

MEDICAL PHYSICS *International*

EDITORIALS

THE SECOND EDITION OF THE ENCYCLOPAEDIA OF MEDICAL PHYSICS AND BRIEF HISTORY OF ITS DEVELOPMENT

DEVELOPING VALUABLE PHYSICS KNOWLEDGE FOR RADIOLOGY RESIDENTS

EQUIPPING MEDICAL PHYSICISTS WITH ARTIFICIAL INTELLIGENCE KNOWLEDGE AND CODING SKILLS

ACOMP PROFESSIONAL COURSE 2021: RADIOBIOLOGY IN THE ERA OF PRECISION MEDICINE

Physica Medica – current status and future perspectives

MEDICAL PHYSICS IN THE EFOMP REGION: HISTORY, EDUCATION, AND PROFESSIONAL RECOGNITION -

DENMARK, FRANCE, HUNGARY, LITHUANIA, MALTA, NORWAY, POLAND, SPAIN, SERBIA, SWEDEN, UKRAINE

MEFOMP 2021 VIRTUAL CONFERENCE: EXPANDING KNOWLEDGE AND MEETING CHALLENGES

Medical Physics History, Professional and Educational Development in Pakistan

EMBRACING ULTRASOUND QUALITY CONTROL

TEST OBJECTS AND METHODS FOR VISUAL ASSESSEMENT OF THE GAMMA CAMERA INTRINSIC RESOLUTION

Impact of Covid-19 outbreak on radiotherapy of cancer patients: Institutional experiences

The Modern Technology of Radiation Oncology (Volume 4)

Understanding and Optimizing Visibility in Medical Imaging Procedures Image Characteristics

ICTP - Abstracts Booklet of the MMP Thesis (6th cycle)



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

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EDITORIALS

Medical Physics International provides for the publication of manuscripts in several areas of medical physics other than peer-reviewed research reports that is the role of many other medical physics journals. In addition to major topics including developments in education, the evolving status of medical physics programs and organizations around the world, and reviews of scientific and technological advances, the journal is a major resource for the publication and preservation of articles on the history and heritage of medical physics and related medical applications. These articles are authored by many medical physicists whose careers

coincides with the significant developments in medical physics over the last half-century or more in which they provide valuable perspectives and experiences.

These articles are published in the Special History Series of Medical Physics International and can be accessed at: <http://www.mpijournal.org/history.aspx>

This special resource gives us the opportunity to learn about and appreciate our rich heritage and share it with students and future generations of medical physicists.

Perry Sprawls MPI Co-Editor-in-Chief

From its beginning 9 years ago the IOMP Journal Medical Physics International (MPI) aims to support education, training and global professional development of medical physics. During the past 3 years MPI issues were focussed on the development in the different Regional Organisations (Federations) of IOMP. The papers in these issues were following a specific template with topics to be discussed, thus forming a common background on which the various professional developments to be seen.

The MPI Dec 2018 issue presented general papers summarising the status in various Regional Organisations (RO) and Low-and-Middle Income (LMI) countries. These papers were related to the Workshop on LMI professional development held at WC2018, Prague.

The MPI June 2019 issue presented papers from Latin America - the ALFIM Region and some of its members – Brazil, Chile, Jamaica plus a large paper covering all NMOs from Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama). These papers were also associated with the ICMP 2019, held in Chile. Additionally, papers related to some professional research topics in ALFIM were published. This MPI issue also presented a paper from C Orton and M Giger about the history and achievements of the AAPM in North America.

The MPI Dec 2019 issue was dedicated to the 10th anniversary of FAMPO. The NMOs from Africa presented papers from: South Africa, Zimbabwe, Nigeria, Ghana, Morocco, Algeria, Tunisia, Egypt (in the following MPI issues were added papers from Zambia and Rwanda). Also, full papers from FAMPO and from the new African Journal on Medical Physics were published. Additionally, papers related to some professional research topics in FAMPO were presented. Dr Taofeeq Ige and Dr Francis Hasford from FAMPO were acting as MPI Contributing Co-Editors for this issue.

The MPI June 2020 issue was dedicated to the 20th anniversary of SEAFOMP. The NMOs from South-East Asia presented papers from: Vietnam, Indonesia, Thailand, Philippines, Myanmar, Lao PDR. Also, full paper about SEAFOMP history was published. Additionally, papers related to some professional research topics in SEAFOMP were presented. Prof. Kwan Ng and Prof. Anchali Krisanachinda from SEAFOMP were acting as MPI Contributing Co-Editors for this issue.

