/CT2) are ongoing. Regarding the X-ray equipment, during 2020 two new hospitals were established: Mesaieed Hospital (MH) and Ras Laffan Hospital (RLH) with additional 17 X-ray systems (3 CT, 3 fluoroscopic systems & C-arm units and 11 fixed radiographic and mobile X-ray units). Also, the Trauma Department of HGH (Hamad General Hospital) got extended like a new hospital with a total of 15 X-ray systems, bringing the total number of X-ray units which are supervised by MPS to over 300. The increase in hospitals (including the number of X-ray units and Medical Physicists) with respect to the increase of population in the state of Qatar is summarized in **Figure 4**.

IV. Discussion

In the results section the evolution of the QC services of MPS has be presented for the last 17 years along with the revised QC procedures, described in the QC Procedures Handbook and the respective eQC-forms created. It is a fact that the rapid growth of HMC in terms of diagnostic X-ray equipment, has forced the MPS to grow accordingly, nevertheless with a relative time delay as the increase in personnel and QC equipment was slower and not synchronized with the needs in terms of QC services required. Despite difficulties, MPS has grown in terms of personnel and QC equipment but most importantly has evolved in terms of the quality of QC services offered.

The current QC protocols have adopted most of the 3rd period's QC protocols, but with certain revisions and additions, to give more gravity in three main fields: a) the homogenization in terms of QC test procedures, data processing and QC results reporting, b) the evaluation of the image quality of imaged phantoms and the image quality of display monitor used for acquisition or diagnosis of any type of X-ray images, c) the incorporation in QC test of review of patient dose data regarding examinations performed in each X-ray system under QC. This is possible since a Dose Monitoring System was installed in 2018 which collects patient dose related data from almost all radiology systems. In this way the QC includes the results of patient dose data and their comparison with relevant Diagnostic Reference Levels (DRL) set for specific examinations.

Regarding homogenization, the methods used to achieve this, were described in the previous sections and the outcome will be evident in the years to come. Using standardized QC report forms for all X-ray modalities of a certain type will allow the QC results to be easily mined, so that the long term performance monitor of all radiology systems would be easily presented in graphs in relation to time for the years to come.

Regarding image quality, it must be reminded that regardless deviations of any parameter from the limits set, what is the concern is the final product of the imaging chain which is the image itself. An X-ray system that is perfect in terms of all QC parameters related to generator, tube and AEC systems could still produce non-diagnostic images, if for example the image receptor is not properly calibrated or it has artifacts. Furthermore, for digital systems, the digital images will be distributed within the clinic or even to associated hospitals via web and the diagnosis will be made in display monitors whose characteristics and adjustments should be such that the information contained within the digital image is properly displayed to the eyes of the radiologist or any other physician reviewing and interpreting this image.

CT scanners were the first X-ray modalities which were digital right from the start, though in the beginning CT images were printed in films, using wet processors (laser cameras) and later dry printers, and diagnosis was made using viewing boxes. However, it is well known that gradually films were abolished and CT diagnosis for many years now is made using monitors. The same situation now applies for mammography, fluoroscopy and X-ray systems (even for the mobile ones) and dental imaging of all types (intraoral, panoramic and 3D CBCT images). The requirements regarding the technical characteristics of CT monitors are far inferior to those used in mammography, which is the most demanding imaging modality regarding the diagnostic workstations' monitors. Whatever the modality is, QC of monitors was incorporated in our QC procedures, since is a key-element that is often overlooked. Digital images like the SMPTE or TG18 family images can be used to evaluate the diagnostic monitors. Ideally, the same monitors used for diagnosis should be used to score the images of QC phantoms, however, when this is not possible, phantom IQ scoring can be performed in the acquisition workstation monitor as well, which should be always tested, since it is the monitor used for the first image quality assessment made by the radiation technologist in order to decide if the IQ is satisfactory or a repeat examination is required.

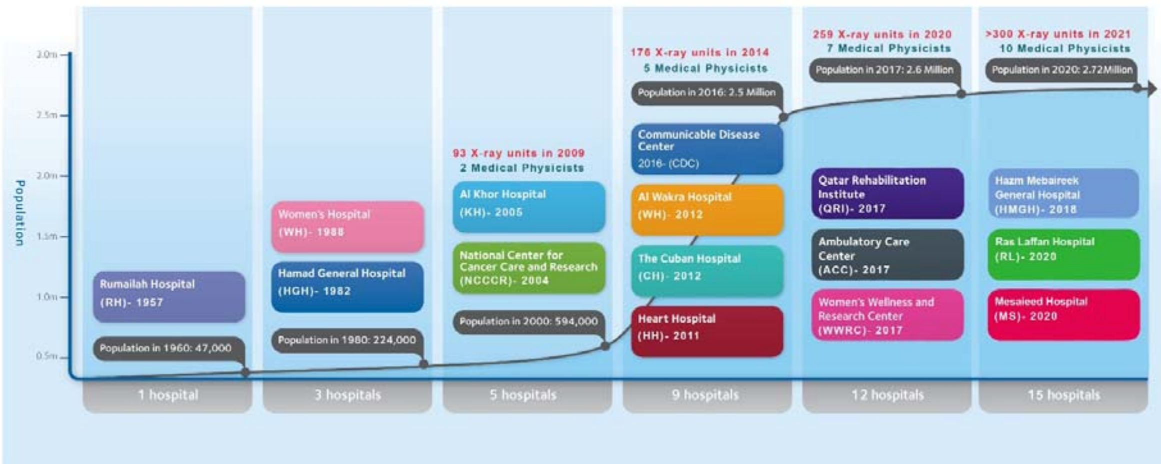

Figure 4 The timeline of the increase of number of hospitals under HMC (including the number of X-ray units and Medical Physicists) with the increase of population in Qatar from between 1957 and 2020.

Finally, the review of patient average doses is meaningful addition in the QC procedures, since in this way it is reviewed not only the X-ray modality performance but also the radiation technologist practices, regarding the radiation protection of patients. This is feasible given the fact that a dose monitoring system (RDM, Medsquare, France) is available and connected to most of the X-ray systems currently operating in our hospital.

What should be also mentioned as a closing argument, is that the extra focus given in image quality and patient dose related QC tests aims to make medical physicists more visible to all medical specialties involved in the use medical imaging. Medical physicists in radiology should assume their new role which is not only what is very graphically described as “the vampire physicist who only appears at night and only leaves reports …” [17, 36]. The results are quite encouraging since the last 2-3 years the MPS are always participating in meetings and projects that aim to improve the existing institutional policies and procedures for the safe and effective use of radiation, but also to research activities related to patient radiation safety and diagnostic image quality.

Therefore, it is important for all medical physicists which work in the field of diagnostic radiology worldwide, to comprehend that hard work and continuous effort is needed to achieve the goals that promote both the essence and the appearances of the qualified clinical medical physicist profession. Medical physicists should be knowledgeable and have the appropriate QC tools to be able to evaluate the performance of the X-ray systems, interpret the QC test results and identify the possible cause of a failed QC test. They should be able to keep up with the pace of the evolution of radiology equipment which generates the needs of new QC tests and this means that they should follow the international literature related to this field. Most important medical physicists should comprehend that being useful to radiologists, technologists, service engineers, is a major goal and helps the medical physicists to be visible and indispensable for the operation of a radiology facility, not only for reasons related to radiation safety of personnel. However, it should be always remembered that the ultimate goal of our profession is to be useful to the patients who should be able to have their medical images being acquired with the least possible radiation dose and the best possible image quality.

V. Conclusions

The MPS of HMC started its operation in 2000 and during the last 17 years has grown in terms of personnel and equipment number, but most importantly has evolved in terms of QC services offered for the HMC hospitals’ radiology equipment. Starting form 93 X-ray systems that could not be all supervised, now the section is at a point where over 300 X-ray systems are all supervised using state-of-the-art QC equipment and procedures.

Despite the recent accreditation from the MEFOMP organization which gave the MPS staff added confidence to carry out their duties with sheer perseverance, it is always good to remember that there is always room for improvement and that QC is an ongoing process that should be continuously evolve to keep up with the evolution of the X-ray equipment. For this reason, the international developments regarding QC procedures in new techniques (like for example breast tomosynthesis and dental CBCT) were implemented, and as experience is gained, the QC test procedures, performance limits and eQC-forms may be further enriched and revised. This article will hopefully serve as guidance for medical physics groups that want to update their QC services, obtain accreditation, keep up with the pace of the rapidly evolving technology of radiology equipment and make themselves visible to the rest medical professionals.

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IMPACT OF COVID-19 ON MEDICAL PHYSICS IN QATAR

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Abstract — **The history of Medical physics started in Qatar as Hamad Medical Corporation (HMC) grew from three hospitals in the early 1980's, to 15 hospitals in 2021. Qatar Medical Physics Society (QaMPS) started in 2009 as a small group of medical physicists in Hamad Medical Corporation (HMC). The mission of QaMPS is to advance medical physics practice in Qatar and to promote and support the medical physics profession. QaMPS is one of the founding members of the Middle East Federation of Organization of Medical Physics (MEFOMP). The number of Medical physicists grew from 9 in 2009 to 38 in 2021. The number of Medical Physicists per million is about 13. The average number of Linacs, CT and Nuclear Medicine units are 1.9, 22.2 and 4.4 units per million population, respectively. Medical Physicists in Qatar played a significant role during this unprecedented COVID-19 pandemic, both in sustaining its essential role to the healthcare system and in optimizing the preventive effort of humankind in the control of this pandemic.**

Keywords — **medical physicist, radiotherapy, nuclear medicine, diagnostic radiology, COVID-19, Qatar.**

I. INTRODUCTION

The history of Medical physics started in Qatar as Hamad Medical Corporation (HMC) grew from three hospitals in the early 1980's, to 15 hospitals in 2021. HMC has invested greatly on the radiotherapy, nuclear medicine and diagnostic radiology equipment. Most of these equipment use ionizing radiation, and involves certain risk for the patients and the medical personnel using these equipment. Therefore, the operation of these equipment should comply with certain requirements in the national radiation protection laws and regulations in Qatar (Qatar Radiation Protection Law, Decree Number 31 of 2002 and Minister of Municipality and Environment Decree Number 4 of 2003 on the Executive Regulations for Law No.31) [1 and 2]. In response to these requirements in diagnostic radiology and nuclear medicine, the radiation safety services of HMC grew from a small Radiation Protection Unit at the Radiology (the name changed to Clinical Imaging) Department in 2000, to a fully functioning Radiation Safety Section within the Occupational Health and Safety Department in 2010. This section was recently renamed to Medical Physics Section (MPS). Similarly, the Department of Radiation Oncology was established in 2004 at Al Amal Hospital. In 2009, the radiation oncology department underwent major upgrade of its facility including the commissioning of new equipment, the implementation of new techniques and modalities as well as recruiting new staff including a team of Radiotherapy Medical Physicists. After the major technology upgradation, Al Amal Hospital had been renamed as the National Center for Cancer Care & Research (NCCCR).

II. QATAR MEDICAL PHYSICS SOCIETY

Qatar Medical Physics Society (QaMPS) started in 2009 as a small group of medical physicists in Hamad Medical Corporation (HMC). The mission of QaMPS is to advance medical physics practice in Qatar and to promote and support the medical physics profession and to provide opportunities for education and professional development, while promoting excellence in the profession to achieve the highest standard of patient care [3]. The objectives of the QaMPS are to strengthen and promote Medical Physics in Qatar by:

1. Organizing national and international cooperation work in medical physics and allied subjects;
2. Contributing to the advancement of medical physics in all its aspects, in governmental and non-governmental healthcare organizations; and

Table 1 Total number of medical physicists in QaMPS from 2009 until 2021 and the approximate number in each specialty of Medical physics.

Year	Total Number of medical physicists	Medical Physicists in each Specialty			
		Radiotherapy	Nuclear Medicine	Diagnostic Radiology	Health Physics
2009	**9**	3	-	3	3
2010	**9**	3	-	3	3
2011	**12**	5	-	4	3
2012	**15**	5	-	4	4
2013	**14**	5	1	4	4
2014	**14**	5	1	4	4
2015	**17**	6	1	6	4
2016	**20**	7	1	7	5
2017	**25**	11	2	7	5
2018	**29**	11	3	8	7
2019	**34**	11	3	9	10
2020	**38**	12	4	13	11
2021	**38**	12	4	13	11

3. Representing the medical physics in Qatar at both regional and international levels.

QaMPS is one of the founding members of the Middle East Federation of Organization of Medical Physics (MEFOMP). Currently the president of QaMPS is also the president of MEFOMP until the next election in 2022. QaMPS is also a member of International organization of Medical Physics (IOMP).

The number of Medical physicists grew from 9 in 2009 to 38 in 2021. The medical physicists in QaMPS are not only in HMC but also in other public and private health and academic institutions. Figure 1 shows the increase in the number of medical physicists in QaMPS from its establishment until now in the different specialties of Medical physics. The number of Medical Physicists per million is about 13. This seems a relatively acceptable number, as the average number in the world is about 2.7; 15–20 per million population in the developed countries and 1–5 per million population in developing countries. On the other hand, in many underdeveloped countries this number is close to 0 [4]. Most of the Medical Physicists are expats and locals are only about 15%.

Table 2 shows the approximate number of medical equipment in radiation therapy, nuclear medicine and diagnostic radiology. The number of linac units per million population in Qatar is 1.9 unit per million population. According to the World Health organization (WHO), this number brings just below the first band of countries including Western Europe and North America where the number of Linacs per million population is between 3.3 and 72.8 [5].

It is evident from the Table 2 that the number of CT scanners per million population is about 22.2 CT units per million, which is just about the mean number of CT scanners per million population in the Organization for Economic Co-operation and Development (OECD) countries, which is 22.9 [6].

The approximate numbers of equipment used in the nuclear medicine procedures (including Gamma Cameras, Positron Emission Tomography (PET), Single Photon Emission Computed Tomography (SPECT), PET-CT, SPECT-CT and Positron Emission Mammography (PEM)) are shown in Table 2. It is clear that that the number of units per million population is 4.4, which is significantly higher than the average of 2.3 units per million population in the Middle East Region reported in 2015 [7].

Medical physics education in Qatar has been through completion of a BSc degree in Physics or Allied health science followed by a postgraduate degree from abroad. There are no national medical physics academic education program such as BSc or MSc.

Table 2 Approximate number of medical equipment in radiation therapy, nuclear medicine and diagnostic radiology.

Equipment	Total	Unit per million population
Radiation Oncology		
LINAC (one will be installed soon)	4	1.9
Cyberknife	1	
Brachytherapy	1	
Nuclear Medicine		
Gamma Camera	2	
SPECT	3	
SPECT/CT	3	
PET/CT scanner (one will be installed soon)	3	4.4
PEM (will be installed soon)	1	
Medical Cyclotron	1	
Diagnostic Radiology		
MRI systems	30	11.1
CT scanner	60	22.2
Mammography	25	9.3
Standard Radiology	250	92.6
Fluoroscopy and angiography systems	150	55.6
Bone Densitometry	10	2.7

QaMPS worked on the improvement the standards of medical physics specialty in the Qatar's academic and health institutions through regular meeting every three months and conducting training courses, workshops and conferences. QaMPS encouraged the Medical Physicist in Qatar to participate the international medical physics certification board (IMPCB) examinations and also the QaMPS sponsoring the examination fees to all the candidates from Qatar.

III. National Center for Cancer Care and Research

As part of the National Cancer Strategy launched by Her Highness Sheikha Moza Bint Nasser, refurbishment of Al Amal Hospital has been accomplished in 2011. This aims to provide international standard, high-quality cancer care to patient in Qatar. New equipment including advanced systems such as stereotactic radiosurgery with a dedicated magnetic resonance imaging unit for radiotherapy simulation (MR-SIM) were installed. In addition, the department was the first one in the world to commission the GEM RT Open Head & Neck suite (GE Healthcare) for the radiation therapy planning. After the major technology upgradation, Al Amal Hospital had been renamed as the National Center for Cancer Care & Research (NCCCR).

The patient care quality of the Radiation oncology department was demonstrated by the center of competence award from Quality Improvement Quality Assurance Team for Radiation Oncology (IAEA), which reviewed the quality of all the components of the radiotherapy practice at our center. Also, the department is actively participating every year in the remote beam output audits provided by the MD Anderson Radiation dosimetry services, which independently measure the accuracy of machine calibration.

The robotic couch along with the Exactrac system was introduced in 2013. This helped for the treatment of frameless Stereotactic Radiosurgery (SRS) for patients with intra-cranial lesions of both a primary and metastatic nature. Since then, our intra-cranial treatment was reformed, eliminating the need for the invasive frame-based technique, improving patient safety and satisfaction and increasing the treatment precision.

The department was the first in the region to implement a sophisticated interventional radio-oncological procedure, Magnetic Resonance Imaging Guided Adaptive Brachytherapy (MRI-GABT) in 2014. In addition to MR-GABT, the department of Radiation Oncology initiated a partnership with TomAblate® for the commissioning and early adoption of MR Guided High Intensity Focused Ultrasound (MRgHIFU). The Department was one of the pioneers to introduce the new technology that will substantially improve the quality of care in the treatment of non-invasive treatment/ablation of painful bone metastases. The MRgHIFU system was upgraded for the treatment of uterine fibroids in 2016. This process involved a multidisciplinary team working on clinical practice guidelines and protocols along with on-site specialized support.

The Cyberknife M6 system was introduced in 2016 at NCCCR. This system was the latest technological advancement for robotic radiosurgery and the first of its kind in the region. The clinical implementation process involved the establishment of a dedicated commissioning team following construction of the suite. In addition, a multidisciplinary team established to develop clinical guidelines and process protocols for cranial stereotactic treatments.

More than 60% of the radiotherapy workload is contributed by breast cancer and in an effort to improve the breast treatments, the surface guided radiotherapy (SGRT) was introduced in 2018. This system is currently used for the accurate patient positioning of not only for the breast, but also for other sites such as thorax, abdomen and pelvis. In addition, the deep inspiration breath hold treatments based on SGRT is successfully implemented for left sided breast cancer treatments.

Total Body Irradiation (TBI) treatment technique based on translational couch was implemented in 2018 and our TBI team actively collaborating with the bone marrow transplant unit at NCCCR for the successful bone marrow or peripheral blood stem cell transplantation procedures.

IV. Clinical and Research Activities

Clinical Physicist at Radiation oncology involves in various aspects of medical physics, which includes treatment planning, QA and maintenance of radiotherapy equipment, new protocol and policy development, commissioning and establishing new treatment techniques and radiation safety.

There is no professional certification organization for medical physicist in Qatar. Most of the clinical physicist at Radiation oncology are certified by the professional organizations such as American Board of Radiology (ABR), Australasian College of Physical Scientists & Engineers in Medicine (ACPSEM) etc. The medical physicist who are not certified are encouraged to participate in international medical physics certification board (IMPCB). Lately, the IMPCB is included as one of the acceptable professional certification for the Physicist job at HMC.

In addition to clinical activities, medical physicists are actively involved in research and education, which has been of particular interest in the department of radiation oncology since 2005. Indeed, with the aim of improving patient care, competitiveness and visibility at the national and international level, our department at the NCCCR has implement a research strategy in 2005 including the creation of long-term research projects and building a research team. As such, two medical imaging scientists under the medical physicist family has been recruited and research projects related to the use of imaging to guide radiation therapy has been defined.

Since then, the department of radiation oncology at the NCCCR is heavily engaged in research activities. As part of an innovative research project on the use of MRI as unique method for establishing external radiotherapy treatment plans, several studies have been developed and conducted. One of these studies concerns the characterization of the MR geometric distortion of MRI scanners commissioned for radiation therapy planning. Another study concerns the generation of synthetic CT for MRI-only external beam radiotherapy. Till now these studies has led to the publication of 4 journal papers in 2015, 2016, 2017 and 2018 and several abstracts at international conferences.

As a continuity of these studies, new studies have been developed such as the establishment of a comprehensive QA program for the MR-SIM including the development of a software for automatic QA and the construction of new phantoms using the 3D printing technology. Finally, within the era of Artificial Intelligence (AI), new projects on the use of these tools to automatically predict QA results, contouring, dosimetry are being initiated lately. In support to the research activities, our department has received several grants and continues to actively contribute to international peer reviewed journals across disciplines, of note in the field of MR led research and image guided brachytherapy.

Furthermore, Continuous Research, Education and Advances Meetings at the Department (CREAM) sessions was initiated in 2013 as the education/research meetings of our team. These sessions have evolved further and provided an interesting and valuable source of continuous medical education, specific to the field of Radiation Oncology. Several international speakers were invited to give their presentations. The CREAM sessions serve as a platform to further strengthen the exchange of information, knowledge, and scientific achievements between the different members of our multidisciplinary teams. The CREAM sessions take place monthly twice.

In addition to research activities, education has been a high priority in our department. As such, year 2015 saw the establishment and roll out of a Radiation Oncology structured curriculum and school program for medical oncology fellows with multi-disciplinary input from the radiation oncologist, medical physics and radiation therapist teams.

V. Impact of Covid-19 on Radiotherapy Medical Physics ntroduction

Medical Physicist group working at NCCCR in HMC, which is the only hospital in Qatar providing comprehensive cancer care and radiation therapy, takes part with the rest of the world in the fight against COVID-19 pandemic while continuously delivering treatment and care to its patients.

It has been anticipated that during the outbreak, NCCCR may be impacted by significant staff shortages that could potentially affect its ability to deliver routine cancer care to patients in the form of Radiation therapy. Accordingly, at the start of the escalation phase of the COVID-19 pandemic, mitigation measures have been implemented across HMC, NCCCR and the Radiation Oncology Department, to minimize risk of exposure to the novel coronavirus, protecting Staff and Patients.

As an immediate response to the pandemic, a dedicated ‘Task Group’ was created, with representatives from every Team in the Department (doctors, physicists, therapists and nurses), who will work closely together with the Infection Control team monitoring the crisis, identifying active issues and planning strategies as the pandemic evolves.

The Task Group developed a Clinical Response Plan, which contains general measures introduced at the beginning of the outbreak, to protect patients and staff. It moreover, seeks to stratify appropriate adjustment of the clinical service, dependent on the staffing level. As the pandemic evolves, this document will be reviewed regularly and adjusted accordingly.

In developing this plan, the following principles were observed:

- Protection of staff and patients from COVID-19 infection by applying risk mitigation strategies;
- Where possible, those treatments that provide a chance of long-term cancer control or cure will be prioritized;
- Treatments aimed at palliation alone or a minimal extension of life may have to be temporarily deferred or suspended during the peak of a COVID-19 outbreak;
- Patients who have commenced a course of radiation therapy should be prioritized and supported in completing their treatments.

This Clinical Response Plan also aims to describe recommended staffing adjustments. The teams - all medical and non-medical Staff were divided in two separate entities, i.e. two Teams: Team 1 and Team 2, working in 2 shifts daily. These shifts are fixed, i.e. either only in the morning or in the afternoon, without any swapping or contact between the two Teams, to minimize any potential spread of the infection between them, patients, as well as with other Team members across our Department. The department continued providing internal educational presentations under the department’s Qatar Council for Healthcare Practitioners (QCHP) accredited educational activities. These are conducted virtually through Microsoft Teams.

Lastly, at the research end, we submitted a research proposal to the Institutional Review Board for the use of Low dose radiation therapy (LDRT) in the treatment of critically ill COVID-19 patients and is under review. At this point in time, the department is still adhering to this guidelines and will continue to do so until there is a guarantee that COVID-19 infection is no longer a threat to patients and staffs.

VI. Impact of Covid-19 on Diagnostic Radiology and Nuclear Medicine Medical Physics

Thirteen hospital were under Hamad Medical Corporation (HMC) umbrella, and as the COVID-19 crises started two additional hospitals were added to coup with the high number of COVID-19 patients. At the beginning of the COVID-19 pandemic, Qatar government decided to reduce the number of staff working from office to 20% and the rest had to work from home using online remote access. Most of the work was performed from home, and only urgent activities that required physical presence were performed in the hospitals.

The medical physics team played a critical role since the beginning of the pandemic in ensuring that HMC staff are working in a safe environment while following protocols to prevent the spread of the virus to patients and their fellow staff across HMC. The following briefly describes the activities related to all aspects of Medical Physics, Health Physics and Radiation Safety services offered in all Radiology and Nuclear Medicine Departments at HMC during the COVID-19 pandemic. These activities cover quality control (QC) measurements in new (acceptance testing) and existing (routing QC) radiological equipment, workplace monitoring, personal dosimetry (TLD), radioactive waste management, shielding surveys of x-ray facilities and QC testing of lead aprons.

Personal Dosimetry

For personal dosimetry, personnel monitoring is carried out using thermoluminescence dosimeter (TLD) badges to cover about 1400 radiation workers in HMC hospitals. Though the normal monitoring period is two months, due to the pandemic, it was decided to extend the use of the same TLD badges for four months (March-June) to avoid any possible spread of viruses between staff from a potentially contaminated TLD badge. In July of 2020, all the TLD badges were replaced to start the new monitoring cycle. Replacement and reading of TLD badges were made with extreme caution to ensure that any potentially contaminated badges would not be a medium of virus spread.

Medical Physicists took all necessary precautions (using masks, gloves and alcohol sanitizers) in the collection of the old and delivery the new TLD badges to avoid potential contamination at both ends (TLD end users from the new TLD badges, and the monitoring service staff from the used TLD badges). Care to avoid contamination was taken during opening of the TLD badges and reading of the TLD cards. All used holders were stored for at least one week before reusing them and the workers were supplied with new holders.

Diagnostic radiology

Medical Physicists performed all essential QC tests for all x-ray units (CT scanners, fluoroscopy, mammography, general, mobile and dental X-ray units). Apart from routine QC testing in units that was past due and could not be postponed, acceptance QC tests had to be performed in all new radiological equipment delivered in HMC hospitals during the pandemic, some of which have been ordered due to pandemic and therefore had to be set in service as soon as possible. For the new equipment, several Medical Physicists had to come to the hospitals to carry out specified task and submit QC report. During the COVID-19 period, Medical Physicists had to perform acceptance QC tests for 3 CT scanners, 7 mobile X-ray, 1 dental CBCT, 2 General X-ray, 2 C-arm, 1 mini C-arm and 3 fluoroscopic units which were all used to equip COVID-19 designated HMC hospitals.

Moreover, working from home provided an ample time and opportunity for the Medical Physicist team assigned to prepare the new QC User Manual and related electronic QC forms, to progress and finalize their task. The QC User Manual is a document that describes in brief the basic methodology for performing all routine QC test performed in all radiological equipment using ionizing radiation, the quantities measured, the required equipment and the remedial levels. The new electronic QC forms (eQC forms) were re-designed from scratch (using Microsoft Excel) to be in line with the QC User Manual and it is expected to completely replace the old forms by the end of 2020.

Routine safety assessment and workplace monitoring of existing radiation facilities were postponed, except for those new facilities such as those that were opened to accommodate COVID-19 patients. Two members of staff were assigned for QC testing of lead aprons (total of 2000 lead aprons in HMC). The task was carried out in isolated X-ray room with extra care to protect the staff collecting and testing the lead aprons.

Nuclear Medicine

During the COVID-19 pandemic, the medical physicists maintained all its normal services for the Nuclear Medicine departments, including the Nuclear Medicine equipment operating in Hamad General Hospital (HGH), as well as the PET/CT in NCCCR. Medical Physics services include a full range of QC tests performed to provide full evaluation of equipment performance, in order to ensure its optimal operation. The service covers PET/CT, SPECT/CT, SPECT, gamma cameras, as well as, dose calibrators, multi-channel analyzers (MCAs), etc.

Moreover, the medical physicists assigned to nuclear medicine, drafted a new QC Manual (based on NEMA and IAEA guidelines) in order to set local Quality Control testing norms/references.

The radioactive waste management program in the Nuclear Medicine departments and the PET CT facility was continuously performed as planned with extra care to protect the staff collecting and storing the waste packages.

Training and licensing of radiation workers

In line with HMC actions to deal with the current COVID-19 situation, it was agreed with the Ministry of Municipality and Environment (the national regulator), to extend the validity of the Radiation Worker License (expired or due for renewal) automatically for 6 months, starting 1 April 2020, to enable HMC staff to continue practicing as usual without renewal.

In August of 2020, as the pandemic situation began to subside and stabilize, and the government started to ease gathering restrictions, the radiation protection training courses (which is a legal requirement for radiation workers in Qatar to renew their licenses) resumed in HMC. These courses were conducted following the current government guidelines on educational gatherings (organized entry by checking temperature, provision of hand sanitizers and wearing of face masks in addition to physical distancing).

Research and Publications

Working from home also gave Medical Physicists an opportunity to perform several activities related to research and publications. Given the fact that many of the normal activities were postponed or canceled, medical physicists had an ample time to revisit previous QC reports, which gave them chance to gather all data in an excel file for comprehensive analysis and for future use. Furthermore, previously started projects prior to the pandemic were finalized, amidst pandemic. The Medical Physicists published eight papers in peer-reviewed international journals [8-15] and participated in five virtual meetings and conferences. In addition, a book was written titled "Quality Control Procedures for diagnostic X-ray equipment" that will be published soon by HMC [16] and also our Medical Physicist contributed a chapter in recently published book on "Medical Physics during the COVID-19 Pandemic: Global Perspectives in clinical practice, education, and research" [17].

VII. Conclusion

Qatar Medical Physics Society (QaMPS) started in 2009 as a small group of medical physicists in HMC, with the mission to advance medical physics practice in Qatar and to promote and support the medical physics profession. QaMPS is one of the founding members of the Middle East Federation of Organization of Medical Physics (MEFOMP). The number of Medical physicists grew from 9 in 2009 to 38 in 2021. The number of Medical Physicists per million is about 13. The average number of Linacs, CT and Nuclear Medicine units are 1.9, 22.2 and 4.4 units per million population, respectively.

Medical Physicists in Qatar played a significant role during this unprecedented COVID-19 pandemic, both in sustaining its essential role to the healthcare system and in optimizing the preventive effort of humankind in the control of this pandemic.

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MEDICAL PHYSICS PROFESSION IN THE KINGDOM OF SAUDI ARABIA

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Abstract— **The field of medical physics in Saudi Arabia has witnessed a significant improvement in the last few decades. There is a good number of medical physicists who have been sent abroad to complete their post-graduate degree/residency in medical physics. The estimated number of medical physicists in Saudi Arabia has surpassed 700 with a slightly growing number of board-certified medical physicists. Universities are continuing to improve and advance their programs through strengthening their connection with medical institutes to provide clinical training for graduates. These graduates are currently being utilized by the growing number of governmental/private hospitals. The national radiation regulatory bodies have gone through various phases of development and improvement. Policies and regulations are being continuously updated and enforced. The IAEA support has its continuous positive impact on the field of medical physics in the Kingdom. There is always room for growth and advancement which the local medical physics community is working on through offering and organizing relevant educational and training programs and events.**

Keywords— **Medical Physics, Medical Physicist, Education, Radiation Oncology Physics, Diagnostic Radiology Physics, Nuclear Medicine Physics**

I. INTRODUCTION:

Several sectors provide health services in the Kingdom of Saudi Arabia. Ministry of Health (MOH), being the main health service provider, provides 60% of the services while the private sector provides 23%[(1)]. Several other governmental sectors like the Army Forces Medical Services, Ministry of National Guard hospitals, Security Forces Medical Services, University hospitals, King Faisal Specialist Hospital and Research Centre (KFSH&RC) hospitals as well as many others participate in providing primary and specialized medical services [(2)].

With the continuous expansion of these hospitals and the noticeable increase in the utilization of machines producing or using radiation, the need for medical physics services was deemed necessary. In the second half of the 1970s, two medical physics departments were established in Riyadh. One at KFSH&RC and the other at the Prince Sultan Military Medical City (PSMMC), previously known as Riyadh Military Hospital (RMH). Both departments consisted of main medical physics branches such as radiation oncology physics, imaging physics, nuclear medicine physics and health physics. Since then, awareness of the necessity for having this specialty increased and medical physics departments were established in other hospitals.

In year 2006, a founding committee established the Saudi Medical Physics Society (SMPS) under the umbrella of the Saudi Commission for Health Specialties (SCFHS). In year 2009, the first board of directors (BOD) of the SMPS was elected. Since then, every four years an election is conducted to elect a new BOD. The number of society members increased over the years and reached around 720 members in the year 2020. The society is active in conducting training and educational activitiesin the form of conferences, courses and workshops.

Medical physicists are mainly employed in hospitals providing a wide range of services in all fields of medical physics including radiation oncology, radiology, nuclear medicine as well as health physics and radiation protection. In addition, they play a major role in teaching and training junior medical physicists, along with others from related specialties. They are also involved in research projects and participating in advancing protocols and related clinical procedures. Medical Physicists also involved as teaching staff at local universities teaching this profession to graduate and post-graduate students in the medical physics program along with other related programs.

The Saudi authorities founded the Radiation Protection Unit as part of King Abdulaziz City for Science and Technology (KACST) to work hand in hand with the Ministry of Interior (MOI) to regulate and supervise the use of radiation and its applications. This unit was expanded with time to eventually become the “Nuclear and Radiological Regulatory Commission (NRRC)” which is responsible for the radiation safety regulations in the Kingdom. Recently, they published the “Basic Safety Standards in KSA” (NRRC-RR-01)[(3)]. The “Saudi Food and Drug Authority” (SFDA) established Radiation Protection and Safety Section in the year 2010. Both commissions regulate the use and the handling of all ionizing and non-ionizing radiation practices and employ several medical and health physicists.

II. EDUCATIONAL PROGRAMS

Pioneers of medical physics in the Kingdom started their studies at western universities in the 1970s. Several students obtained their M.Sc. and Ph.D. degrees in Europe and North America through support from the government. They were the core team that introduced medical physics in hospitals and universities.

The first undergraduate medical physics degree program started in 1982 at Umm Al Qura University, with an average of 14 - 15 graduates per year. In year 2007, King Abdulaziz University started a medical physics program under the Nuclear Engineering Department with an average of 3 – 5 graduates per year. At the same university, the Science College started a medical physics program in year 2013 with an average of 40 graduates per year.

As for master of science degree in medical physics, King Fahd University of Petroleum and Minerals (KFUPM) started their program in 2002 with an average of 2 – 3 graduates annually. In 1998, Umm Al Qura University also started a master of science program in medical physics with an average of one graduate per year. They redesigned their program recently with an annual intake of around 20 students. Several universities are considering opening new M.Sc. programs in medical physics in the near future. Currently, two universities (King Abdulaziz University & King Saud University) are offering Ph.D. degrees in medical physics as part of other related programs. All these degrees include coursework accredited by the "National Center for Academic Accreditation and Evaluation" (NCAAE). Postgraduate degrees contain a research project as part of their degree requirements.

III. Clinical training

The first formal clinical training program in medical physics started at the RMH in the first half of the 1980s. This program was arranged with the Institute of Physics and Engineering in Medicine (IPEM), England. Several trainees graduated from this program. Unfortunately, at the beginning of the 1990s, this program stopped. In year 2013, the Biomedical Physics Department at KFSH&RC started a residency training program in radiation oncology physics in collaboration with the International Atomic Energy Agency (IAEA). Several trainees graduated from this program. In the same department, a Nuclear Medicine Physics Residency training program started in 2017 with three graduates so far. SMPS and KFSH&RC are working on designing a national residency training program in medical physics under the umbrella of the SCFHS. This program will include all three subdivisions of medical physics, *i.e.,* Radiation Oncology Physics, Diagnostic Radiology Physics and Nuclear Medicine Physics.

Several hospitals require board certification for senior medical physics positions. This encouraged many local medical physicists to obtain their board certification from the American Board of Radiology (ABR) or the International Medical Physics Certification Board (IMPCB). The board-certified medical physicists with the pioneer medical physicists who have long and extensive experience will be the main instructors in the planned national residency programs.

One must mention that since the 1980s, most of the major hospitals and universities have been participating in training and educating local medical physicists through training courses, workshops and conferences. These activities utilize local expertise and/or international experts in the field. A good example of these efforts is the International Conference on Medical Physics (ICRM). This conference has two versions, a major biennial conference which is held on even years and a Courses and Workshops Symposium which is held on odd years. These two series of events are usually conducted in collaboration with the IAEA and the World Health Organization (WHO) along with leading national and international organizations, The conference attracts more than 60 top notched international and 70 local speakers with more than 2,000 attendees. This event runs for 4 – 7 days and includes hundreds of lectures and more than 50 workshops in medical physics and related fields. In years 2019 and 2020, ICRM successfully collaborated with IMPCB to conduct board exams as part of the conference.

IV. Infrastructure

The Kingdom of Saudi Arabia occupies most of the Arabian Peninsula with a total area of approximately 2,150,000 km^2 and a population of 34,218,169 inhabitants in the year 2019(4). The medical services in the Kingdom grew rapidly in the last several years. There are more than 504 hospitals with 20.4(5) beds per 10,000 inhabitants.

There are around 15 radiation therapy centers distributed mainly among the three major cities i.e. Riyadh, Jeddah and Dammam. The other cities of Tabuk, Taif and Dhahran have one center each with two linear accelerators. The existing systems in these centers include different kinds of radiotherapy machines (conventional linear accelerators, helical tomotherapy, dedicated stereotactic radiosurgery and IORT systems) with an estimated total number of 38 linear accelerators(6). The total number of brachytherapy machines in major hospitals is estimated to be ten systems. It is worth mentioning that the first proton therapy facility in the Middle East is installed at King Fahad Medical City in Riyadh and will start treatments of patients shortly.

Most of the medium size and major hospitals have various diagnostic modalities, like CT scanners, MRI machines, fluoroscopy machines (C-Arm and Cath Lab,) ultrasound machines, general and mobile X-Ray machines and mammography systems. Main hospitals usually acquire the most advanced technologies available in the market.

In nuclear medicine, the Kingdom is expanding these services by opening new centers and acquiring the most recent and advanced equipment in the market. There are around 60 nuclear medicine centers in the Kingdom covered by 41 medical physicists(7). Nuclear Medicine systems in the Kingdom include 55 SPECT/CT systems, 35 SPECT machines, 30 PET/CT systems and 77 DEXA machines[7], in addition to dose calibrators and thyroid uptake systems. The number of cyclotrons in the Kingdom has expanded in the last three years to reach 11 cyclotrons distributed in the three major cities.