The MPI Dec 2020 issue was dedicated to the 20th anniversary of AFOMP. The NMOs from Asia-Oceania Region presented papers from: Australia and New Zealand, Bangladesh, Japan, India, Korea, Malaysia, Mongolia, Nepal, Philippines, Singapore, Thailand (and later Pakistan in 2021). Also, full paper about AFOMP history was published. Additionally, papers related to some professional research topics in AFOMP were presented. Prof. Arun Chougule, Prof. Eva Bezak and Prof. Anupama Azhari from AFOMP were acting as MPI Contributing Co-Editors for this issue.

The MPI June 2021 issue was from the MEFOMP Region. The NMOs from the Middle East Region, presented papers from: Iraq, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, Yemen. Also, full paper about MEFOMP history was published. Additionally, paper related to the virtual MEFOMP Conference is presented in MPI Dec 2021. Dr Huda al-Naemi and Dr Mohammad Hassan Kharita from MEFOMP were acting as MPI Contributing Co-Editors for this issue.

The MPI Dec 2021 issue presented here is related to the EFOMP Region and celebrates its 40th anniversary. The NMOs from the European Region presented papers from: Denmark, France, Hungary, Lithuania, Malta, Norway, Poland, Spain, Serbia, Sweden, Ukraine. Also, full paper about EFOMP history is prepared for publication, as well as a paper from the EFOMP Journal *Physica Medica*. Prof. David Lurie, Dr Efi Koutsouveli and Prof. Paddy Gilligan from EFOMP are acting as MPI Contributing Co-Editors for this issue. As a summary, 265 pages of papers related to the professional development, history and future plans from 60 countries and 6 regional organisations were published in the MPI Journal for the past 4 years. These present a very good picture to support the global development of medical physics and the potential for its growth towards the expected 60,000 medical physicists globally by 2035.

We would like to thank all authors, all Contributing Co-Editors and the Technical Editor Prof. Magdalena Stoeva, who supported this important activity. We are using this opportunity to wish all of them a Good, Healthy and Prosperous New Year 2022!

Slavik Tabakov, MPI Co-Editor-in-Chief

EDUCATIONAL TOPICS

THE SECOND EDITION OF THE ENCYCLOPAEDIA OF MEDICAL PHYSICS AND BRIEF HISTORY OF ITS DEVELOPMENT

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Abstract

The paper describes the second Edition of the Encyclopaedia of Medical Physics - published by CRC (Taylor and Francis Group) at the end of 2021. This new edition is about 25% updated and in the next MPI Journal (May 2022) we shall explain in detail the updates.

The paper also describes the road of the Encyclopaedia idea – a huge project which development started some 25 years ago.

THE FIRST STEPS

The need of an Scientific Dictionary and Encyclopaedia of Medical Physics emerged from the practical application of our first e-learning materials EMERALD (developed in the period 1995-1998) [1]. These materials aimed at support for medical physics training (e-books and Image Databases). These were the first e-learning materials in medical physics and consisted of training tasks covering the physics of: X-ray Diagnostic Radiology, Nuclear Medicine and Radiotherapy, supported with an educational image database with over 1000 images. These materials were engraved on a CD – the second CD-ROM with ISBN number in the world.

These materials were first tested (in the period 1996-1999) at the ICTP College on Medical Physics and at the new MSC in Medical Physics at Plovdiv (developed in Bulgaria through our project ERM). The EMERALD materials were written in English and it was obvious that their use by the large community of international students would be facilitated by a Scientific Dictionary of Medical Physics Terms. This idea was also supported by the delegates of the First International Conference on Medical Physics Training, which we organised in 1998 at ICTP, Trieste, Italy. Developing a Dictionary, required the development of a Thesaurus, which was also the basis of an Encyclopaedia. This way we decided for both future projects (Scientific Dictionary and Encyclopaedia) to be developed together [1].

Our next project EMERALD – INTERNET ISSUE (EMERALD II, 1999-2000) developed the first educational web site in medical physics (now www.emerald2.eu) [1]. This activity assured us that the idea about an Encyclopaedia PLUS Scientific Dictionary will have to be developed initially as an open-access e-Encyclopaedia (at that time Wikipedia did not yet exist). Naturally, this was an extremely complex endeavour and it required careful planning in several phases, which will be summarized here below.

I. THE THESAURUS AND THE SCIENTIFIC DICTIONARY

Phase 1 of the large Encyclopaedia with Dictionary project was to develop a Thesaurus – a bank of necessary scientific terms. This task, plus the first steps of the Scientific Dictionary, was included in our next project EMIT (2001-2003), which widened the scope of the training materials created in project EMERALD [1].

EMIT added Ultrasound and MR Imaging training modules. It also planned to develop a Thesaurus and translate it initially in 5 European languages: English, French, German, Italian and Swedish (the languages were related to the members of the EU project Consortium).