The Kingdom also has three secondary standard dosimetry laboratories (SSDL) in Riyadh and Dhahran. Two of these laboratories mainly provide radiation protection calibration services. KFSH&RC's SSDL has a full range of calibration capabilities including; radiation protection, diagnostic radiology and radiation therapy calibrations. These calibration laboratories are traceable to the International Bureau of Weights and Measures (BIPM) through the IAEA.

All these systems and modalities are supported by well-trained medical physicists. Major hospitals usually cover their needs for medical physicists from the local market or contract international experts. MOH has a policy forcing hospitals with 200 beds or more to have a medical physicist. In addition, NRRC and SFDA require each center using radiation-based clinical services to have a radiation safety officer (RSO). They also require centers to perform certain quality control procedures on all radiological machines by a local medical physicist or through a contracted company.

V. Conclusions

Medical physics in Saudi Arabia has noticeably evolved in the last few decades. Facilities expansion, national regulations as well as board certification and program accreditation are expected to contribute to the advancement of the medical physics profession in the Kingdom.

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MEDICAL PHYSICS DEVELOPMENT IN SYRIA

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***Abstract*— Medical physics began in the seventies of the last century at the Nuclear Medicine Center in Damascus, which is dedicated as radiation oncology center, At the beginning of the twenty-first century, the teaching of a diploma in radiation protection began, which was the fruit of scientific cooperation between the Atomic Energy Commission of Syrian (AECS), the University of Damascus and the International Atomic Energy Agency (IAEA). In 2013/2014, a two years master's degree in qualification and specialization in medical physics was created in order to fill the gap in this important field for the development of work in the medical field; where 14 students enrolled yearly. Its curriculum based on the recommendations mentioned in the IAEA publications on medical physics. The medical physics role within national healthcare facilities and hospitals has become more effective and the cooperation with the regional and international organizations will accelerate the development of clinical training and establishing the professional accreditation services. The development of competences usually acquired through IAEA fellowships under TC projects.**

***Keywords*—** Medical Physics, Education, Training, Accreditation

I. Introduction

Syria has a population of 19.8 million, with a total area of 185,180 km^2 [1]. Syrian has an average life expectancy at birth of 72.7 years [2]. According to the Ministry of Health statistics, 2053 health units are available around the country where 30875 medical doctors provide different health services to the public [3]. The medial use of radiation in the country is an important source for diagnostic and therapy, which contribute to improve the patient treatment plans. In 2019, the number of radiological images was 2998133 for 2424359 patients [3].

The medical physicist works in health care and apply his knowledge in the field of physics to the better use of medical radiation devices, and technologies. The medical physicists have an important role in the safe and effectiveness use of radiation in medicine for diagnosis and treatment of diseases. Cancer rates are rising worldwide, therefore, proper number of well-qualified medical physicists requiring is required. Moreover, in recent years, the increasing complexity of equipment producing radiation and used both for diagnosis and treatment, coupled with the raising of the expectations of good health care, as well as the implementation of more stringent radiation safety standards and accreditation requirements have exacerbated the already critical shortage of fully competent medical physicists.

Close cooperation between the AECS and University of Damascus is exist to provide education and training related to Nuclear Science and Technology including radiation protection and medical physics. Postgraduate education Diploma and MSc in the field of radiation protection and medical physics were established since 2000. In addition, AECS established the Nuclear Science and Technology Training Centre (NSTTC) in February 2010. The strategy of the NSTTC is to meet training plans and needs of the AECS, the national government and private sectors, in addition to the Arab and international organizations. It aims to establish a dynamic structure capable of considering and assessing the national training needs in medical and industrial fields and setting plans to build training programmes to meet these needs.

Medical physicists in Syria are mostly employed in radiotherapy hospitals and provide a wide range of services to radiation oncology, diagnostic radiology, nuclear medicine and a variety of other areas. However, challenges remain with professional recognition and accreditation. The present paper discusses these challenges and their relation to education and accreditation.

II. Infrastructure

The radiation therapy was established in Syria at the Nuclear Medicine Centre (the oldest radiotherapy center in Syria) in 1970s. Co-60 teletherapy and deep x-ray machines were used to treat cancer patients. Recently, more than 4000 patients are diagnosed with cancer in Syria, and are treated with external radiation beams (high-energy photons or electrons beams) and some of them are treated using radioactive sources placed inside the patient (brachytherapy, nuclear medicine).

The radiation doses delivered to patients are monitored with accurate radiation dosimeters in order to safe patients from radiation injuries. These dosimeters are calibrated at the National Radiation Metrology Laboratory (NRML), which is a member of IAEA/WHO's SSDL network . In addition, a dedicated Quality Audit program (QA) of the radiation doses delivered to patients in the radiotherapy centers around the country is established.

In nuclear medicine, the unsealed radiation sources are used in Syrian hospitals for diagnostic and treatment of patients. Approximately, 10,000 patients receive radionuclides for diagnostic purposes per year. Radiation protection local rules are established in order to obtain the safe and successful use of radionuclides for medical diagnosis, which depends mainly on the accurate measurement of the activity administered to the patient.

In diagnostic x-ray modalities, the patient radiation dose is minimized according to ALARA principle by applying IAEA recommendations. AECS in cooperation with the Ministry of Health established a Quality control (QC) program 20 years ago, in order to monitor the quality of the diagnostic equipment and measure the radiation doses received by patients during radiology procedures in order to achieve the acceptable image quality levels. The number of radiological equipment in the country is given in Table 1 while the statistical values related to different imaging modalities in 2019 are shown in Table 2.

Table 1 Number of radiological facilities/equipment in Syria (as set of Dec. 2020)

Facilities/Equipment	Number
Radiotherapy:	
Co-60 Units	5
EBRT (including LINAC, IMRT, IGRT)	4
Brachytherapy System	1
Nuclear Medicine:	
Gamma Camera (including SPECT System)	7
PET/CT Scanner	4
Medical Cyclotron	1
Diagnostic Radiology	
CT Scanner	340
Fluoroscopy and angiography system	908
Mammography	206
General X-ray system	1119
Dental X-ray Equipment	3870

Abbreviations:
EBRT: External beam radiotherapy.
LINAC: Linear accelerator
IMRT: Intensity-guided radiotherapy.
IGRT: Image- guided radiotherapy.
SPECT: Single photon emission computed tomography.

Table 2 The number of patients and produced diagnostic images for several imaging modalities in Syria (2019)

Imaging Modalities	Patients	Images
Conventional X-ray	1516658	1789403
Computed Tomography	196275	211178
MRI	30773	34263
Mammography	22659	43626
Dental Panorama	20556	24488

III. Graduate Training

The increasing number of new radiotherapy centers in Syria, and the growth in Linear Accelerators (LINAC) and digital imaging technology need to improve the quality assurance and quality audit services according to international standards, thus contributing to improving the quality of medical service and thus patient safety. In Syria, Decree No. 64 of 2005 and its executive regulations and instructions related to the ionizing radiation safety and security emphasized the need for a medical physicist to be present in hospitals where ionizing radiation is used in both diagnosis and treatment.

Moreover, the IAEA assigns high priority to education and training in nuclear and radiation safety, considering them key mechanisms in strengthening radiation protection around the world. AECS applied the standard syllabus of IAEA (in Arabic) [4] for the Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources (PGEC) since 2000. PGEC is a ‘long-duration’ course that provides the initial basic professional training (in medical and non-medical fields) for young professionals who are expected to become, over the course of time, regulators, decision makers, qualified experts in radiation protection or trainers in radiation protection and safety of radiation sources. More than 500 students were graduated from different Arab countries.

In addition, the M.Sc. of Medical Physics has established at Damascus University on 2013, in collaboration with Atomic Energy Commission of Syria, in order to graduate qualified medical physicist to work in hospitals. The master consists of two academic years, and the curriculum was developed based on the recommendations mentioned in the IAEA publications on medical physics to cover its theoretical and practical aspects [5-8]. This curriculum is taught in Arabic language by a group of specialized researchers in this field from Atomic Energy Commission and Damascus University. The first academic year consists of several fundamentals of: radiation physics and radiation detection; Electronics and medical image processing; Physiology and human biology; Diagnostic radiology physics; Nuclear medicine physics; in addition to the General principles of radiation protection. The second academic year is dedicated to the internal and external radiotherapy physics and practical sessions in hospitals and radiotherapy centers. The most of practical and clinical training is hold at AlBairouni University Hospital (the old name was Nuclear Medicine Center), which have the all medical physics facility which needs for clinical training in field of diagnostic radiology; nuclear medicine and radiotherapy. The average number of students enrolled in this master is about 14 students per year and from the both sex.

IV. Clinical Training

Training and continuous professional development are vital to ensure safe and effective use of radiation in medicine, and human health (specifically radiation medicine) is one of those areas of activity. For the last 30 years, The AECS has organized numerous courses and seminars in medical physics and radiation protection for physicists and radiographer, radiation oncologists and radiotherapy technologists who are working in hospital in order to strengthen and maintain a high level of medical physics on site.

The most of the medical physicists, who are working in hospital; were trained on-the-job after obtaining their postgraduate degrees. On the other hand, some of them were trained under the IAEA's Technical cooperation program, via TC project related to a Post-Graduate Educational Course in Medical Physics at MSc which has been established at the University of Jordan as well as with others IAEA's projects (Strengthening Medical Physics in Radiation Medicine). In addition, a clinical training program document for ARASIA Member States has been established under a TC project, and adopted by the ARASIA Member States. The elaborated document will be used as a training tool of medical physicists in the hospital setting. Also, during 2014-2016 a national IAEA TC project entitled "Strengthening Quality Control and Quality Assurance Services in the field of Diagnostic Radiology in Syria" had established in order to strength and train the medical physicists in field of Diagnostic Radiology. Another IAEA national TC project entitled "Strengthening Radiation Protection in Medical Exposure" was running from 2018-2020. The project plan includes several external fellowships and scientific visits for a number of medical physicists who trained abroad on diagnostic radiology, nuclear medicine and radiotherapy. These IAEA's TC programs have been very useful to enhance the capacity of medical physicists and to develop their practical skills and apply it in their field of work. Table 3 shows the distribution of medical physicist according to sub-disciplines in Syria as set of December 2020.

Table 3 Distribution of Medical physicist according to sub-disciplines in Syria (as set of Dec. 2020)

Facilities/Equipment	Number
Radiotherapy	18
Nuclear Medicine	4
Diagnostic Radiology	5
Other Sub-Discipline (researcher, QC team and Calibration)	10

V. Future Opportunities and Challenges

Medical Physics is a small profession however; the number of students in this discipline starts to increase in Syria to cover not only radiotherapy centers but also to reply to the real demands in diagnostic radiology and nuclear medicine. The medical physics role within national healthcare facilities and hospitals has become more effective and clear as an important branch of healthcare professionalism especially during the COVID-19 pandemic, where the medical physicists stands with the frontlines to preserve the quality of healthcare services.

The on-site clinical training and professional accreditation services are the most important challenges towards developing the medical physics in our hospitals as the number of the qualified medical physicists and experts are still limited. However, a close cooperation with regional and international medical physics organizations will accelerate the steps to overcome this problem and establish a national accreditation and training standard to correlate with the clinical practices change. In fact, Medical physicists from Syria participated in many regional events related to medical physics (such as the MEFOMP Workshop on Medical Physics in Diagnostic Radiology from 28 – 29 September 2019 in Muscat, Oman).

VI. Conclusions

Medical physics training and practice has seen steady progress over the past 10 years. A two years post graduated M.Sc. of medical physics has been started in 2013 where 14 students enroll yearly. The proposed curriculum based on the recommendations mentioned in the IAEA publications on medical physics. The development of competences usually acquired through IAEA fellowships under TC projects. The medical physics role within national healthcare facilities and hospitals has become more effective and the cooperation with the regional and international organizations will accelerate the development of clinical training providing and establishing the professional accreditation services.

Acknowledgment

We would like to acknowledge the contributions of the IAEA in sponsoring fellowships and scientific visits and training course through TC projects in order to improve the medical physics national programs and to develop our human resources. Special thanks go to MEFOMP for their continuous support.

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MEDICAL PHYSICS STATUS IN YEMEN

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Abstract — **The history of medical physics in Yemen first started in October 1996. At that time, the work of physicists in the medical field was unknown and questionable to be accepted. Due to the lack of knowledge on the importance of medical physicists, it was difficult to be employed by the Ministry of Health. The perseverance and the hard work by the pioneer medical physicists succeeded to convince to health authority about the importance of this profession and raise awareness among professionals in the medical field. There are still big challenges related to the lack of needed medical equipment and the difficulty in the education and clinical training of medical physicists.**

Keywords — **Medical Physicist, radiotherapy, nuclear medicine, Education and Training**

I. Introduction

Yemen, as many other low and middle income countries, is beginning to face a double health burden: while communicable diseases are highly prevalent, non-communicable diseases are increasing and the country needs to prepare many different aspects for its control. Cancer incidence and burden in Yemen is increasing and is expected to double by 2030. As the number of cancer cases continues to grow in Yemen, capacities to treat patients remain underdeveloped and limited. The country's only cancer therapy centre, located in Sana'a, relies on two radiotherapy machines [1], too few to cater for the population of over 30 million [2]. The financial resources in health planning dedicated only 5% for cancer of the annual health care budget, a disease known for its associated high costs of diagnosis and control.

Cancer has emerged as a major public health concern in Yemen. According to World Health Organization (WHO), International Agency for Research on Cancer Globocan 2020 estimates, the number of new cancer cases expected annually in Yemen is 16,476; with 7,159 new cases among men and 9,317 among women, and the number of death was (9,061) cases. [3]

During the supply of a 6MV Linear accelerator and a simulator in 1995, there were no specialized cadre in radiotherapy nor medical physicists to handle the machines and therefore they were stored in one of the warehouses at the Ministry of Health and they got badly damaged due to the long time storage.

This incident was the first step to realizing the importance and the demand for medical physicists in Yemen.

II. Infrastructure

The country has experienced several and different stages of development in terms of availability of machines and equipment related to radiotherapy, nuclear medicine and diagnostic radiology, for example, in public sector; two Cobalt 60 machines, and two brachytherapy. Due to the inability to import radioactive sources caused one of the Cobalt 60 machine and the two brachytherapy machines to become out of service.

In private sector two linear accelerators without MLC were installed, recently one of them got out of service due to the country's current situation.

The current situation of the country has also caused the nuclear medicine system to be out of services, and the inability to import radioactive sources and maintenance of equipment and machines.

Because of the urgent need for these devices and equipment, tremendous efforts are being made to develop the health sector and purchase needed equipment in the field of radiotherapy, diagnostic radiology and nuclear medicine.

Table shows medical equipment that are currently available in the country and are still functioning.

Table 1 Medical equipment for radiotherapy, diagnostic radiology and nuclear medicine

Equipment	Total
Co-60	1
Linear accelerator	1
Gamma camera	2
Dose calibrators	2
CT	70
Fluoro. C-Arm and Cath. lab.	>500
Mammography	50
Standard Radiology	>1000
Interventional	40
MRI	30

III. Regulation of Medical Physics

The legislative basis for radiation safety is provided through Decree No. 126, 1999 [4], which establishes the National Atomic Energy Commission (NATEC) as the sole Regulatory Authority, and NATEC Decisions No. 1 and 2, which adopt the IAEA Basic Safety Standard (BSS) as the national regulation for radiation safety in all practices including medical exposure. Within this regulatory framework in the country, it requires the presence of Medical Physicists in any radiotherapy center or any nuclear medicine center. Unfortunately for diagnostic centers due to the lack of specialized staff, there is some relaxation. Table 2. shows the available staff in this medical field.

Table 2 Distribution of medical physicists in Yemen

Medical Physicists	Male	Female	Total
Radiotherapy	3	--	03
Radiation Physicists	5	1	06
Diagnostic Radiology	2	--	02
Nuclear Medicine	5	--	05
Outside the country	3	5	8
Total	18	6	24

IV. Education and training

Medical physics education and training in Yemen is based on BSc degree in Physics and postgraduate degree abroad, followed by a two-year internship.

At the national level, there are no proper medical physics education and training program available in Yemen. Currently, in the country has one program at Ibb University for BSc. in Applied Physics (Medical).

Clinical Training program at the National Oncology Center (NOC), which is concerned to train graduates of Ibb University in the field of radiotherapy physics, in addition to training graduate from Sana'a University - health physics department in field of dosimetry, quality and radiation protection. There are also future plans to expand this clinical training program into academic and clinical training to meet the needs of diagnostic, radiotherapy and nuclear medicine centers of qualified and well-trained cadre.

V. Conclusion

The country difficult economic status and the low income of Medical Physicists has encouraged most of the employees to migrate and prefer to work abroad. The number of known employees outside the country is more than half of those in the country as indicated in Table 2.

It is worth mentioning that the absence of advantages and benefits besides the scarcity of workshops and short training courses deprived the existing staff in the Medical physics field has also been a factor encouraging migration. This makes it difficult to retain qualified personnel in the country.

Despite all these circumstances, the situation will hopefully be better and in the near future will hopefully embrace new cadres of medical physicists, and until then the symphony of medical physics will continue to play silently.

Acknowledgment

We would like to acknowledge the contributions of the IAEA in the support provided in the establishing of the Radiotherapy and the Nuclear Medicine centers.

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DEVELOPMENT OF MEDICAL PHYSICS IN RWANDA: ONGOING CONTRIBUTION FROM IAEA, GONO UNIVERSITY AND ICTP

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Abstract— **Medical physics in Rwanda has long been obscured mainly by the absence of radiotherapy and nuclear medicine facilities in the country, however, the recent establishment of the first country's radiotherapy centre triggered the urgent need for medical physicists in the country's healthcare system to support the national expanding radiological services. Currently, medical physics development in Rwanda is in its initial phase where the first cohort of students, trainees and pioneers of this profession are continuously undertaking medical physics education and training from various Universities in the world, through cooperation with different international institutions and organisations (currently: IAEA, Gono University and ICTP). The first batch comprises seven (7) Rwandan students. Of these, the first two (2) students have completed their academic program and currently doing clinical training in collaboration with IAEA; the next two (2) more students are doing their master's thesis work at Gono University/Bangladesh; while the remaining three students (3) are waiting to start their academic program early next year at ICTP-college on medical physics. Nevertheless, medical physics education and training in Rwanda and East Africa region is still relying heavily on the international scholarship and/or limited to few of those with substantial wealth to afford the international education cost. Furthermore, the lack of medical physics education programs in the whole region continues to constrain the interests of many East African young generations who are keen to join this profession. Therefore, the establishment of a medical physics education program at least in one of the East African countries (as proposed in Kigali/Rwanda) can be the ideal way to bridge the existing gap between current status and the required professional development.**

Keywords—**Medical Physics, Rwanda, IAEA, Gono University, ICTP.**

I. INTRODUCTION

Medical Physics is an applied branch of physics devoted to the application of concepts and methods of physics to the diagnosis and treatment of human disease. Medical physicists are in practice dedicated to the improvement of the quality and safety of patients in different fields such as radiation therapy, nuclear medicine, diagnostic radiology and radiation protection [1]. Medical physics further plays an essential role in radiation oncology and it has been identified as one of the key areas that need to be developed in order to improve healthcare services provision [2]. However, the shortage and/or full absence of qualified medical physicists in developing countries, and Rwanda in particular, imposes serious constraints on professional development and modern healthcare standards which requires a particular attention [3]. Medical physics profession and its recognition in the Rwandan healthcare system have long been obscured mainly by the absence of radiotherapy and nuclear medicine facilities in the country. Currently, Rwanda is among the African countries in which there are no available national qualified medical physicists but with continuously updating technology in modern medical imaging, radiotherapy and radiation protection in civil services.

Being the second-most populous continent, Africa is also the least developed continent in the framework of medical physics resources, equipment and qualified professional staff. The continent possesses 54 countries among which 32 states (about 59%) have available medical physicists with/without medical physics societies, while the remaining 22 countries including Rwanda (about 41%) do not have qualified medical physicists at the time of this publication [4]. Figure 1 indicates African countries with (white colour) and without (red colour) qualified medical physicists (*Islands and archipelagos are not indicated on this map*). The black half-cycle indicates the Rwanda country on the African map.

Figure 1: The African countries with available medical physicists (in white colour) and without medical physicists (in red colour), at time of this publication [5]. On the map, Rwanda is marked by the black half-cycle.

For the development of medical physics in Rwanda, education and training, residency programs as well as accreditation and certification procedures need to be realised. Therefore, this study reviews the educational efforts of the ongoing education and training of the first cohort of students and pioneers of medical physics in Rwanda from different educational institutions in the world. For instance, the collaboration with the International Atomic Energy Agency (IAEA) through the University of Ghana, the Gono University through its Medical Physics and Biomedical Engineering department and the Abdus Salam International Centre for Theoretical Physics (ICTP), College on medical physics through the 2-years Master of Advanced studies in Medical Physics (MMP) program. Furthermore, this study reviews the national wide imaging capacity together with the available radiotherapy equipment and explores the importance of medical physics professionals in the Rwandan healthcare system, as per WHOs' guidelines, one million people needs one linear accelerator (linac) with two (2) medical physicists per linac. The purpose of this study is to provide an overview on the medical physics development in Rwanda, highlighting the importance of medical physics professionals in the country's healthcare system with the goal to guide and enhance the medical physics recognition in the country. The study describes the ongoing contribution from the mentioned international institutions and organisations to train the first batch of Rwandan medical physicists and further propose the future prospective of the medical physics profession in the country.

Rwanda is a small sub-Saharan, landlocked country that lies to the south of the equator in the East-Central African region. It is a low-and middle-income country of 12.5 million population, with a current life expectancy of 67 years and gross national income per capita (GNI) of US$820 according to the World Bank [5, 6]. Known for its breath-taking scenery, Rwanda is often referred to as the land of a thousand hills (in French: "*le pays des mille collines*") because the country is characterised by undulating hilly and mountainous terrain, with rainforest on the western heights and heavy-cultivated fields in the valleys below. The country is geographically bounded to the north by Uganda, to the east by Tanzania, to the south by Burundi, and to the west by the Democratic Republic of the Congo (DRC) and Lake Kivu. The Rwandan population is largely agricultural workers, with more varied occupations within the capital city, Kigali. Rwanda is as well known for its traumatic history, including the 1994 Tutsi ethnic genocide, as for its courageous recovery to become a stable, well-run and reunited country. In just a few years, Rwanda has successfully managed to exit fragility with promising growth rates, emerging in 2020 as a "frontier economy," with access to global markets and private finance.

II. Rwandan healthcare system

Rwanda has made remarkable progress in rebuilding its healthcare system over the recent years by placing the health and wellbeing of the people at the forefront of the agenda. The country has one of the best organised healthcare systems in Africa, where all citizens (local communities) are able to obtain community-based healthcare insurance through a system called "*mutuelles de santé*" [7]. The healthcare insurance payment rate varies on a sliding scale according to family wealth, with the poorest family entitled to free healthcare insurance, while the wealthiest paying premiums of US$8 per adult. Every year more than 80% of the population is covered by this scheme. Moreover, there are separate national healthcare insurance schemes for private, public servants and soldiers. The patient's care is provided from the bottom of the pyramid structure by the Community Health Worker (CHWs). From the CHWs, the case can be scaled up to a *health post* (over 1000 health posts exist in the country). Then, the beneficiary will be sent to a *health centre* (about 600 health centres in the country), from health centres the patient can be referred to a district hospital (39 in the country). At the top of the pyramid, there are four (4) *provincial hospitals* and seven (7) *referral hospitals*. Patients can only use these hospitals if they are referred through this network [8].

III. Infrastructure

The genocide of 1994 left the country's healthcare infrastructures devastated. In the post-genocide period, Rwanda has had an uphill climb in the recovery of its healthcare infrastructures. The country has currently infrastructures for medical imaging situated in the private and public (government) centres, and one government radiation therapy facility. There are different medical imaging facilities in Rwanda with them having machines such as CT, MRI, X-ray, C-arm and ultrasound (Table 1). However, the country's imaging capacity is still under the needed level but it is continuously being upgraded to modern medical imaging infrastructures day by day.

The radiotherapy unit in Rwanda known as Rwanda Cancer Centre (RCC) is based at Rwanda Military Hospital (RMH) in Kigali city and started treating patients in early 2019. It is equipped with two Elekta linear accelerators (6 and 10 MV) and a dedicated CT scan. The facility is able to use the advanced treatment technique, Volumetric Modulated Arc Therapy (VMAT), which delivers the prescribed dose of radiation to the cancerous tissue while sparing the critical structure. Till now, above 800 patients have been treated, with more than 50% of treated patients treatment expenses have been covered by local community healthcare insurance "Mutuelle de Sante" while others have been privately funded. Currently, the centre is averaging 50 patients per day but with the full capability to treat up to 150 patients per day [9]. The centre is planning to add a high-dose-rate brachytherapy machine in the future in order to cover full cancer treatment for patients in need of brachytherapy. Furthermore, the Rwanda government is planning to continue building the required healthcare infrastructures, acquire the most advanced equipment for cancer treatment and build the first country's modern cancer hospital which will be dedicated to provide the full comprehensive cancer patients care and research. Going forward on cancer-fighting, among the suggested strategic priorities for Rwanda's cancer system in the next 5 years include upgrading the existing imaging capacity and establishing the nuclear medicine department equipped with PET/CT scan for diagnosis and treatment of diseases. This obviously imposes an urgent need for highly qualified professionals including medical physicists and the development of education, training programs and political policies for standard service delivery and effective use of these facilities.

The Rwandan radiotherapy centre complemented the already existing chemotherapy unit in operation, the Butaro Cancer of Excellence, that is based at Butaro district hospital located in rural area of the Rwandan northern province. This has been providing comprehensive cancer care since 2012, from initial pathology to curative treatment and palliative care, with the exception of radiotherapy [10-12].

Table1: Medical equipment for medical imaging and radiation therapy in Rwanda.

Equipment	Total
PET/CT	None
Co-60 Teletherapy Machine	None
Linear Accelerators	2
Brachytherapy	None
MRI scanner	2
CT Simulator	1
Diagnostic CT scanner	10
C-Arm Fluoroscopy	6
Mammography	5
Standard Radiology	>60
Interventional Radiology	None
Dental X-ray	-
Ultrasound	>80

IV. Cancer status in Rwanda

Cancer is among the global leading causes of death and disability worldwide, claiming over 70% of its victims in low-and middle-income countries, where prevention and treatment facilities still remain limited [13, 14]. This has become a burden to the forefront, especially in low-and middle-income countries, and the Rwandan government has been working hard to identify the possible solutions which tackled the vast financial and human resource requirements in fighting cancer and related diseases. There is no long-term precise data on cancer incidence and morbidity in Rwanda mainly because cancer-specific and population-based registry was recently resumed in 2018. Merely, the 2018s' estimates from the International Agency for Research on Cancer (IARC) indicate the incidence in Rwanda to be 10,704 new cancer diagnoses, where 4520 cases among men and 6,184 cases among women were registered and the country's annual cancer mortality rates stood at 7,662 (above 70%) [15]. In addition, 50% to 60% of all cancer patients required radiotherapy in the course of their treatment [16]. The most commonly occurring cancer types in Rwandan society per gender are breast and cervix uteri cancers for females and prostate for males, with common types such as colorectum, head and neck, liver, stomach cancers, etc occurring in both genders [15].

To deal with cancer incidence and its control, Rwanda has recently in 2020 launched officially the country's 5-year national cancer control plan, the national cancer registry and the national cancer management guidelines, the three key milestones for the success of the established cancer centre, which aim to reduce cancer mortality and morbidity nationwide. Moreover, the Rwandan ministry of health organises different cancer awareness and/or cancer screening programs across the country for its prevention, as cancer prevention is the most cost-effective and sustainable intervention to control the disease. Through these cancer awareness programs; people are continuously sensitised on the cancer risk factors and how to implement prevention methods into their everyday lives.

V. Medical physics in Rwanda

The roles and responsibilities of medical physicists are very crucial with respect to medical exposure, patient protection and safety in divergent areas that typically include radiation oncology, diagnostic radiology and nuclear medicine. Furthermore, the safe and effective implementation of novel technologies in radiation medicine requires medical physics support [17, 18]. There is a day-to-day development of medical infrastructures which employ ionising radiation in Rwandan private and public healthcare sectors. Such vast applications highlight the need for a trained workforce that includes medical physicists and the recent establishment of a radiotherapy centre triggered the national-wide need for clinically qualified medical physicists to run and monitor these facilities, and further provide support to all needed radiological services. However, there is no national clinically qualified medical physicist (CQMP) available today. The responsibilities of medical physicists in the national radiotherapy centre are currently being fulfilled by one foreign medical physicist from the Ivory coast.

The shortage and/or absence of clinically qualified medical physicists in the country obviously highlights the lack of full access to physics expert's support for the available radiation therapy facilities and the diagnostic radiological services as recommended by international standards [19, 20]. Nevertheless, the developments in medical physics in Rwanda and the region cannot be successively achieved without the collaboration with regional bodies and international organisations such as the Federation of African Medical Physics Organisations (FAMPO), the International Atomic Energy Agency (IAEA), the International Organisation of Medical Physics (IOMP), as well as with international universities/institutions, etc. In this regard, through different collaborations, the first batch of Rwandan young generation is being trained in order to start a medical physics profession in the country and contribute to regional professional development. The following subsections give a brief description of each ongoing education and training, the involved partnership and students' experience. Contributions are listed according to the year of establishment (i.e., from the first to the recent).

A. International Atomic Energy Agency (IAEA) Contribution

Rwanda has become an IAEA member state since September 2012 and signed the first Country Program Framework (CPF) in May 2017. This aimed towards leveraging nuclear technologies for development in areas of agriculture and health care, as well as radiation safety & security and human capacity building. Since then, Rwanda has received the Agency's invaluable contribution in promoting nuclear technology for peaceful uses. For instance, the IAEA provides technical support to accompany the government efforts that ensure the highest nuclear safety standards and application of the best practices in utilising nuclear technologies for development.

The IAEA continued support to build and strengthen human capacity towards the development of medical physics in Rwanda has started in 2017, in response to the urgent need for adequately trained medical physicists in the country healthcare delivery system to support the national expanding radiological services. This was done through the Agency's collaboration with Rwanda Utilities Regulatory Authority (RURA) and Rwanda Biomedical Centre (RBC). Initially, this started with providing scholarships for two Rwandan students, named TUYIZERE Sarathiel and MAKURAZA Joseph, with a physics background, to pursue medical physics education and training at the University of Ghana (UG). The University of Ghana offers well-structured and coordinated medical physics education and training that follows the IAEA's harmonised regional syllabus for academic and clinical training. This involves a two-year academic program and a one-year clinical internship in an accredited hospital/clinic/institution. Moreover, the University of Ghana was recognised by IAEA as a regional designated centre for medical physics training within the African region [21, 22]. Both students successfully completed the 2-years academic program and they are currently doing full time supervised clinical training at Institute Nationale d'Oncologie (INO) in Rabat-Morocco.

B. Gono University Contribution through its Medical Physics and Biomedical Engineering (MPBME) Department

The Global Health Catalyst took initiatives to support the medical physics development in Low-and middle-income countries of Africa, specifically Rwanda. This was done through a collaboration initiated by the former Rwandan Minister of Health (MOH), Dr. Diane Gashumba, with the coordinator of the University Medicine Mannheim (UMM), Prof. Dr. Frederick Wenz, shown in Figure 2. This collaboration is under the umbrella of the Global Health Catalyst based in Harvard Medical School in Boston, it aims to ultimately initiate and develop the radiation medicine profession in Africa, especially Rwanda through providing adequate training to the young generation who will be among the pioneers and coordinators of the professional activities. By referring to Germany's pioneering work to the development of medical physics in Bangladesh, there is a hope that this collaboration will help to bridge the existing gap between current status and the required development of medical physics in Rwanda and the region. During the conference the founder of medical physics in Bangladesh, Prof. Zakaria offered Dr. Gashumba the scholarship for two students from Rwanda to study medical physics at Gono University in Bangladesh. For this collaboration, Prof. Zakaria along with some important members (Prof. Wilfred Ngwa, Prof. Ahmed Elzawawy and others) of Global Health Catalyst (shown in Figure 3) had a 5 days official visit in Kigali/Rwanda during the 25th -29th October 2018 period for evaluating the country's situation and further cooperation.

Fig. 2: Group photo: Collaboration between the Low-and Middle-Income Countries (Rwandan Minister of Health, Dr. Diane Gashumba) with the Global Health Catalyst and the University Medicine Mannheim (Prof. Frederick Wenz) at the Global Health Catalyst Conference in UMM, Mannheim from 31th August to 2nd September 2018 (In photo: Prof. Wilfred Ngwa, Prof. Stephen Avery, Dipl.-Ing. Volker Steil, Prof. Golam Abu Zakaria and others)

Fig. 3: Group photo of the invitees: Prof. Dr. Wilfred Ngwa, Prof. Dr. Luca Incrocci, Dr. Johannes Schweizer, Prof. Dr. Ahmed Elzawawy, Prof. Dr. Golam Abu Zakaria with the former Rwandan Health Minister, Dr. Diane Gashumba, and her team in November 2018 in Kigali.

The initial phase of this collaboration started with training two fresh physics graduate students from Rwanda, named KAMANZI Jean D'amour and RANGIRA Laurent shown in Figure 4, with a full scholarship at Gono University in the Medical Physics and Biomedical Engineering (MPBME) department. The two students are currently doing the last master's coursework and thesis in the medical physics-related field and expecting to complete the academic program by May 2021. Figure 4 shows students from Rwanda with MPBME department authorities: Prof. Zakaria giving them welcome and Prof. Dr. Azhari during practical session.

Fig. 4: Two students from Rwanda in the MPBME department with Prof Zakaria (upper photo) and with Chairman, Prof. Dr. Hasin Anupama Azhari of MPBME (lower photo).

Gono University is one of the biggest private universities in Bangladesh located in Savar near Dhaka capital city. It was established on 14th July 1998 by Gonoshasthya Kendra (GK) public charitable trust, with the purpose to provide a high quality of education which meets the demands of the modern age. The Gono University's unique department in the whole country, Medical Physics and Biomedical Engineering (MPBME), was founded in 2000 in cooperation with Heidelberg University from Germany, German cancer research centre (DKFZ) and University Medicine Mannheim (UMM) from Germany [23]. The MPBME department started initially with providing post graduate courses (2-years MSc. program in 4 semesters) in medical physics and biomedical engineering, with respect to knowledge and competence at local, national and international level. Since the 2005 year, the MPBME department offers education from honours (4-years BSc. program in 8 semesters) to master's level and above 150 students have completed their program from this department and are further offering services in divergent fields [24]. Moreover, the MPBME department has invaluable cooperation with national, regional and international universities and hospitals in Germany, China and India. This provides a great opportunity for MPBME students to perform their practical training, to undertake advanced studies and research in collaboration with experts in the field.

On the way toward building a strong professional career, the two students from Rwanda participated in the hands-on workshop on "Dosimetry of Small Fields in External Beam Therapy: Reference and Relative Dose Determination" from 2nd to 4th October 2019, organised by the South Asia Centre for Medical Physics and Cancer Research (SCMPCR) and they successfully passed the workshop examination. This workshop was accredited by European Board for Accreditation in Medical Physics (EBAMP) as a CPD event for medical physicists at EQF level 7 with 37 CPD points and IOMP in category 1 with total 35 CPD points [25]. At completion of the education program, the students are ambitious to serve their community and contribute to the development of medical physics in their home country (i.e., Rwanda) and the African region. Figure 5 indicates the SCMPCR 5th Hands on Workshop (HW-05) attendees with two students from Rwanda.

Fig. 5: The participants of the SCMPCR 5th hands-on workshop (HW-05) including the two students from Rwanda, in October 2019.

C. The ICTP-College on Medical Physics Contribution

The Abdus Salam International Centre for Theoretical Physics (ICTP), College of Medical Physics has been successively training medical physicists from developing countries through the 2-years Master of Advanced studies in Medical Physics (MMP) program. The ICTP trainees have enormously contributed to the development of the medical physics profession in their home countries, through their pioneering activities such as the establishment of academic departments and societies; leading and coordinating medical physics activities as well as comprehensive patient's healthcare provision [26]. Recently, for the first time three (3) Rwandan national students have got an incredible opportunity to take medical physics education and training at ICTP-college on medical physics, Trieste, Italy. This marks a forward milestone towards the country's medical physics development which will be strengthened by the student's experience after closing their studies. The ICTP training is further witnessed to be the backbone of medical physics development in many Low-and Middle-Income (LMI) countries. Therefore, having this opportunity for Rwandan nationals to be trained at ICTP centre will equip them with relevant knowledge that is needed regionally in order to boost the standard healthcare provision and contribute to what regional scientists are doing towards rising-up and harmonising the medical physics profession in Africa. All three students were confirmed for the 2021/2022 academic year and they are currently processing the necessary documents for starting their academic program, which is supposed to begin in February 2021.

VI. DEVELOPMENT OF QUALIFIED MEDICAL PHYSICISTS (QMP) IN RWANDA WITH INTERNATIONAL MEDICAL PHYSICS CERTIFICATION BOARD (IMPCB) EXAM-2021

Medical Physicists must demonstrate skills and competencies requirements in order to develop the ability of working independently in their area of specialisation and also need to be certified by an appropriate professional certification body so as to ensure the best quality of service provision. Furthermore, the medical physics certification is very important in order to achieve and maintain the professional standards required by today's health care. In this regard, the first batch of Rwandan postgraduate medical physicists will sit for the IMPCB written exam Part I which will take place after the 21st Asia-Oceania Congress of Medical Physics (AOCMP) "Science for Radiation Medicine" on 10th -12th December 2021 in Bangladesh. The International Medical Physics Certification Board (IMPCB) is a 3-parts exam (i.e., two written and one oral) similar to the American Board of Radiology (ABR) designed to support medical physics activities, through defining and assessing minimum professional standards of medical physicists for improving their practice in all part of the world especially in countries or regions that do not have certification bodies as well as already existing national programs in IOMP member states [27a,b]. This is achieved by conducting the examination to test the candidate's competence for board certification in the field of medical physics and successful candidates are awarded certification. Therefore, when it is achieved, the IMPCB certification will be an added value to the medical physics development in the country and the region. This will further inspire other regional colleagues and peers to sit for the exam in order to look for the international licence to practice their profession.