Phase 2 – during this phase an original system for the Dictionary development was created, which uses Identification numbers (ID) for each term from the Thesaurus. This was necessary for the cross-translation between any of the languages in the Multilingual Scientific Dictionary. In this system, all translations to various languages were based on the IDs of the English terms from the Thesaurus. Phase 2 continues from that time gradually adding new languages to the Dictionary [2,3].

Groups of translators were formed for each language, usually including specialists in the main fields of the profession (Physics of: X-ray Diagnostic Radiology, Nuclear Medicine, Radiotherapy, Ultrasound Imaging, Magnetic Resonance Imaging, Radiation Protection). General terms were covered by all translators (mainly terms related to relevant frequently-used terminology from physics, mathematics, medicine, etc).

After several updates and consolidation, the Thesaurus reached 3500 terms by 2003. The Thesaurus and first-edit Scientific Dictionary were engraved on a mini-CD and distributed for free at the World Congress on Medical Physics and Biomedical Engineering in Sydney, Australia (2003). The need for a Dictionary triggered another wave of demands for additional translations, while some Asian countries even used our Dictionary CD as catalyst to create their own national Dictionaries to/from English. Later we developed a special web site for the Dictionary, which worked some 10 years and was merged with the web site of the e-Encyclopaedia.

The value of this Multilingual Scientific Dictionary was underlined by the delegates of the First International

Conference on e-Learning in Medical Physics, which we organised in November 2003 in ICTP Trieste. Further our unique Scientific Dictionary of Medical Physics Terms played a significant role in selecting the project among almost 500 applications for the coveted EU Award for vocational training – the Leonardo Da Vinci Award. The project was the first to receive this Award (in Maastricht, 2004) [1]. This Award added a lot for the visibility of our profession – medical physics.

The full development of the Thesaurus and the Scientific Dictionary were described earlier in MPI [2,3].

II. THE ENCYCLOPAEDIA DEVELOPMENT

Phase 3 – in this period was the development of the entries/articles for the Encyclopaedia of Medical Physics. The phase was based on the already developed Thesaurus. This phase was made as a consecutive EU project- EMITEL (2005-2009) supported by the core of the previous partners and also colleagues from all over Europe and other countries associated with the IOMP [1].

There were no guides on how to develop Dictionary or Encyclopaedia and we created original methodology for this. First was important to establish what type of Encyclopaedia was to be created. A number of specialist Encyclopaedias include a relatively small number of large articles plus an extensive Index of terms, mentioned in the articles. Other Encyclopaedias consist of a large number of small articles - these are easier to search and update, however such Encyclopaedias are more difficult to organise as they include many Authors, many entries and many Reviewers. A well-known general knowledge Encyclopaedia with large number of small articles is Larousse.

As we already had the Multilingual Scientific Dictionary, based on our Medical Physics Thesaurus, it was logical to accept the second design (with a large number of small articles). This was also suitable as a Reference in the dynamic profession of Medical Physics, where updates would be necessary quite often. This concept was also used by Wikipedia, which at that time was gaining popularity.

It was agreed that the level of the Encyclopaedic entries should be at Master level and above (MSc, or equivalent, which is usually the case for most medical physics university courses around the world). Being linked with the previous educational projects, EMITEL included a number of images from their image databases. The Encyclopaedia – First Edition was developed with around 2800 full articles/entries (all entries were written in English).

The coordination of such a huge project was extremely complex, as the articles/entries were developed by seven Groups working in parallel. These were Groups in Medical Physics of: X-ray Diagnostic Radiology, Nuclear Medicine, Radiotherapy, Ultrasound Imaging, Magnetic Resonance Imaging, Radiation Protection and General terms (Fig.2).

A special system was developed to organise the large amount of entries, each with its own text, image files and

other data (Fig.1). For ease of reference, we kept the ID numbers of the entries identical to those in the Dictionary and each Entry file had to go through several stages of reviewing. The internal process of reviewing included not only the authors and reviewers, but also the users of our materials – the students.