VII. IMPLICATION OF EDUCATION AND TRAINING ON MEDICAL PHYSICS DEVELOPMENT IN RWANDA AND THE REGION

As per IAEA TCS 56 guidelines, medical physicists' specialised education, training and competencies are basically required in order to apply concepts and techniques of physics in medicine [28]. It is further stated that an appropriate academic qualification in medical physics (or equivalent) at the postgraduate level is mandatory for a clinically qualified medical physicist (CQMP) [29, 30]. Education and training are further the important factors that strongly support medical physics activities and it is highly recommended that medical physicists need to have continuous professional development which can be achieved by obtaining the appropriate educational qualification [31].

Currently the medical physics education and training in Rwanda and the East African region rely heavily on the international institution and organisations such as IAEA, ICTP and individual contribution like Gono University, which requires qualified students to go abroad in varying countries for their studies. This has historically imposed serious limitations on those who are keen and interested to join this profession due to the insufficiency of scholarship opportunities or lack of substantial wealth to afford the international study cost. Despite the advanced and standardised educational institutions available in this region, none of them offers medical physics training at the moment and this also continues to be among the factors hampering the development and recognition of medical physics in this region. Therefore, the establishment of a medical physics education and training program at least in one of the East African countries (as proposed in Kigali/Rwanda) will be the ideal and promising way to sustainably develop the medical physics profession among regional countries. This can be successively achieved if the states governments continuously work together with the regional bodies and international entities/associations such as the AFRA, FAMPO, IAEA, IOMP, etc, to set a country-by-country basis regulations for the radiation protection procedures and proper legislation of the medical physics among the national professions.

The present era of the information revolution has resulted in a huge amount of educational material (electronic medical physics lectures and teaching files) freely available to students and trainees. This has promoted further medical physics education and training throughout the world and all involved initiatives deserve special congratulations for their contributions towards establishing educational resources and making them freely accessible. For instance, medical radiation physics (x-ray diagnostic radiology, nuclear medicine, radiotherapy, ultrasound and magnetic resonance imaging) training modules developed by a consortium of European universities and hospitals through EMERALD and EMIT projects are being extensively used to support medical physics education all over the world [32, 33]. Many other available materials from IAEA and WHO are providing a remarkable contribution to medical physics education and training of young medical physicists from developing countries. These resources can be explored in case any medical physics education and training program is established in the East Africa region. This will significantly boost the medical physics development among the regional countries, through providing the necessary skill level and staff in the field.

VIII. Summary and future professional prospective

Medical physics profession has undergone tremendous development in the past century where major discoveries and inventions revolutionised the practice of medicine. The existing novel technologies are driving the growth of healthcare delivery with cutting-edge biomedical research, and the role of medical physicists have been recognised in the baseline. Despite the recognised physics support with respect to international standards in providing comprehensive cancer care and medical imaging, the medical physics profession is still under the level of recognition and totally absent in many Low-and Middle-Income countries including Rwanda. The inclusion of the medical physics profession into the International Labour Organisation (ILO) classification as an occupation (ICSO-08, under physicists and astronomers) has proved a forward step towards its development and recognition worldwide [34].

So far in Rwanda medical physics is being initiated where the first cohort of medical physics students are being trained from different universities across the world, through collaboration with different international organisations and institutions. This proves the professional foundation, which needs extensive and pioneering work to be done by the first country’s batch of medical physicists in order to attain the required field development for their society's benefits, nation and the region. The future of medical physics in Rwanda highly needs much collegial collaboration between the national medical physicists that will be available with the regional and international medical physicists and organisations so as to learn from each other's experience. The provision of high-quality physics support in national services will inherently require the local government authorities to play a very important role such as establishing effective long-term policy goals that support the available medical physicists in national healthcare institutions. Issues such as planification of a country-based program for adequate medical physics education and training will be highly needed in the future in order to assist the proper learning engagement that will develop the required skills level and staff for the national and regional field perspectives. Moreover, the establishment of a national medical physics society should be among the prior goals of the first national medical physicist’s batch. This will play an important role in coordinating their local activities with regional bodies, setting proper communications with higher authorities and creating awareness, as well as establishing policies, guidelines while assuring good professional productivity.

As there are no available CQMPs in Rwanda at present, the government should facilitate and support the first batch of medical physicists already holding postgraduate qualifications to undertake clinical training in various regional and international accredited hospitals, in order to complement their academic education program and gain practical skills in various medical physics subfields necessary to work in hospitals. They should also be facilitated to participate in different residency programs and to attend different regional and international continuous professional development (CPD) programs in order to upgrade their knowledge needed for standard service provision.

For further cooperation, the South Asia Centre for Medical Physics and Cancer Research (SCMPCR), the Gono University and the University Medicine Mannheim (UMM) combined are planning in the next collaboration phase to include African students especially the Rwandan students for medical physics education and training through different sponsorships. This will promote medical physics education, training, delivery of clinical services and research in Rwanda and the region. Through this collaboration Rwandan students and residents will get opportunities to upgrade their knowledge through participating in different multidisciplinary hands-on training and education programs organised by SCMPCR. Moreover, the SCMPCR in collaboration with Germany will help in the establishment of medical physics education and training for the East and Central African region, which is proposed to be based in Kigali/Rwanda and hosted at the ICTP’s partner institute, the East African Institute for Fundamental research (ICTP-EAIFR). This regional-based education will provide concrete and effective professional development among countries in this region and the continent. Many keen and interested students will get the opportunity to start their career development pathway in medical physics with a near-based education. The proper planification and detailed guidelines such as the academic collaboration and exchange program between international universities/institutions that are involved in this cooperation will be addressed in this collaboration phase.

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HOW TO

ASSESSMENT OF PATIENT RADIATION DOSE FROM RECURRENT CT EXAMINATIONS

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Abstract- **Earlier reports showed that the patients undergoing recurrent radiological procedures can received the cumulative effective dose (CED) from 50-1000 mSv or more [1]. Several hundred hospitals in USA and European countries assessed the average percentage of 1.33(0.64-3.4) with CED ≥100 mSv among more than 2.5 million recurrent CT patients [2]. The purpose of this study is to assess the cumulative effective dose (CED) from the recurrent CT examinations at 100 mSv and above for the period of five years at one pilot, tertiary care facility in Thailand. The percentage of those patients with and without malignancy, at less than 40 years at age and above was also assessed. Methods: Initially the data was retrieved retrospectively from the Hospital Information System (HIS) then from the established radiation dose monitoring systems in 2017 by setting the threshold value of 100 mSv. The number of patients with the CED ≥ 100 mSv only from recurrent CT examinations during a period of five years was identified. The age and gender distribution of these patients were assessed to identify the magnitude of patients in the relatively lower age group of ≤ 40 years. Results: Of the 208,731 CT exams from 2015 to 2019, nineteen patients received CED ≥ 100 mSv in a single day at less than 0.01% of total CT examinations. Six patients at 22- 40 years of age and thirteen patients at 41 - 78 years of age received CED ≥ 100 mSv in a single day. The median CED was 106.7 (100.90-139.32) mSv. The acquisition protocols with the clinical diagnosis of those nineteen patients had been reported.**

Keywords- **Cumulative effective dose, CED, Recurrent CT, Radiation protection, Patient radiation dose**.

I. INTRODUCTION

The use of diagnostic CT in the United States has risen nearly 20 folds since the early 1990s and the medical imaging accounts for more than 50% of the radiation exposure, half of which related to CT scan. The rapid availability of CT, along with their diagnostic accuracy, has led to dramatically increased use in acute care. Early detection of the disease, the reduction in mean hospitalizations, had been attributed to greater use of CT. With the current expansion of CT in medical practice, an increased understanding of cancer risks and strategies for reducing radiation dose is of utmost importance. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [3], the International Commission on Radiological Protection (ICRP) [4], and the National Council of Radiation Protection and Measurements (NCRP) have successfully evaluated the radiation – related adverse effects, particularly cancer, at or above the absorbed dose of 100 mGy. The NCRP had reviewed all studies in the world at the absorbed dose below 100 mGy and concluded that the linear no- threshold (LNT) model should be used for radiation protection purposes [5]. The U.S. Food and Drug Administration [6] has stated that compared with the natural incidence of fatal cancer in the United States of approximately 1 chance in 5, an effective dose from CT of 10 mSv may be associated with the possibility of fatal cancer in approximately 1 in 2000 patients. This is similar to the overall BEIR VII cancer estimate of 1 in 1000 per 10 mSv [7]. Pearce et al. [8] documented a three times increased relative risk of leukemia among children who had received a cumulative radiation dose of at least 30 mSv. These findings appear to be consistent with the linear no-threshold model, though the American Association of Physicists in Medicine (AAPM) has responded by emphasizing the low incidence of leukemia in children [9], which can exaggerate relative risk. For elderly patients, estimates made with BEIR VII models revealed a minimally increased attributable risk (0.03–0.04%) for development of cancer related to ionizing radiation [10]. Multiple CT examinations can lead to high CED (50–200 mSv). Compared with the dose from a single CT examination, a cumulative dose of 120 mSv (approximately eight CT examinations) can increase lifetime risk of cancer development from 1 in 1000 to 1 in 82.

In 2019, the technical meeting on radiation exposure of patients from recurrent radiological imaging procedures, organized by the IAEA which the IAEA Experts and the representatives of 46 IAEA Member States had been participated on March 4 to 6, 2019 and made the summary of the findings and conclusions of (a) look at the data from different countries collected specifically for this meeting through the IAEA-MGH survey on patients with CED ≥ 100 mSv, (b) discuss available literature on patients with CED ≥ 100 mSv and radiation effects at this level of radiation dose, (c) create awareness about the findings on the number of patients with CED ≥ 100 mSv, (d) discuss limitations, if any, of the current framework on radiation protection in dealing with new findings, and (e) develop plans for future work.[1]

More data provided strong evidence of an increased cancer mortality risk at equivalent dose at greater than 100 mSv, an increased risk at doses between 50 and 100 mSv, and reasonable evidence for increased risk at dose between 10 and 50 mSv. The use of ionizing radiation for medical purpose provides many benefits, but it also increases the risk of cancer later in life. The justification and the radiation dose optimization have been continuous emphasized on, including the development of new CT technologies, [11] for the purpose of the patient dose reduction.

II. Materials and methods

The study is a retrospective, observational, at a single center. The Institutional Review Board, Faculty of Medicine Chulalongkorn University has approved the IRB 815/13 title 'The survey of the cumulative effective dose (CED) exceeds 100 mSv in a single day from diagnostic CT systems at King Chulalongkorn Memorial Hospital' on December 24, 2020. During January 2015 and December 2019, the number of patients was acquired by six CT scanners, of two Philips, two GE, one Siemens and one Canon systems. The number of CT examinations, patients, procedures and related data had been retrieved from HIS and dose tracking platform Radimetrics version 2.9b Bayer Healthcare, USA, installed in 2017. The ratio of CT exams per patient is shown in Table 1. Table 2 shows the number of CT examinations and the percentage in each year. The demographic data of the patients with CED ≥ 100 mSv in a single day had been collected from Radiometrics of all recurrent CT patients. A patient-level search was performed using a threshold of CED 100 mSv from January 2015 to December 2019. The effective dose (mSv) is calculated using organ weighting factor from ICRP103.[12] Since the data collection time frame ended in December 2019, the patient age was estimated in December 2019 as detail in Table 3

Table 1 Number of patients and CT exams acquired by 6 CT scanners, retrieved from the Radimetrics (2015-2019) at one tertiary healthcare center in Bangkok, Thailand.

CT scanner	Model	period	No. of patients	No. of CT exams	CT exams/ patient
Philips	Brilliance 64	2015-2018	16,158	20,839	1.29
Philips	Ingenuity	2016-2019	11,993	16,480	1.37
Siemens	SOMATOM Force	2015-2019	27,052	38,098	1.41
GE	Revolution	2017-2019	11,296	15,628	1.38
GE	Discovery750HD	2015-2019	21,453	34,478	1.61
CANON	Aquilion ONE	2015-2019	28,572	40,925	1.43
		Total	116,524	166,448	Mean 1.43

Table 2 Number of CT Examinations per year (2015-2019) collected from the HIS.

Year	Number of CT Examinations	Percent
2015	34,307	16.44
2016	40,304	19.31
2017	54,185	25.95
2018	44,208	21.18
2019	35,727	17.12
Total	208,731	100.00

III. Results

Table 3 The demographic of nineteen patients with CED ≥100 mSv in a single day

Patient Number	Age at year 2019 (year)	Gender	Weight (kg)	Height (cm)	Patient diameterǂ (mm)	CED (mSv)
1	31	M			227.63	102.58
2	64	F	80	165	347.71	116.07
3	64	F			267.89	102.17
4	53	F	160		419.73	101.56
5	62	Fǂ			256.57	105.01
6	59	Fǂ	70		300.91	111.17
7	57	F	67		258.26	139.32
8	23	M	80	170	205.70	110.41
9	36	M			276.99	101.68
10	35	F	55		244.23	103.80
11	61	M			316.56	100.90
12	52	M	170		441.38	113.24
13	28	F			274.37	103.15
14	78	F			262.69	109.43
15	79	M	75	165	317.94	113.78
16	38	F	72.6	160	399.20	121.39
17	73	M	70	160	300.98	101.54
18	70	M	62		265.15	122.23
19	61	M	59.2		220.27	106.70
Mean	54.0	#	85	164	295.0	110.0
Median	57.0	#	71	165	274.0	107.0
	<40 = 6 >40=13	M=9 F=10				

Table 4 Data of nineteen patients with CED ≥ 100 mSv in a single day

Total patients CED ≥ 100 mSv	Max CED (mSv)	Median CED (mSv)	Min CED (mSv)	Mean no. of CT exams/patient	Max no. of CT exams/patient	No. of Follow Up (cases)
19	139	107	100.90	4	13	9

Table 5 Patient distribution among various acquisition protocols for cohort with CED≥ 100mSv in a single day

CT Chest Whole Abdomen	CT Brain without contrast	CT Abdomen with & without contrast	CT Angiogram heart with and without contrast	Total
2	4	6	7	19

Table 6 The acquisition protocol and clinical diagnosis of six patients with CED ≥ 100 mSv in a single day at age ≤ 40 years

Patient Number	Age at 2019 (year)	Gender	No. of CT (2015-19)	CED (mSv)	Acquisition protocol	Clinical diagnosis
1	31	M	1	102.58	CTA Brain & Neck +Whole Aorta	Trauma
2	23	M	1	110.41	CT Brain+ C-Spine + CTA Upper Extremity Runoff	Trauma
3	36	M	4	101.68	CT Brain+ C-Spine +Whole Abdomen	Trauma
4	35	F	5	103.80	CT DE thoracic aorta	Takayasu arteritis
5	26	F	1	103.15	CT Brain +Facial bone +C-Spine +Whole Aorta	Trauma
6	38	F	4	121.39	CT Whole abdomen	Cryptogenic Cirrhosis

Table 7 The acquisition protocol and clinical diagnosis of thirteen patients with CED ≥ 100 mSv in a single day at age > 40 years

Patient Number	Age at 2019 (year)	Gender	No. of CT (2015-19)	CED (mSv)	Acquisition protocol	Clinical diagnosis
1	64	F	1	116.07	CT Chest +Whole abdomen	A few tiny caliceal stones
2	64	F	4	102.17	CT Brain+ Whole aorta	Trauma, Head injury
3	53	F	3	101.57	CT Whole abdomen	Morbid obesity, hypermenorrhea
4	62	F	4	105.01	CT Whole aorta with ECG-gating	Aortic arch aneurysm post TEVAR
5	59	F	13	111.17	CT Larynx + Chest +Whole abdomen	DLBCL Post 6th R –CHOP
6	57	F	5	139.32	CTA Thoracic aorta	Aortic dissection (Stanford type A)
7	61	M	8	100.90	CT Whole abdomen	Bilateral renal cyst and renal stone
8	52	M	1	113.24	CT Whole abdomen	Morbid obesity post sleeve gastrectomy
9	78	F	4	109.43	CTA Whole aorta	Concealed rupture aortic arch aneurysm post TEVAR
10	79	M	3	113.78	CT Nasopharynx + Chest +Whole abdomen	Aspiration pneumonia
11	73	M	2	101.54	CT Whole abdomen	Left stage horn stone post left PCNL
12	70	M	4	122.23	CTA Thoracic Aorta Prospective with ECG-gating	Aortic aneurysm with severe AR
13	60	M	2	106.70	CT Cardiac Prospective with ECG-gating	TVD Post CABG

IV. Discussion

The number of CT examinations per patients within five years range from 1.29 to 1.61 among 6 CT systems. The recurrent CT of 208,731 exams from the year 2015 to 2019 shows the number of the cumulative effective dose of greater than 100 mSv in a single day at 19 cases or 0.01% of all examinations. The maximum CED of 139.32 mSv in a single day is obtained by a 57 year old female with 67 kg body weight. The study protocol was a CTA Dual Energy thoracic aorta and the clinical diagnosis of aortic dissection (Stanford type A), multiple myeloma oncology. The second largest CED, 122.23 mSv, obtained by a 70 year old male whose protocol was a thoracic aorta prospective and the clinical diagnosis was an aortic aneurysm with severe aortic regurgitation. Four from six cases of young patients were trauma of two CT aorta, one CT abdomen, and one CT brain. Two from six of young patients were CT Dual Energy Aorta and one CT abdomen of cryptogenic cirrhosis. The patients at the age of over 40 years old with CED≥100 mSv consist of 6 CTA, 2 CT chest and whole abdomen, 4 CT abdomen, and 1 CT Nasopharynx.

V. Conclusion

The overall patients undergoing multiple CT exams and obtained CED ≥ 100 mSv have been assessed with the number of 19 patients whose age of less than 40 years old in 2019 was 6 and over 40 years old was 13. The total number of CT examinations was 208,731 which result in the percentage of patients with CED ≥ 100 mSv at 0.01. The percentage is much lower than the report from the survey of 324 hospitals in US and EC hospitals at 1.33(0.64-3.4). The assessment shows the requests of multiple CT scans at CED≥100mSv were CTA- trauma, CT abdomen, CT brain and CT nasopharynx respectively. There were a few cases of cancer patients at the Section of Diagnostic Radiology. The cancer patients obtain the follow up on CT study at the Section of Radiation Oncology by using CT/MR simulator. Further study at other local centers with Radimetrics dose tracking is encouraged to monitor the patients with CED≥ 100 mSv, in order to have the national data on the appropriateness in requesting for CT examination and the radiation protection of patient on the recurrent CT examinations.

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QUALITY CONTROL OF WHOLE BODY IMAGE UNIFORMITY

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Abstract--- **Whole body (WB) imaging facility is available in modern SPECT without exception and it is used in a significant proportion of patient studies in daily work. In Bulgaria, this part represents 60 to 80% of the total number of studies.**

WB scan consists of 3 phases that are performed sequentially in continuous mode without pause between them - electronic, mechanical and electronic scanning. It is essential that the camera maintain its spatial resolution and sensitivity as the camera system moves over the patient. It is generally the opinion that to ensure good WB image uniformity the electronic scan speed at the start and stop regions of a scan should be equal to the scan speed of the mechanical motion.