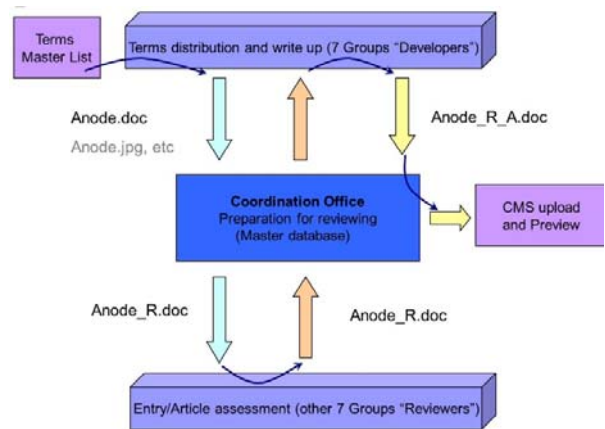


Fig.1 System for file name changes during the various steps of Encyclopaedia development

Phase 4 was created in parallel to Phase 3. This was the development of the web database and the web site to host the e-Encyclopaedia. The web site was created and maintained by our IT partner AM Studio (M Stoeva and A Cvetkov). The web site was made with a user-friendly and flexible structure, and crucially with our own design, not based on external templates. All our educational web sites were purpose built without external software and have been running non-stop since their creation. It is important to note that the longevity of any such product is affected by updates of third-party software. The original web site built by our project serves flawlessly the profession for over 10 years. The web site was built with its own Content Management System (CMS) to allow easy future updates [4].

The main validation of the Encyclopaedia at the International Conference (ICTP, Trieste, 2008) included 21 present and past Presidents of Medical Physics Societies. Further this was validated also at a Topical Workshop at the World Congress on Medical Physics and Biomedical Engineering in Munich, Germany (2009). All participants had online access to the Encyclopaedia and expressed their appreciation of the usefulness of the project. The feedback from these events was implemented in the final editing of the materials made in early 2010. With this the EU project was completed.

In parallel to all this, Phase 2 (translations of the Scientific Dictionary terms) continued with full speed and by 2009 the number of languages increased to 27 (in 9 alphabets): Arabic, Bengal, Bulgarian, Chinese, Croatian, Czech, English, Estonian, French, German, Greek, Hungarian, Italian, Japanese, Latvian, Lithuanian, Malaysian, Persian, Polish, Portuguese, Romanian, Russian, Slovenian, Spanish,

Swedish, Thai and Turkish. Many of these translations were made by former attendees to the ICTP College on Medical Physics.

The huge parallel coordination of so many simultaneous contributions to the Encyclopaedia and to the Dictionary by various Workgroups from many countries was made by the Project Manager and Coordinator (S Tabakov) and the Network Coordinator (V Tabakova), who devoted their spare time to the project (Fig.2). This activity was the largest international project in the profession, its results being used by thousands of colleagues each month.

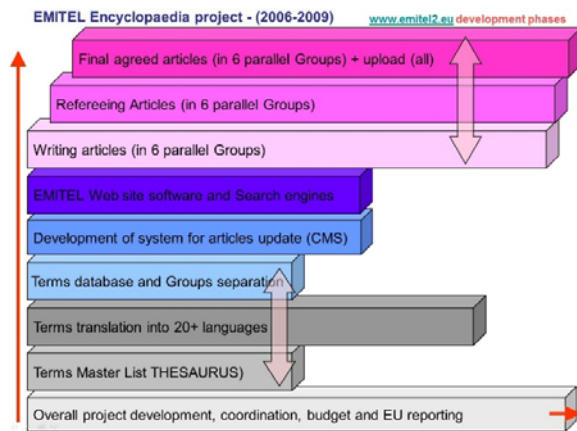


Fig.2 Phases of the Encyclopaedia and Dictionary development

In order to combine the Encyclopaedia entries (in English) with the Multilingual Dictionary, the website (www.emitel2.eu) was extended and was equipped with two search engines – one multilingual (for the Dictionary) and one in English (to search inside the text of the entries). This activity was made by M Stoeva and A Cvetkov. The fact that the Internet browsers at that time were already supporting various alphabets was very important for the work of the Dictionary.

III. FURTHER DEVELOPMENT OF THE ENCYCLOPAEDIA

Phase 5 of the Encyclopaedia (2010 – 2013) was a self-funded independent project. Its aim was to support and update the Encyclopaedia, including preparations for a paper print of the encyclopaedic entries by CRC Press.

The main CRC paper print phase was carried by the Coordination office of the Encyclopaedia and the first Editors - S Tabakov, F Milano, S-E Strand, C Lewis, P Sprawls and Editorial Assistant V Tabakova (all of them members of the previous projects). This activity underwent another editing of the content (together with CRC Press).

The CRC paper print was published in 2014 and a number of University Libraries included it in their catalogues [5]. Alongside this, the open-access web site continued to be used by colleagues from all over the world with thousands of users

per month especially from Low-and-Middle-Income (LMI) countries.

In the next several years the support for the Encyclopaedia update and web site was mainly through its coordination office. Another update of the Thesaurus and entries was made during this period and the Dictionary was enriched with 5 more languages - Finnish, Korean, Georgian, Ukrainian and Vietnamese. Currently the Multilingual Scientific Dictionary of Medical Physics Terms cross-translates in 32 languages (11 alphabets) [3].