Quality control (QC) is one of the corner stones of nuclear medicine and an obligatory prerequisite for adequate diagnostic imaging. Two parameters determine the quality of WB image: resolution and uniformity. While QC methods have been developed to quantify the resolution the problem of quantifying WB image uniformity remains open. Therefore, the QC program requires a precise test to periodically check the constancy of scan speed during WB scan. Such a test will in fact be an assessment of the condition for achieving high quality WB image uniformity.

In this paper we present a comprehensive set of QC procedures which can be applied for acceptance testing and for regular quality control of WB image uniformity. The tests for continuous monitoring of WB scan speed are described in detail and results are presented.

Keywords--- **quality control, whole body image uniformity, whole body scan,**

I. INTRODUCTION

Whole body (WB) scan capabilities are available in contemporary SPECT gamma cameras without exception. This function constitues the majority of gamma camera applications. In Bulgaria it takes up 60 to 80% of all SPECT examinations.

The WB scan is performed by either moving the camera gantry or by moving the patient bed such that the total length of the patient passes the field of view of the detector(s). Any WB scan comprises three phases (steps), which are performed continuously with no intervals in between. The first and third phase can be referred to as electronic scanning, with the detector being still. The second phase, with the detector moving with regards to the patient can be labelled mechanical scanning.

The electronic scan speed at the start and stop regions of a scan should be equal to the scan speed of the mechanical motion. It is essential that the camera maintain its spatial resolution and sensitivity as the camera system moves over the patient. Constant sensitivity during the WB scan ensures uniform WB image. Literature on the field has so far provided no satisfactory description of the principles (algorithm) of WB scans.

WB image quality is defined by two parameters: resolution and uniformity. While resolution capability has long been merited with established methods for quantitative assessment [1], such methods pose an open topic when it comes to WB image uniformity. It is evident that WB image uniformity depends on the proper and unobstructed functioning of the scanning device.

Quality control (QC) of WB image uniformity demands a procedure for continuous monitoring of WB scan speed, which should yield appropriate data for quantitative assessment. The latter should be subject to minimal error, so as to supply objective grounds for comparison with assessments in further procedures.

Since the introduction of WB scan, it has been heavily emphasized that “the speed should be calibrated periodically” [2] as this is the foremost requirement to achieve the necessary WB image uniformity.

In internationally acclaimed guides on gamma camera QC such as National Electrical Manufacturers Association (NEMA), the problem of assessing WB image uniformity was initially raised in 1994 [1], augmented in 2001 [3] and remained unchanged until 2018 [4]. The first WB image uniformity quality control procedure [1] recommends qualitative assessment of the WB image uniformity by attaching a Co-57 sheet source to the collimator and performing a WB scan. It is expected that “visual inspection of the WB image will highlight most non-uniformities”. The grounds for adopting a qualitative assessment was the suspicion that a quantitative assessment of uniformity would be difficult to acquire with clinically relevant scan speed. NEMA later recommended a semi-quantitative approach [3], which was based on the assumption that “The perpendicular resolution, measured with line sources parallel to the direction of motion, is affected primarily by the performance and alignment of the scanning mechanism". This opinion regarding the QC of WB speed remains unchanged up to the last issue of NEMA [4].

The Co-57 sheet source method grew largely popular and was proposed by different authors in slightly altered versions. In one of them, the Co-57 sheet source is put in three different places on the patient table, then three WB scan are performed continuously [5]. The ensuing statistical processing of the collected data is expected to yield a representation of the degree of WB image uniformity.

Another method [6] has the WB scan performed on the Co-57 sheet source placed under a 4 quadrant phantom, the latter rotated 45^o along the length of the detector motion. The method then prescribes a visual assessment of the WB image quality.

It is worthwhile mentioning that a principal disadvantage of Co-57 flood disk source is its high cost and limited useful life (T1/2 - 270 days). To avoid the application of a Co-57 sheet source, one author [6] proposes a WB scan of 10 point sources of equal activity arranged on the table equidistant apart. The statistical processing of the 10 captured images is used for assessment of WB image uniformity.

An additional approach was proposed [7] which included a WB scan of a single point source with a subsequent assessment of the data in the graph. A value of the point in graph that falls outside the +/- 2 average standard deviations interval is considered a malfunctioning of the scanning system. Although not explicitly stated, it is presumed that during post processing the author excludes both high intensity endpoints in the graph. A drawback of this approach is that when using a single point source the beginning and end of the WB scan are missed by the procedure.

The methods discussed so far utilize either a qualitative assessment [1], [6] or propose discrete point, instead of continuous, surveys [3], [6], [4], [5] of WB image uniformity.

The first and so far only publication that is wholly dedicated to a quantitative assessment of WB uniformity is by Blokland et al. [8]. The authors propose placing a Co-57 sheet source on top of the lower detector during the WB scan and retrieve from the WB image a longitudinal profile. The graph of the profile will be flat if WB scan speed is constant. The retrieved profile however carries a considerable statistical noise, which hampers pinpointing WB scan speed fluctuations that are small in amplitude and short in duration. This is the reason why this method cannot find practical application.

This approach was also described in other publications [9], [6], yet existing graphs as a result of its execution are only 2 [8], [9].

This otherwise clever system has two shortcomings, the latter being why so much statistical noise exists, thus significantly diminishing the utility of the method:

- Width of the profile. In majority of gamma cameras width of the profile is restricted to 5 pixels. Five pixels span only 2% of the Co-57 sheet source surface (circa 8 MBq) which results in high statistical noise.
- Scan speed. It is obligatory to apply clinically relevant scan speed – 10-12 cm/min.

A considerable advantage of the approach is that it affords a continuous monitoring of WB scan speed, thus also of WB image uniformity. To bring out the full potential of the approach the Co-57 flood disk source could be replaced by a suitable phantom to produce a profile with acceptable levels of noise, comply with clinical speed scanning requirements and generate a count rate of up to 20 kcps.

II. Materials and method

We developed phantoms and a method for quality control of WB image uniformity, which ensure little noise at clinical speed of scanning and a count rate lower than 20 kcps.

Figure 1 displays the two phantoms which are filled with colourized water and placed on the detector in their working positions. Phantom №1 is a Plexiglas box with internal dimensions 455 x 10 x 20 mm and volume nearly 90 ml. Phantom №2 is a capillary plastic tube with length 50 cm and internal diameter 1,2 mm. The tube is fixed in a strictly straight line on top of a solid base. Both phantoms are equally suitable for the purposes of this study, hence going forward one phantom is referred.

The phantom is filled with a homogenised Tc-99m solution. Activity around 200 MBq generates a count rate less than 20 kcps if LEHR collimator is used. In order to reduce personnel radiation exposure, a protective lead shielding in the form of a U section could be placed covering the phantom. The shielding

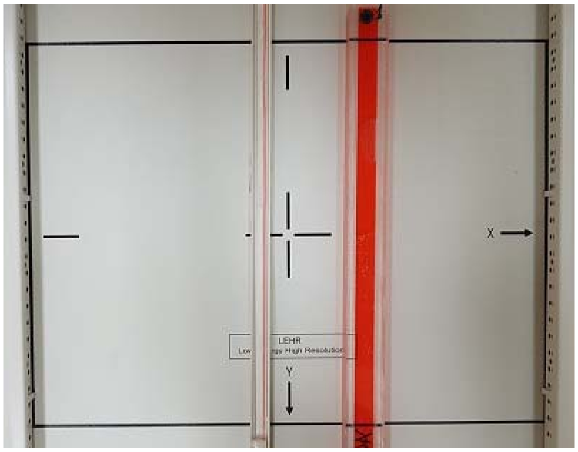

Fig. 1 The two phantoms placed on the detector 2

may be used as a container for the safe carry of the phantom.

With regards to gamma cameras with two detectors, it is advised that only detector 2 (lower detector) is switched on, while detector 1 remains switched off, in order to avoid confusion while processing the WB scan results. Users should also not forget to switch off Autocontur (Body contour) before commencing WB scan.

Pre-requisite: prior to executing a WB scan, a successful test has been carried out of the uniformity of the detector field.

1)Place the phantom on the face of the collimator in parallel with the scan direction. Check that the count rate is less than 20 000 cps.

2)Acquire a static image of 5 mln counts into matrix 256x256 and draw a profile along the phantom image. If the profile is a flat line - proceed to 5).

If the profile is not a flat line consider two issues – the phantom solution is not homogenies or the sensitivity of the detector in this direction is not uniform.

3)Rotate the phantom at 90^o and place it in CFOV, in parallel with the long axes of the detector.

4) Acquire a static image of 5 mln counts into matrix 256x256 and draw a profile along its length.

If the profile of the static image is not a flat line – consider refilling the phantom with homogenized solution of Tc-99m and proceed to 1) again.

If the profile of the static image is a flat line – stop the WB test and consider checking of the detector uniformity.

5)Set the scan speed to 12 cm/min and scan length to be 200 cm.

6)Acquire a WB image and draw a profile along its length.

If the profile of the WB image is a flat line – WB scan yields a uniform image.

If the profile of the WB image is not a flat line – consider service call.

There exists a speedier avenue for ascertaining the constancy of WB scan speed with two point sources:

1)Have two sources available. Each source has a volume of around 0,5 ml in a 2 ml syringe. It is recommended that the activity of one source be around 70 MBq, and of the other – around 100 MBq (LEHR collimator).

2)Place one source close to the upper (leading) edge and the other source close to the lower edge of detector field.

3)Set the scan speed to 12 cm/min and scan length to be 200 cm.

4)Acquire a WB image.

5)The WB image retrieved from each source is a line between two points with high intensity. Fig. 2. Draw a profile along each line excluding the endpoints.

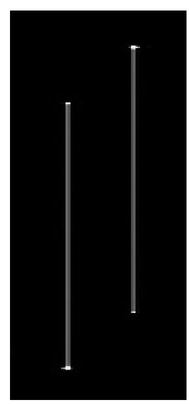

Fig. 2 WB image of two syringes placed on D2

This method is convenient for a quick check, when there is reason to suspect faulty WB scan speed. When the activity of the two point sources is different, the profiles will not overlap, which will aid visual analysis.

III. Results

Profiles of a static image of the phantom and of WB image are displayed in Fig. 3. Evidently the scanning mechanism of the tested gamma camera works perfectly as the electronic and mechanical scan speeds are visually the same.

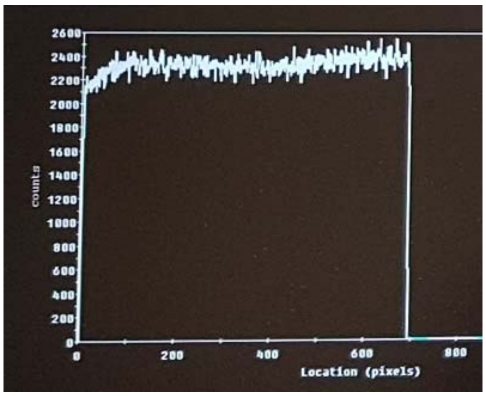

Fig. 4 Profile indicates problem of scanning mechanism.

Fig. 4 shows an illustrative example of a gamma camera where a difference exists between the electronic and mechanical scan speeds, possible due to transportation system malfunction.

Post processing in the two-syringe method is slightly different – any of the two lines of the WB image end with two points of high intensity (Fig. 2). The profile must lie between the 2 endpoints (Fig. 5 left), in order to derive reasonable graph representation (Fig. 5. Right). The green graph corresponds to the initial electronic speed of scanning and the mechanical scan speed, while the red graph displays the mechanical scan speed and the final electronic scan speed. The two profiles provide enough information to make inferences regarding equivalence between the three speeds of scanning as well as the transitions between them.

This method is practicable solely if the processing software permits to draw a profile with restricted length between 2 points. Otherwise, when the profile runs from one end of the WB image to the other, the result will resemble Fig. 6. In this case, one does not have available details of the graph of each line.

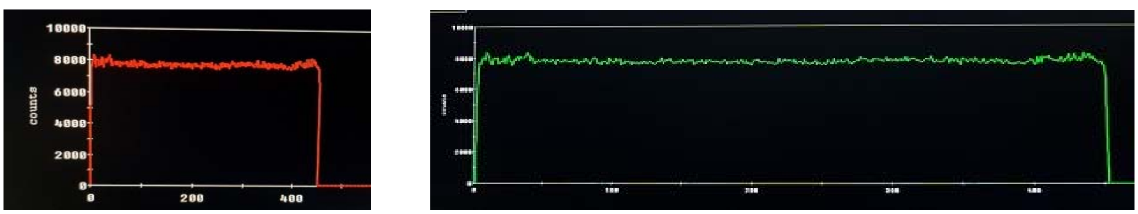

Fig. 3 Profile of the phantom (left) and profile of the WB image of the phantom (right)

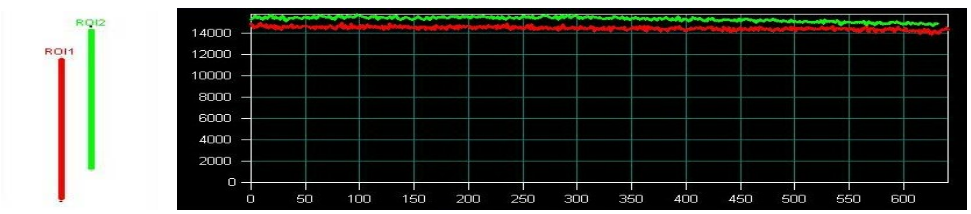

Fig. 5 Profiles span the lines without the endpoints.

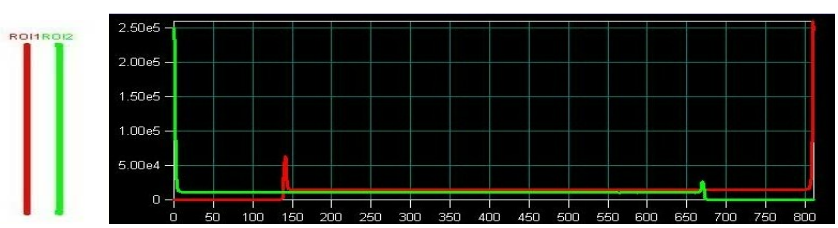

Fig. 6 Profiles span the entire length of the whole body image.

IV. Discussion

The paper has proposed a method and phantoms with the aim of testing for WB image uniformity. The submitted two phantoms are easy to make. Their construction allows uncomplicated and swift filling, which minimizes radiation exposure of staff. The relatively small volume (90 ml) of the Plexiglas phantom facilitates the in-advance homogenization of the Tc-99m solution in a 100 ml syringe. The volume of the plastic tube is around 1 ml and homogenization is not a concern.

The proposed method for QC of WB image uniformity depends on the availability of Tc-99m generator and excludes the need for the expensive and with relatively short useful life Co-57 sheet source. Activity of the phantom around 200 MBq generates count rate around 10 kcps (LEHR collimator), i.e. there is room for availing of even higher activity in order to further decrease statistical noise. This increases the sensitivity of the method in discovering comparatively small deviations of WB scan speed with low amplitude and short surges. The recommended scan speed is the clinical standard of 10-12 cm/min. The method includes obligatory verification of uniformity of the phantom, whereby it ensures objective premises for deriving reliable data.

The approach put forth enables continuous estimation of every moment of the WB scan in a graphic form that can be additionally exploited to yield meaningful data for further quantitative estimation.

The paper also advances an express method using two point sources to check the performance of WB scan when suspicion of fault arises. Even visual inspection of the two retrieved profiles lends reliable assessment as to the performance of the WB scan along the length of the entire table. This method can be further developed to yield more information by adding more point sources placed on various spots on the detector field, e.g. for continuous estimation of sensitivity during WB scan. We consider the variants with more than two sources redundant, as long as sensitivity of detector field is ensured with uniformity correction which is always switched on.

Application of the method with any of the two phantoms is relatively easy and straightforward and it is very unlikely that an error is made during performance or post processing. The two-syringe method requires more caution and expert knowledge of the properties of the profile drawing software. This method is not recommended if the software does not allow to draw a profile with a definite length but only affords an end-to-end profile of the detector field.

Final remark. When performing a QC of WB scan (unlike all other procedures) perhaps we should more closely simulate clinical conditions, viz. we ought to load the table with the weight of a normal patient – 70-100 kg. The reason for this being that some WB scan malfunctions are more likely to arise precisely when the table has weight on.

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PhD ABSTRACTS

Investigations on the effects of the flattening filter free treatment mode in radiotherapy based on the therapy of localized prostate carcinoma and pituitary adenoma

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Keywords— **flattening filter free, plan quality, secondary malignoma risk, IMRT, VMAT.**

I. Introduction

Modern linear accelerators for radiotherapy are optional available with flattening filter free (FFF) mode. In the beginning, this mode has been developed to increase the dose rate and to reduce the treatment time for stereotactic treatments if the flattened field is not necessary as the planning target volumes are small. Fluence modulating techniques as intensity modulating radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT) do not require a flattened field either. Moreover, the flattening filter is a source of scattered radiation. Therefore, it has been discussed that peripheral regions of patients treated with flattening filter will obtain a higher dose than in FFF mode. As radiation has the potential to induce secondary malignancies, the risk for such malignancies might be reduced by FFF.

Aim of the present thesis was to investigate the impact of this new mode regarding the plan quality and the secondary malignancy risk. IMRT and VMAT in both modes, with and without flattening filter were investigated. The technical feasibility and quality assurance plays an eminent role at the implementation of new treatment techniques. Therefore, dosimetric plan verifications were performed. The secondary malignancy risk was quantified by the application of different mathematical models to peripheral dose measurements and to the calculated dose distributions in the treated region.

II. Material and methods

Two patient groups were selected for these investigations: The first contained 10 patients with localized prostate carcinoma, the second 11 patients with pituitary adenoma. The applied systems were a linear accelerator, type Synergy™ with Agility™ head and the treatment planning system Oncentra® (all from Elekta Ltd.). The dosimetric plan verification was performed by means of the detector arrays MatrixxEvolution (IBA) and SRS MapCheck® (SunNuclear). The plan quality was evaluated by the following parameters: homogeneity index, conformity index, dose to the organs at risk, and treatment time. The secondary malignancy risk was calculated by the application of different dose response models. In the treated region dose volume data from the treatment planning system were exported; in the periphery measured doses to selected points in an anthropomorphic phantom were used (fig.1). The Wilcoxon signed rank test was used as statistical test.

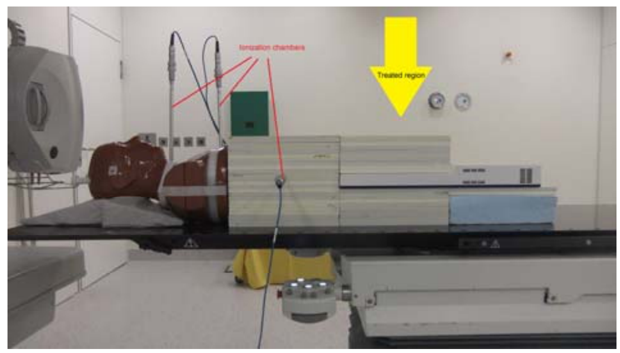

Figure 1. Measurement setup for the prostate cases using an anthropomorphic phantom and stacks of solid water equipped with ionization chambers for peripheral dose measurements and a 2D array for plan verification. The yellow arrow indicates the treated region [2].

III. Results

The dose to the organs at risk in the treated region was similar for both modes. The same was found for the homogeneity index and the conformity index. Both indexes improved by the application of VMAT compared to IMRT. Treatment times have not been shortened essentially by the application of FFF. However, treatment times with VMAT technique were only about one third compared to IMRT. The plan verifications with the detector arrays were successfully completed.

The secondary malignancy risk in the treated region is slightly reduced in the FFF mode. The risk for secondary sarcomas is about one magnitude smaller than for secondary carcinomas for all techniques. Regarding pituitary adenoma treatment, the risk for secondary brain carcinoma is higher for VMAT than for IMRT (fig.2). The peripheral dose point measurements resulted in a statistically significant reduced risk by the application of the FFF mode.

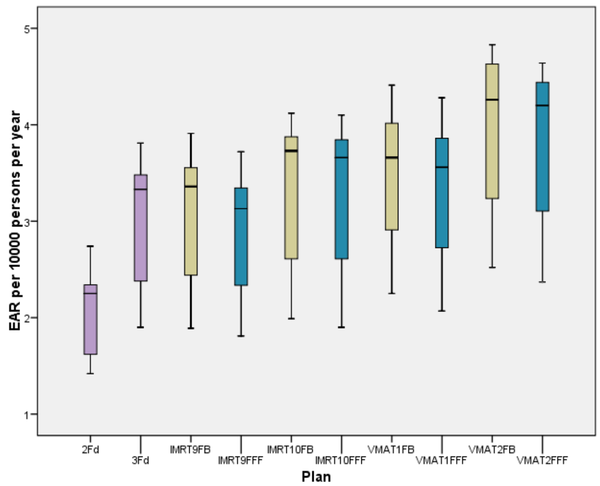

Figure 2. Risk for secondary brain cancer after radiotherapy of the pituitary gland expressed as excess absolute risk (EAR) for different techniques and number of fields, some plans containing non-coplanar fields (IMRT10, VMAT2). With flattening filter (yellow), without (blue) and with 3D conformal technique of 2 and 3 fields (purple) [3]

IV. Discussion and conclusion

From the clinical point of view, the differences between plans with and without flattening filter and for different techniques as IMRT and VMAT were small. This has also been the result of many other publications for different localizations of tumor, treatment units and planning systems.

Shortening of the treatment time was one aim at the development of VMAT. The results of the present investigation are in the same range as found for other entities. Shorter treatment times increase patient comfort and reduce the risk of intrafractional dislocation.

However, treatment times have not been shortened by the application of FFF. Although a higher dose rate is possible, there are counteracting influences: The inhomogeneous dose distribution must be compensated by additional segments which takes time. The limitations of the speed of the gantry or collimator parts constrain the dose rate. Therefore, treatment times are influenced marginally only.

The results of the risk for secondary malignancies in the treated region were statistically significant smaller with FFF, however on a low level. Secondary brain cancer seems to depend on the treated volume (fig. 2). Therefore, non-coplanar techniques cause a higher risk than coplanar, and VMAT more than IMRT. The risk for secondary sarcomas being one magnitude smaller than for secondary carcinomas coincides to the results of the atomic bomb survivors.

There is a clear evidence for a higher risk for secondary malignancies in the periphery using flattening filter mode which can be explained by additional scattered dose from the filter as described in the introduction. This effect has also been observed for other entities and is an argument to use FFF in IMRT and VMAT treatments.

Acknowledgment

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The thesis has been written in German and has been published electronically in the repository of University Regensburg [1]. However, in a large part the important contents have been pulished in English in peer reviewed journals [2, 3, 4].

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Degree: Dr. scientiarum humanarum

BOOKS

Book Review
DIAGNOSTIC RADIOLOGY PHYSICS WITH MATLAB®: A PROBLEM-SOLVING APPROACH, by J. Helmenkamp, R. Bujila and G. Poludniowski

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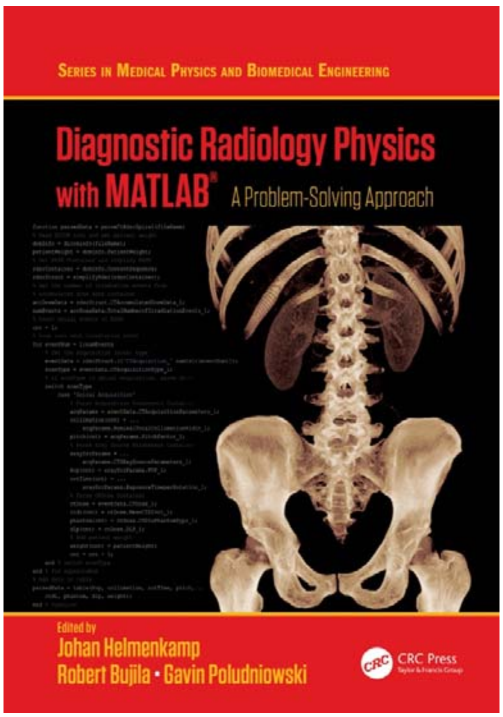

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292 Pages, 10 Color & 64 B/W Illustrations

Computers are essential to the practice of modern diagnostic imaging. Gone are the days when radiological images would be acquired on film and viewed directly using the backlight. Radiologists today are likely to spend most of their day sitting in front of a computer, scrolling through image slices and typing in their findings. The same is true for medical physicists, who rely heavily on computer software for many of the data-heavy tasks they perform as part of their job.

In "Diagnostic Radiology Physics with MATLAB®: A Problem-Solving Approach," Johan Helmenkamp, Robert Bujila and Gavin Poludniowski argue, with merit, that computer programming is an essential skill that every medical physicist should possess. However, medical physics programs still fall short when it comes to teaching trainees how to code. For instance, in northern America, the Commission on Accreditation of Medical Physics Educational Programs (CAMPEP) does not currently include computer programming in its core curriculum. Hence this book, which aims to address this shortcoming by providing the foundational elements of computer programming relevant to diagnostic imaging physics.

As we all know well, computer programming skills are in high demand nowadays, which has led to a proliferation of books and guides all promising to turn us into expert coders. This book is specifically geared toward medical physicists who may wish to learn programming to enhance their professional skills and become more effective on the job.

While the first half of the book offers general principles for programming in MATLAB, the second half takes us deep into the "trenches," with examples of computer programs provided online and explained in detail. More than a dozen authors, some working in medical physics, others employed by the publisher of MATLAB, have come together to contribute their code and expertise in this volume. The book includes relevant problems and examples such as:

- how to compute X-ray cross-sections and X-ray tube spectra using the xrTk toolkit
- how to automate quality assurance tests
- how to estimate absorbed dose during imaging

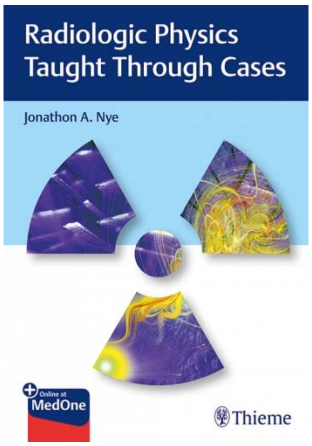
Reading through the book, one will appreciate topics that are seldom discussed in the programming literature, such as quality assurance of medical software and regulations concerning the use of patient data in software. While a few of the chapters may seem dense and highly technical, many others are written engagingly and filled with colorful language and humor. Some noteworthy chapters are those that discuss the licensing and dissemination of software, good programming practices, and the integration of MATLAB programs with other application programming interfaces.

For all the criticism against it, MATLAB is and will remain one of the most widely used programming languages in engineering and the sciences. It is well suited for exploring data interactively and quickly prototyping a script that automates analysis and plots the results. A few more clicks, and one can add a graphical user interface to make the prototype code easier to use to a wider user base. And, with powerful toolboxes, a short piece of code is often sufficient to deploy complex and powerful algorithms, including specialized functions to interact with DICOM data and analyze images. Although its dominance is being contested by open-source packages such as NumPy and SciPy, MALTAB still runs much of the code used in academic research, thus becoming proficient in its programming is a worthwhile investment.

In sum, while this textbook will probably be most useful to the beginning programmer, I expect it will become a reference text for anyone who routinely uses MATLAB in medical physics practice and research.

Book Review
Radiological Physics Taught Through Cases

Jonathon A. Nye



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Published in 2020 by Thieme Publishers New York, this book provides a novel approach to exposing diagnostic radiology residents to physics of radiology in 154 pages with 231 illustrations. It should be noted that the expected audience for this book are radiologists-in-training and not necessarily physics or medical physics students. This book is organized in 7 chapters, authored by different physicists, and each chapter is subdivided into 10 sections followed by some review questions in section 11 of each chapter. In the preface, Professor Nye correctly asserts that the many approaches used to teach physics of radiology to residents often fall short of covering the fundamental physics necessary to teach the physics of the different modalities in sufficient detail. As such, the typical once or twice a month lectures each concentrating on a different modality, cram a tour-de-force presentation of the factors responsible for image creation and display, without really concentrating on interpreting images. This book adopts an example-based approach, primarily focusing on artifacts observed in images and explaining their causes. They provide references to guide the reader to texts where the physics and mathematics of image formation are discussed. Each section starts with a case presented, followed by the findings, a discussion of the findings, and the section is concluded by a summary (referred to as "Resolution.")

In this review, we will look at each chapter, give a summative narrative of the coverage keeping the intended audience in mind, and share a few important topics, which might find their way into the next edition of this book. We have extensive teaching experience and draw upon our own experiences both in teaching and practice.

Chapter 1: Fluoroscopy by Rebecca Milman Marsh and Michael Silosky.
Fluoroscopy with its uses in IRs, Cath Labs, portable C-arms and O-arms, CT Fluoroscopy, Digital Subtraction Angiography (DSA), Cone Beam Tomography and some combinations of these procedures have become an ever more present modality of X-ray imaging in hospitals and operating rooms. While the cases presented here deal with different fluoroscopy modalities, the underlying theme is a comparative evaluation of the dose -- Peak Skin Dose (PSD), Dose Area Product (DAP), Kerma Area Product (KAP), Dose Length Product (DLP) -- in the different fluoroscopy procedures (DSA, CINE, HDR Fluoroscopy, CBCT, etc). In one case, they show how motion artifact can render DSA images less useful. They share cautionary remarks on use of lead shielding, anti-scatter grids, and high dose rate image acquisition modalities.

The approach is highly engaging and keeps the audience's attention. A section on strategies to reduce dose to the physicians and staff, a discussion of frames per second and pulses per second, dose rate versus field size, and proper uses of low dose and high dose rate modes could be useful.

Chapter 2: Mammography by Ingrid S. Reiser.
With the refinement of digital detector technologies, mammography has made significant advances. Dr. Reiser describes this modality as the unique modality that is "dedicated to and optimized for a single anatomy." This chapter primarily deals with presenting cases where artifacts are seen due to patient positioning, patient motion, detector or detector-row dropout, other detector artifacts showing as micro-calcifications, imperfection in compression paddles, and other artifacts due to presence of heart-assist devices. There is also a section on the selection of technique factors in light of patient thickness to reduce Average Glandular Dose (AGD) and optimize image contrast.

While the emphasis on artifacts in mammograms cannot be overstated, it would have been nice to add a section discussing typical dose levels in mammography, resolution and low-contrast detectability levels, statistics on specificity (False-Positive and True-Negative), and perhaps a whole section on tomosynthesis would be helpful. The latter is clearly a lead-in to the next chapter.

Chapter 3: Computed Tomography by Karen L. Brown and Jason R. Gold.
Computed tomography calculates the attenuation coefficient μ of each voxel in a patient relative to that of water, μ_w. The CT number of each pixel in Hounsfield unit is defined as CT # (HU) = 1000 x (μ - μ_w) /μ_w. This number associated to each pixel in the image provides a gray level that is adjusted by the window width and level on the monitor. In this chapter the authors describe the ring, beam hardening, partial volume, and metal and motion artifacts and provide typical images showing these artifacts. In addition, in treating dose in CT (CT Dose Index ($CTDI_{vol}$)) and Dose-Length Product (DLP)) they provide a nice discussion of the effect of kV on image quality and dose, relationship of $CTDI_{vol}$ and patient size, and image quality variation with slice thickness and reconstruction filter.

While the discussion is quite complete, a brief discussion of the geometry of CT machines, helical versus axial reconstruction methods, and a brief discussion of dual energy CT units can be added.

Chapter 4: Magnetic Resonance Imaging by Puneet Sharma.
Magnetic Resonance imaging is a (relatively) newer mode of imaging that is revolutionizing diagnostic radiology due to its ability to provide unparalleled contrast between different tissue types. With the rapid development of new reception technologies, pulse-echo sequences and pre- and post-processing techniques leading to better signal-to-noise ratio and reduced scanning times, this modality will largely replace many other radiographic exams. The artifacts demonstrated in the case-by-case studies here include motion artifacts (ghosting), high signal intensity artifact leading to "pile-up" affecting visualization of surrounding structures, aliasing leading to extra anatomy superimposed on the primary anatomy, edge ripple (Gibbs phenomenon) that can be "presumed to be motion" artifacts, chemical shift artifact leading to dark etching between soft tissue and fat interfaces, effect of field inhomogeneity or poor shimming within FOV on fat suppression protocols, signal-to-noise variation in FOV and flow-related contrast issues.

While there is a masterful choice of artifacts demonstrated here, the complicated discussion of pulse-echo sequences, k-space filling of signals, T1, T2, T2* and proton density weightings, frequency and phase encoding, and discrete Fourier transform cut-off leading to aliasing artifacts will certainly leave the audience gasping for air. With the prevalence of contrast studies, chemical shifts, spin echo versus gradient echo sequences, some additional comments on their specific uses could direct the reader to further sources.

Chapter 5: Nuclear Medicine by Jonathon A. Nye, James R. Galt and John N. Aarsvold.
Nuclear medicine differs from other modes of radiology in that planar projections and tomographic images are constructed from radionuclides administered to patients. Data collection is "photon starved" leading to substantially lower signal to noise ratio, grainy images, and considerations such as geometry, energy gating, collimation, detector inhomogeneity and many other factors leading to degradation of image contrast and spatial resolution. Due to the above factors many forms of artifacts may arise here. The authors demonstrate artifacts due to geometry, positron range in FDG imaging (PET), patient motion, attenuation correction errors, images formed from incorrect choice of collimators, poor camera positioning relative to the patient, and improper reconstruction parameters and energy discrimination. There are also two sections outlining how parallel processing is used and how smoothing is used to improve contrast through a reduction in statistical noise.

The choice of artifacts here are comprehensive and include 2D and 3D nuclear medicine imaging including gamma cameras (single-head and multi-head), SPECT and PET cameras. The discussion of data acquisition and image formation are quite brief. A discussion of dose and data acquisition time may be useful in rationalizing the question of data starvation. Some discussion of typical expected resolution could also be helpful.

Chapter 6: Ultrasound Imaging by Zheng Feng Lu.
Due to its low cost and safety, ultrasound imaging is used extensively in radiology. In this section the author summarizes the myriad of issues that can lead to artifacts or incorrect measurements of distances in B-mode ultrasound images. These are errors arising from a "constant speed of sound" assumption, artifacts due to transducer element dropout, effect of controls (transmit power, gain, time gain compensation, dynamic range) on appearance of images, reverberation artifacts, range ambiguity and shadowing, and doppler imaging aliasing. The author also adds a brief section on harmonic imaging and its advantages and differences in the appearance of images based on monitor luminance.

The discussion here is quite complete. If we had to add something, we would provide some quantitative information and how the artifacts could degrade that information. Some of this could include a brief discussion of signal-to-noise, typical tissue attenuation coefficients as a function of frequency, resolution versus depth, low contrast detectability and acceptable levels of screen luminance.

Chapter 7: Image Processing by Jonathon A. Nye and Randahl C. Palmer.
In this chapter, which departs both in format and intent from the other chapters, the authors discuss a few image processing techniques used to either highlight specific features in images (edge filters, bandpass filters, maximum intensity projection for PET), and a few multi-modalities

(fused imaging) to enhance specificity and sensitivity to specific features/pathologies.

In conclusion, this book presents a novel and highly useful model to excite radiologists-in-training to caveats of different modalities of diagnostic imaging and to alert them to artifacts that may arise and their causes. The discussion is tailored to cover the most important issues in a very limited time, perhaps at the cost of covering more physics, instrumentation, image acquisition and formation concepts. The list of 20 or so review questions at the end of each section is a wonderful resource for both the teachers and students. We definitely recommend this text for teaching the residents in diagnostic radiology.

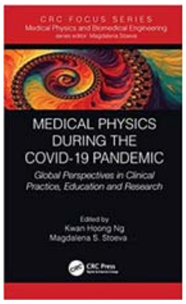
P.S. As a final remark, we would like to add that like most fields, radiological physics has become full of acronyms. The author(s) are well-served by posting a page online or adding an index of acronyms to each chapter (or to the entire book) to identify these acronyms and make the task of the reader browsing through the book easier.

Ngoneh Jallow and Farhad Jafari
University of Minnesota, Department of Radiology

Book Review

MEDICAL PHYSICS DURING THE COVID-19 PANDEMIC
Global Perspective in Clinical Practice, Education and Research

Editors: Kwan Hoong Ng and Magdalena S Stoeva, ISBN: 978-0367693756, Part of CRC Focus Series in Medical Physics and Biomedical Engineering



This book shows the impact of COVID 19 on one whole profession – medical physics. The book has been written during the pandemic and collects the experience of leading specialists in continuing the delivery of their professional activities. The Editors have made a very suitable structure giving a real picture of the overall activities in one profession.