Phase 6 was initiated in 2016 - also a self-funded independent project – preparing an update and second paper print of the e-Encyclopaedia by CRC Press. This phase was facilitated by a group of the active members of the initial stages of EMITEL. A new team of contributors was gathered to revise the existing material and to add new medical physics terms plus creating new encyclopaedic entries for these. This project was guided by the Encyclopaedia Editorial Board - S Tabakov (Chair), F Milano, M Stoeva, P Sprawls, S Tipnis, T Underwood - and was supported by many colleagues from various countries and by alumni from the MSc at King's College London.

This project phase also added new fields to the Encyclopaedia and the Scientific Dictionary – Non-Ionising Radiation Safety and Medical Equipment Management. 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) and also F Fedele, E Chaloner, E Iadanza and L Pecchia. The update resulted in over 650 new terms related to the new developments of medical physics. This phase was completed in 2020.

Phase 7 - The update of some of the existing encyclopaedic articles and the inclusion of the new articles formed a new phase, which required a further system for coordinating activities of the Editorial Board (Fig.3). In parallel continued the update of all 31 translations of the Scientific Dictionary, based on the updated Curriculum. This phase was completed in 2021 and the paper print was available at the end of the year [6]. Currently the Editorial team updates the free web site of the Encyclopaedia and the Dictionary www.emitel2.eu

After this update the Encyclopaedia of Medical Physics Second Edition includes over 3300 cross-referenced full entries related to medical physics and associated technologies. The materials are supported by over 1300 figures and diagrams. The Encyclopaedia also includes over 600 synonyms, abbreviations and other linked entries. The details of the updates of the Encyclopaedia will be described in the MPI issue May 2022.



Fig.3 Work with several computers for the synchronized update of the Encyclopaedia second edition

IV. CONCLUSION AND ACKNOWLEDGEMENTS

About 150 contributors from 30 countries took part in the development of the Encyclopaedia of Medical Physics through its various stages.

Additionally over 200 colleagues took part in the translations of the Multilingual Scientific Dictionary of Medical Physics Terms into various languages.

Despite the long period of time, many of these colleagues continue to be among the leading figures in the national and international medical physics fields, but some retired and some are no longer with us. All these colleagues made free contributions to this huge project (mostly in their spare time) in order to support the global development of medical physics.

As I developed and coordinated the described projects/phases, and invited personally most of these colleagues, I am truly grateful to each one. Given the numerous and frequent use of the results from our projects during the past 25 years, I am also sure, that most young medical physicists around the world appreciate highly and are grateful for this generous collegial contribution.

In the Website (www.emitel2.eu), we have listed all colleagues who contributed to the project for Encyclopaedia of Medical Physics and Multilingual Scientific Dictionary of Medical Physics Terms. The entire network of these colleagues from over 50 countries is a real example of international collaboration.

We gratefully acknowledge the contribution of all colleagues to this huge endeavour, the initial financial support from EU to the listed projects, and the support from various institutions and organisations.

Medical Physics is a dynamic profession – in the past decades it changed dramatically and will continue to grow and develop. The constant introduction of new methods and equipment will require constant update of medical physics education. This will undoubtedly be reflected in the future

updates of the Encyclopaedia with Dictionary, as one of the main reference resources of the profession, supporting our educational activities, and also as evidence of the important contribution of medical physics to healthcare.

V. ENCYCLOPAEDIA CONTRIBUTORS

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DEVELOPING VALUABLE PHYSICS KNOWLEDGE FOR RADIOLOGY RESIDENTS

Perry Sprawls

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Abstract— Physics is the foundation science of radiology and medical imaging. A comprehensive conceptual knowledge is required to enable physicians, especially radiologists to obtain required diagnostic information with the various imaging modalities and methods. The visibility provided by each image is determined and controlled by a combination of image characteristics that depends on the selected imaging modality, method, and procedure protocol factors. A set of educational resources have been developed and provided here that can be used by medical physicists teaching in radiology residency programs. It provides residents with physics knowledge that is needed early in the residency program and develops interest and appreciation for additional physics instruction.

Keywords— Controlling image Visibility, Teaching Radiologists, Perceptions of Physics.

I. INTRODUCTION

Medicine, as practiced by physicians, is the application of science along with clinical knowledge and experience to prevent, detect, diagnose, and manage the treatment of diseases, conditions, and injuries for the benefit of society. Each of the sciences is supported by professional scientists with that specialization who conduct research, support clinical applications, and teach other medical professionals including physicians. Examples of these sciences include anatomy, physiology, microbiology, epidemiology, and **physics**.