The chapters and their authors are;

-Consolidating Wisdom from Diverse Talents (Kwan Hoong Ng, Magdalena Stoeva)

-Medical Physics Services in Radiation Oncology - Pandemic Trials and Tribulations (Tomas Kron, Richard Dove, Matthew Sobolewski, Swamidas V. Jamema, Mulape M. Kanduza, May Whitaker)

-Adjustments to Nuclear Medicine Physics Services in Response to the Pandemic (Jim O'Doherty, Bruno Rojas, Carla Abreu, Maria Holstensson, Stefan Gabrielson, Rachael Dobson, Hsieh William, Dylan Bartholomeusz, Kevin Hickson, James Crocker, Kitiwat Khamwan, Yassine Toufique, Amal Guensi, Brahim Idbelkasl, Niall Colgan, David Lavin, Brendan Tuohy)

-Adapting in a Crisis - Radiology Medical Physics Service Provision during a Pandemic (Zoe Brady, James M. Kofler, Mika Kortesniemi, Kosuke Matsubara, Jose M. Fernandez-Soto, Yoon Yongsu, Kwan Hoong Ng)

-Education and Training during COVID-19 Pandemic - Lessons Learned and the Way Forward (Jeannie Hsiu Ding Wong, Annette Haworth, Ana Maria Marques da Silva, Vassilka Tabakova, Kwan Hoong Ng)

-Role of Medical Physicists in Scientific Research during COVID-19 Pandemic - Switching to the "New Normal" (Magdalena Stoeva, Byungchul Cho, Azim Celik, Francis Hasford, Leidy Johana Rojas Bohorquez)

-IOMP's Global Perspectives for Medical Physics during the COVID-19 Pandemic (Magdalena Stoeva, Kwan Hoong Ng, John Damilakis, Madan M. Rehani)

-Medical Physics during the COVID-19 Pandemic -Global Perspectives—Asia-Pacific (Xiance Jin, Fu Jin, Hasin Anupama Azhari, Woo Sang Ahn, Cheryl Lian Ling Pei, Congying Xie, Hui-yu Tsai)

-Medical Physics during the COVID-19 Pandemic - Global Perspectives—Middle East (Huda Al Naemi, Mohammad H. Kharita, Meshari Al Nuaimi, Refat Al Mazrou, Rabih Hammoud, Zeina Elbalaa, Zakia Al Rahbi, Hanan Al Dosary, Ismail A. Abuawwad, Ibtesam Nasser Al-Maskari)

-Medical Physics during the COVID-19 Pandemic - Global Perspectives—Europe (Paddy Gilligan, Efi Koutsouveli, McClean Brendan, Carola Van Pul)

-Medical Physics during the COVID-19 Pandemic - Global Perspectives—Africa (Christoph Trauernicht, Francis Hasford, Taofeeq Abdallah Ige)

-Medical Physics during the COVID-19 Pandemic -Global Perspectives—North America (Brent C. Parker, David W. Jordan, Charles Kirkby, M. Saiful Huq)

-Medical Physics during the COVID-19 Pandemic - Global Perspectives—Latin America and the Caribbeans (Carmen Sandra Guzmán Calcina, Patricia Mora Rodríguez, Simone Kodlulovich Renha)

-Medical Physics Journals during the Time of COVID-19 - The Editor's Experience February–October 2020 (Slavik Tabakov, Perry Sprawls, Paolo Russo, Iuliana Toma-Dasu, Jamie Trapp, Michael D. Mills, Simon R. Cherry, Stoeva Magdalena)

-The Response of Medical Physics for World Benefit to the COVID-19 Crisis (Jacob Van Dyk, Parminder Basran, Robert Jeraj, Yakov Pipman, L. John Schreiner, David Wilkins)

-Early Career Medical Physics Experience during the COVID-19 Pandemic - Experience and Perspectives from a

Medical Physics Leadership and Mentoring Program (Luiza Goulart, Louise Giansante, Lukmanda Evan Lubis, Iyobosa Uwadiae, Josilene C. Santos)

-Communicating Leadership in Adversity (David Yoong, Ray Kemp, Kwan Hoong Ng)

Each chapter is about 10 pages and presents specific activities, problems and solutions during the pandemic crisis. Special attention is given to the Regions of IOMP – professional reaction in various continents.
The book includes 91 contributors from 39 countries and will be a historic account of the impact of the COVID-19 virus on the field of one whole profession, related to healthcare - medical physics.

The collective opinion from educators, researchers and major medical physics journal editors-in-chief is presented, showing how the pandemic has affected the quality of these areas and related publications.

It is interesting to see the opinion of both established specialists and young colleagues with narratives of their experiences of coping with life during the pandemic. This is also linked with communicating leadership in times of adversity.

The book will be of interest to wide audience of readers from the fields of medical physics and other healthcare professionals, but also administrators and regulators.

The book will be an important reference and in future will surely be explored by specialist in science history and sociology.

Reviewed by:
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Reviewed by:
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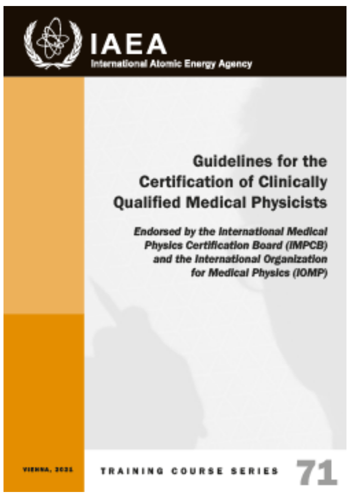
Book Review

IAEA TCS 71: GUIDELINES FOR THE CERTIFICATION OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS

IAEA ISSN 1018–5518, 2021



This IAEA Guide is an important addition to the existing IAEA TCS 56 Guide Postgraduate Medical Physics Academic Programmes, 2013.

The Guide highlights the need for medical physics certification and shows its benefits. It also provides information on the establishment of national or regional certification schemes.

The Guide is 34 pages and has the following structure:
1.Introduction
2.Terminology
2.1.Medical Physics Professionals
2.2.Other Relevant Terminology
3. Certification Frameworks
3.1. Benefits of the Certification Of Clinically Qualified Medical Physicists
3.2 The Scope of the Medical Physics Profession
3.3. General Requirements for Medical Physics Certification
3.4. Documentation Required for Certification
3.5. Assessment Process of Candidates by the Certification Body
3.6. Ethics and Data Security
4. Establishing a Certification Process
4.1. Equivalence of Certification
4.2. Pathways Towards the Establishment of a Certification Body: Availability Of Professionals
4.3. Establishing a Certification Body
4.4. Factors Affecting the Sustainability of a Certification Body
5. Maintaining Certification
5.1. Registry
5.2. Continuing Professional Development Process
5.3 Re-Certification
6. Conclusions

The Guide includes definitions of medical physics professionals from various organisations. It also presents Framework for Certification as well as its benefits for medical physicists.

The requirements for certification are listed, including the necessary documents. These are further complemented by description of the assessment process related to certification. The certification process is very well described, including the pathway for establishing a Certification Body (supported by a flowchart of the necessary steps). Further the factors for sustainability of a Certification Body are listed.

The Guide describes the maintenance of registration – Register and CPD process, supported by a possible system of categories for CPD. The re-certification is also included.
The Guide includes an Appendix with examples for Certification Application Forms and references.

The Guide has been developed by IAEA in collaboration with established specialists from various Regional Organisations of IOMP.

The contributors to the Guide are:
Azangwe, G. National University of Science and Technology, Zimbabwe
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Ravindran, P. Christian Medical College, India
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The Guide has been endorsed by the International Medical Physics Certification Board (IMPCB) and the International Organization for Medical Physics (IOMP). It can be downloaded from:
https://www.iaea.org/publications/14746/guidelines-for-the-certification-of-clinically-qualified-medical-physicists

The IAEA TCS 71 is an excellent publication which will be of great importance for the further global development of medical physics.

I was very happy to be part of the first meeting of the project in May 2018.

Reviewed by:
Slavik Tabakov, PhD, Dr h.c., FIPEM, FHEA, FIOMP, FIUPESM, Vice-President IUPESM, Past President IOMP, King’s College London, UK

INFORMATION FOR AUTHORS

PUBLICATION OF DOCTORAL THESIS AND DISSERTATION ABSTRACTS

A special feature of Medical Physics International (on line at www.mpijournal.org) is the publication of thesis and dissertation abstracts for recent graduates, specifically those receiving doctoral degrees in medical physics or closely related fields in 2010 or later. This is an opportunity for recent graduates to inform the global medical physics community about their research and special interests.

Abstracts should be submitted by the author along with a letter/message requesting and giving permission for publication, stating the field of study, the degree that was received, and the date of graduation. The abstracts must be in English and no longer than 2 pages (using the MPI manuscript template) and can include color images and illustrations. The abstract document should contain the thesis title, author's name, and the institution granting the degree.

Complete information on manuscript preparation is available in the INSTRUCTIONS FOR AUTHORS section of the online journal: www.mpijournal.org.

For publication in the next edition abstracts must be submitted not later than Април 1, 2019.

INSTRUCTIONS FOR AUTHORS

The goal of the new IOMP Journal Medical Physics International (http://mpijournal.org) is to publish manuscripts that will enhance medical physics education and professional development on a global basis. There is a special emphasis on general review articles, reports on specific educational methods, programs, and resources. In general, this will be limited to resources that are available at no cost to medical physicists and related professionals in all countries of the world. Information on commercial educational products and services can be published as paid advertisements. Research reports are not published unless the subject is educational methodology or activities relating to professional development. High-quality review articles that are comprehensive and describe significant developments in medical physics and related technology are encouraged. These will become part of a series providing a record of the history and heritage of the medical physics profession.

A special feature of the IOMP MPI Journal will be the publication of thesis and dissertation abstracts for will be the publication of thesis and dissertation abstracts for recent doctoral graduates, specifically those receiving their doctoral degrees in medical physics (or closely related fields) in 2010 or later.

MANUSCRIPT STYLE

Manuscripts shall be in English and submitted in WORD. Either American or British spelling can be used but it must be the same throughout the manuscript. Authors for whom English is not their first language are encouraged to have their manuscripts edited and checked for appropriate grammar and spelling. Manuscripts can be up to 10 journal pages (approximately 8000 words reduced by the space occupied by tables and illustrations) and should include an unstructured abstract of no more than 100 words.

The style should follow the template that can be downloaded from the website at:
http://mpijournal.org/authors_submitapaper.aspx

ILLUSTRATIONS SPECIAL REQUIREMENTS

Illustrations can be inserted into the manuscript for the review process but must be submitted as individual files when a manuscript is accepted for publication.

The use of high-quality color visuals is encouraged. Any published visuals will be available to readers to use in their educational activities without additional approvals.

REFERENCE WEBSITES

Websites that relate to the manuscript topic and are sources for additional supporting information should be included and linked from within the article or as references.

EDITORIAL POLICIES, PERMISSIONS AND APPROVALS

AUTHORSHIP

Only persons who have made substantial contributions to the manuscript or the work described in the manuscript shall be listed as authors. All persons who have contributed to the preparation of the manuscript or the work through technical assistance, writing assistance, financial support shall be listed in an acknowledgements section.

CONFLICT OF INTEREST

When they submit a manuscript, whether an article or a letter, authors are responsible for recognizing and disclosing financial and other conflicts of interest that might bias their work. They should acknowledge in the manuscript all financial support for the work and other financial or personal connections to the work.

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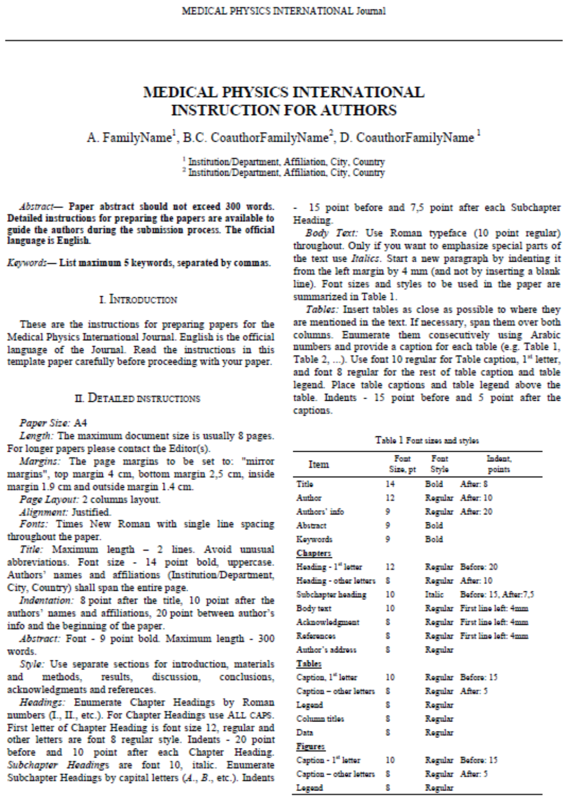
MEDICAL PHYSICS INTERNATIONAL Journal

MEDICAL PHYSICS INTERNATIONAL
INSTRUCTION FOR AUTHORS

A. FamilyName[1], B.C. CoauthorFamilyName[2], D. CoauthorFamilyName[1]

[1] Institution/Department, Affiliation, City, Country
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Abstract— **Paper abstract should not exceed 300 words. Detailed instructions for preparing the papers are available to guide the authors during the submission process. The official language is English.**

Keywords— **List maximum 5 keywords, separated by commas.**

I. INTRODUCTION

These are the instructions for preparing papers for the Medical Physics International Journal. English is the official language of the Journal. Read the instructions in this template paper carefully before proceeding with your paper.

II. DETAILED INSTRUCTIONS

Paper Size: A4

Length: The maximum document size is usually 8 pages. For longer papers please contact the Editor(s).

Margins: The page margins to be set to: "mirror margins", top margin 4 cm, bottom margin 2,5 cm, inside margin 1.9 cm and outside margin 1.4 cm.

Page Layout: 2 columns layout.

Alignment: Justified.

Fonts: Times New Roman with single line spacing throughout the paper.

Title: Maximum length – 2 lines. Avoid unusual abbreviations. Font size - 14 point bold, uppercase. Authors' names and affiliations (Institution/Department, City, Country) shall span the entire page.

Indentation: 8 point after the title, 10 point after the authors' names and affiliations, 20 point between author's info and the beginning of the paper.

Abstract: Font - 9 point bold. Maximum length - 300 words.

Style: Use separate sections for introduction, materials and methods, results, discussion, conclusions, acknowledgments and references.

Headings: Enumerate Chapter Headings by Roman numbers (I., II., etc.). For Chapter Headings use ALL CAPS. First letter of Chapter Heading is font size 12, regular and other letters are font 8 regular style. Indents - 20 point before and 10 point after each Chapter Heading. *Subchapter Headings* are font 10, italic. Enumerate Subchapter Headings by capital letters (*A.*, *B.*, etc.). Indents - 15 point before and 7,5 point after each Subchapter Heading.

Body Text: Use Roman typeface (10 point regular) throughout. Only if you want to emphasize special parts of the text use *Italics*. Start a new paragraph by indenting it from the left margin by 4 mm (and not by inserting a blank line). Font sizes and styles to be used in the paper are summarized in Table 1.

Tables: Insert tables as close as possible to where they are mentioned in the text. If necessary, span them over both columns. Enumerate them consecutively using Arabic numbers and provide a caption for each table (e.g. Table 1, Table 2, ...). Use font 10 regular for Table caption, 1st letter, and font 8 regular for the rest of table caption and table legend. Place table captions and table legend above the table. Indents - 15 point before and 5 point after the captions.

Table 1 Font sizes and styles

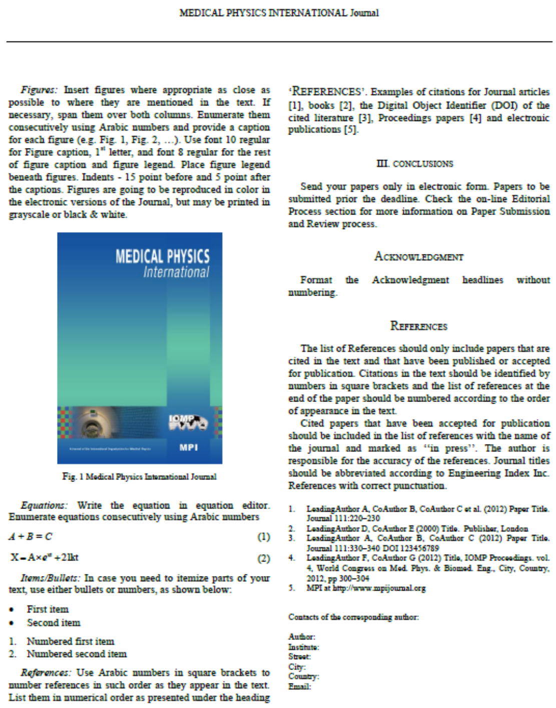
Item	Font Size, pt	Font Style	Indent, points
Title	14	Bold	After: 8
Author	12	Regular	After: 10
Authors' info	9	Regular	After: 20
Abstract	9	Bold	
Keywords	9	Bold	
Chapters			
Heading - 1st letter	12	Regular	Before: 20
Heading - other letters	8	Regular	After: 10
Subchapter heading	10	Italic	Before: 15, After:7,5
Body text	10	Regular	First line left: 4mm
Acknowledgment	8	Regular	First line left: 4mm
References	8	Regular	First line left: 4mm
Author's address	8	Regular	
Tables			
Caption, 1st letter	10	Regular	Before: 15
Caption – other letters	8	Regular	After: 5
Legend	8	Regular	
Column titles	8	Regular	
Data	8	Regular	
Figures			
Caption - 1st letter	10	Regular	Before: 15
Caption – other letters	8	Regular	After: 5
Legend	8	Regular	

SUBMISSION OF MANUSCRIPTS

Manuscripts to be considered for publication should be submitted as a WORD document to: Slavik Tabakov, Co-editor: slavik.tabakov@emerald2.co.uk

MANUSCRIPT PROPOSALS

Authors considering the development of a manuscript for a Review Article can first submit a brief proposal to the editors. This should include the title, list of authors, an abstract, and other supporting information that is appropriate. After review of the proposal the editors will consider issuing an invitation for a manuscript. When the manuscript is received it will go through the usual peer-review process.


MEDICAL PHYSICS INTERNATIONAL Journal

Figures: Insert figures where appropriate as close as possible to where they are mentioned in the text. If necessary, span them over both columns. Enumerate them consecutively using Arabic numbers and provide a caption for each figure (e.g. Fig. 1, Fig. 2, ...). Use font 10 regular for Figure caption, 1st letter, and font 8 regular for the rest of figure caption and figure legend. Place figure legend beneath figures. Indents - 15 point before and 5 point after the captions. Figures are going to be reproduced in color in the electronic versions of the Journal, but may be printed in grayscale or black & white.

Fig. 1 Medical Physics International Journal

Equations: Write the equation in equation editor. Enumerate equations consecutively using Arabic numbers

$$A + B = C \quad (1)$$

$$X = A \times e^{st} + 2lkt \quad (2)$$

Items/Bullets: In case you need to itemize parts of your text, use either bullets or numbers, as shown below:

- First item
- Second item

1. Numbered first item
2. Numbered second item

References: Use Arabic numbers in square brackets to number references in such order as they appear in the text. List them in numerical order as presented under the heading 'REFERENCES'. Examples of citations for Journal articles [1], books [2], the Digital Object Identifier (DOI) of the cited literature [3], Proceedings papers [4] and electronic publications [5].

III. CONCLUSIONS

Send your papers only in electronic form. Papers to be submitted prior the deadline. Check the on-line Editorial Process section for more information on Paper Submission and Review process.

ACKNOWLEDGMENT

Format the Acknowledgment headlines without numbering.

REFERENCES

The list of References should only include papers that are cited in the text and that have been published or accepted for publication. Citations in the text should be identified by numbers in square brackets and the list of references at the end of the paper should be numbered according to the order of appearance in the text.

Cited papers that have been accepted for publication should be included in the list of references with the name of the journal and marked as ''in press''. The author is responsible for the accuracy of the references. Journal titles should be abbreviated according to Engineering Index Inc. References with correct punctuation.

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2. LeadingAuthor D, CoAuthor E (2000) Title. Publisher, London
3. LeadingAuthor A, CoAuthor B, CoAuthor C (2012) Paper Title. Journal 111:330–340 DOI 123456789
4. LeadingAuthor F, CoAuthor G (2012) Title, IOMP Proceedings. vol. 4, World Congress on Med. Phys. & Biomed. Eng., City, Country, 2012, pp 300–304
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