Physics is the foundation science of radiology and radiologists require a comprehensive knowledge of physics to support clinical activities, especially when using the modern and often complex imaging modalities and methods.

II. PHYSICS EDUCATION FOR RADIOLOGY RESIDENTS

During residency programs radiologists learn the physics of medical imaging that is taught by medical physicists. These courses for radiology residents might vary among institutions and countries but often follow a curriculum developed by professional organizations and requirements for program certifications.

These curricula generally provide a comprehensive coverage of physics, but they face a variety of challenges and perceptions including the following:

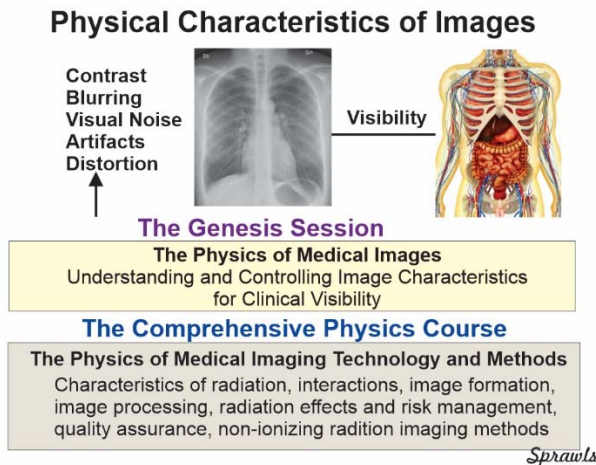
- Physics does not relate to real clinical radiology
- Physics is boring
- Physics classes interfere with clinical activities and learning
- The only reason to learn physics is to pass the certification examinations
- Physics teachers do research and physics things but do not understand clinical radiology
- Some radiology faculty consider physics classes an interference with clinical activities that should not be in the normal daily schedule.

These are issues that must be considered by medical physics educators in providing physics education for radiology residents. A general principle of effective education is to provide learning opportunities at the time and place where they are needed to perform specific functions, for example in performing medical imaging procedures. For radiologists this includes an understanding of the *physical characteristics of medical images* that affect clinical visibility and how to control and optimize image characteristics through the selection of imaging modalities, methods, and especially the procedure protocol factors. That

knowledge is developed throughout a residency program but is most effective if a foundation of specific physics knowledge is developed at the beginning of the program.

III. THE GENESIS SESSIONS

That can be achieved with the initiative described here--a "short course" designated as the *Genesis Sessions*. It is not a replacement for the comprehensive physics course but supports it by developing an interest and appreciation for physics by the residents, and it demonstrates the value of medical physicists in the practice of radiology as illustrated here.



A medical image is the link between *physics* and *clinical medicine*. It is the item used by physicians, especially radiologists, to detect, diagnose, and guide the treatment of many diseases, injuries, and health related conditions. For an image to be of value it must provide adequate visibility of the anatomy and conditions within the human body. Visibility is the highly significant and necessary physical characteristic of an image that applies to every clinical procedure. It is determined by a combination of image characteristics as illustrated. These characteristics and the resulting visibility are in general determined and can be controlled by a radiologist through the selection of imaging modalities, methods, and procedure

protocol factors, but this requires a good knowledge of the image physical characteristics very early in the residency experience.

Genesis is a *beginning* and is an appropriate designation for the program described here--to provide very specific physics learning activities at the very beginning of radiology residency programs. This can be accomplished with a few classroom/conference sessions that are designated as the Genesis Sessions and separate it from the more comprehensive physics courses to be provided later in the program.

The Genesis Sessions within a radiology residency program make several important contributions. First, they are developing physics knowledge that has immediate clinical applications and is interesting and perceived to be of value by residents. These Sessions demonstrate the relationship of physics to clinical medicine with a concentration on image characteristics and visibility. They can create a desire among residents to learn more physics and look forward to the more comprehensive courses.

Resources for adding a Genesis Session to a residency program are provided in the *Addenda*. These include a curriculum overview, a text for residents to study, and PowerPoint visuals to be used by physics educators.

Addenda to the Journal:

1. Text – *Understanding and Optimizing Visibility in Medical Imaging Procedures*
2. Curriculum Overview
3. Visuals for Classroom Discussions

Visuals for teaching this course can be downloaded from: <http://www.sprawls.org/resources/genesis/index.html>

About the Author

Perry Sprawls, Ph.D. is a clinical medical physicist and educator. Currently he is Distinguished Emeritus Professor at Emory University in Atlanta and provides a variety of open access educational resources through the Sprawls Educational Foundation: www.sprawls.org

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EQUIPPING MEDICAL PHYSICISTS WITH ARTIFICIAL INTELLIGENCE KNOWLEDGE AND CODING SKILLS

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Abstract –

Artificial intelligence (AI) has been a promising tool to help us understand complex data patterns and able to recognize underlying data patterns for various applications. In the era of digital medicine and personalized medicine, medical physicists need to acquire basic knowledge of AI to communicate and collaborate with computer scientists. A recent global survey on the perception of medical physicists towards relevance and impact of AI indicated that there is an urgent need to equip them with both knowledge and skills of AI. This article documents our experience in conducting the 14th ACOMP workshop ‘Getting started with Artificial Intelligence’ at the 19th SEACOMP held in Bangkok, Thailand, Oct 22-23 2021. The workshop consists of didactic lectures and hands-on coding using Colab. Positive feedbacks were received that the participants benefited from the learning experience. We plan to conduct more of such workshops in the future.

Keywords- Artificial Intelligence, Machine Learning, Digital Medicine, Coding, Medical Physicists

I. INTRODUCTION

The history of AI starts in 1950 and gained exponential interest in 2016 after it was announced that AI defeated the world GO champion, Lee Sedol. With the advancement of computational powers and the availability of digital data, AI has been showing promising feasibility in making clinical workflow more efficient and accessible [1].

A recent global survey of opinion on the AI role in medical physics from 1019 respondents representing 94 countries revealed that more than 85% of participants agreed that AI will have a significant role in medical physicists’ clinical practice [2]. This highlighted the importance and urgency for medical physicists to equip themselves with AI skills. Medical physicists with AI knowledge and skills will enable them to foster better and more effective collaboration with their computer science and clinical colleagues in advancing healthcare.

Since the ASEAN College of Medical Physics (ACOMP) was formed in 2014, it has organised many workshops and courses [3]. During the 14th SEACOMP held in Bangkok, 21-23 October 2021, a hands-on two-day workshop, ‘Getting started with Artificial Intelligence’, was organised (Figure 1). The objective of the workshop is to introduce the basic concepts and techniques of AI and provide hands-on coding experience to participants in using contemporary AI methods to solve practical problems.

The poster features the ACOMP and SEAFOMP logos at the top. The main title is '14th ACOMP Course' with the subtitle 'Getting started with Artificial Intelligence'. The dates and location are 'October 21-23, 2021, Phuket, Thailand'. A yellow starburst graphic indicates 'Limited Participants'. The registration information states 'Oct 22-23, 2021, 8-10am (GMT +7)' and 'Registration: Please refer to homepage or scan here' with a QR code. The topics listed are 'Lectures on Machine Learning Concepts' and 'Hands-on Coding Using Machine Learning Techniques'. The speakers section identifies Prof. Kwan Hoong Ng (Department of Biomedical Imaging, Faculty of Medicine, Universiti Malaya, Malaysia) and Prof. Chu Kiong Loo (Dept. of AI, Fac. of Computer Science & IT, Universiti Malaya, Malaysia). Dr. Shier Nee Saw is also listed as a speaker. Further information is provided at the bottom: 'Further Info: https://www.seacomp2021.com/ACOMPcourse.php' and 'Enquiry: ngkh@ummc.edu.my'.

Figure 1 Workshop Poster

II. THE EXPERIENCE OF ‘GETTING STARTED WITH ARTIFICIAL INTELLIGENCE’

This workshop on ‘Getting started with Artificial Intelligence’ consists of a two-day workshop of two-hour session each of didactic lectures and hands-on coding delivered by Universiti Malaya lecturers: Kwan Hoong Ng, Chu Kiong Loo and Shier Nee Saw. The topics covered in the workshop are shown in Table 1.

Table 1 Topics covered in the two-day workshop

Topics
1. Lecture: <ol style="list-style-type: none"> a. Overview of AI in medicine b. Introduction to Machine Learning Lecture
2. Hands-on Workshop: <ol style="list-style-type: none"> a. Classification problem hands-on Workshop. b. Regression problem hands-on Workshop c. Develop machine learning model for medical problems

In the first session, an overview lecture on AI in medicine and an introduction to machine learning were given. The lecture presented a brief history of AI, applications of AI in medicine, the concepts of machine learning including supervised, unsupervised learning and deep learning (Figure 2). Through these lectures, students gained a deeper understanding of AI.

AI, ML, Data Science Relationship

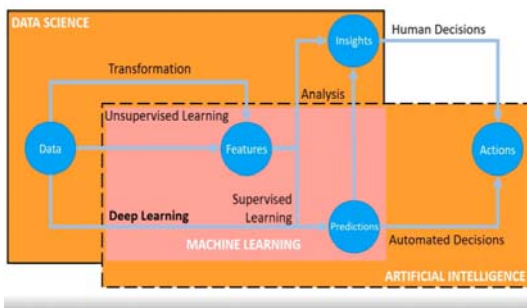


Figure 2 An example of a diagram to describe the relationship between data, features, prediction, insights and actions in the AI context.

The second session was hands-on in which the instructor guided the students to code in the Google Colab platform. Classification and regression lectures were given to enable students to grasp the concepts, followed by a practical session where students were asked to code in developing an AI model. After learning the concepts and examples, students were tasked to develop an AI model to classify whether the fetus is small or normal size (predict small-for-gestational-age, SGA babies). In this exercise, students were required to re-use the concepts and code learned in the workshop to create the AI model. The materials of the hands-on Colab coding workshop are available at https://github.com/shiernee/AI_Tutorial.

II. DEMOGRAPHICS OF PARTICIPANTS, FEEDBACKS AND OUTCOME OF THE WORKSHOP

Sixteen participants from Thailand, Malaysia, Japan and the Philippines attended this workshop. According to the feedbacks, all participants said that they will recommend this workshop to others. The main reason was the workshop was well-paced and participants were able to follow through, the contents were relevant to them and suitable for those who are new to AI and Colab. Due to the COVID pandemic situation, the workshop was held online. Lastly, students requested to include more examples on imaging.

This workshop served to expose and equip students to learn the basic of AI and more importantly, the firsthand experience in coding. After the workshop, students can use the code, extending it to solve other medical problems and pave a path to combine this knowledge and practical skills in their job-related task and research.

III. CONCLUSION

The ‘Getting started with AI’ in the 14th ACOMP has proven to be a great success introducing medical physicists to the realm of AI. The participants could now apply the knowledge and skills acquired in furthering their pursuit of AI. Furthermore, this workshop serves as a model for universities that are considering introducing AI in post-graduate programmes in medical physics.

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ACOMP PROFESSIONAL COURSE 2021: RADIOBIOLOGY IN THE ERA OF PRECISION MEDICINE

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Abstract— Radiobiology is a fundamental field in radiation therapy. There are limited radiobiology refresher courses being offered for medical physicists and related healthcare professionals in the ASEAN region. Hence, ASEAN College of Medical Physics (ACOMP) has taken the initiative to organize the 13th ACOMP Course: Radiobiology in the Era of Precision Medicine. The objective of the course was to provide basic understanding of radiobiology principles, its clinical applications and implementations in radiation therapy. Three two-hour free online sessions were held respectively on 9, 16, 23 April 2021. Six lecturers including one clinical oncologist and five medical physicists from Australia, Malaysia and Romania were invited. 250 participants attended in each session of the course. In conclusion, the course has created a new online learning platform to disseminate the knowledge and experiences in radiobiology which is useful and relevant in routine clinical works.

Keywords— Radiobiology, ACOMP, SEAFOMP, ASEAN, radiotherapy, nuclear medicine, online learning.

I. INTRODUCTION

Radiobiology is a field of clinical and basic medical sciences that involves the study of the interaction of ionizing radiation with biological tissues and living organisms. The field is heavily engaged with physics principles, mathematical algorithms and biology knowledge to estimate the probability of cells death and survival due to exposure to ionizing radiation. Radiobiology is usually integrated as a compulsory module in medical physics, radiation oncology, radiation dosimetry, nuclear medicine, diagnostic and interventional radiology programmes. However, this core module is often offered at the early semesters of the programmes and may not sufficiently cover all the knowledge and skills that are needed for advanced or practical application of radiobiology in clinical practice. There are also limited radiobiology courses offered for clinical medical physicists as a regular continuing professional development (CPD) course in the current settings especially in the ASEAN region. ASEAN College of Medical Physics (ACOMP) has taken note on this demand and hence decided to organize 13th ACOMP Course: Radiobiology in the Era of Precision Medicine. This radiobiology course was dedicated to clinical medical

physicists, oncologists, dosimetrists, radiographers, trainees, etc. Due to the current pandemic and the advantages of free online learning platform, we offer the course free.

II. STRUCTURE OF THE RADIOBIOLOGY COURSE

The course was co-organized by Associate Professor Dr. Chai Hong Yeong from the Taylors' University and Dr. Aik Hao Ng from the Kuala Lumpur Hospital, under the mentorship of Professor Dr. Eva Bezak. It was divided into three sessions, i.e. basic, intermediate and advanced, of two hours each and was conducted over three consecutive Friday afternoons (9th, 16th and 23rd April 2021). This was to allow participants a sufficient time gap to digest information and prepare for the next session. The course programme is shown in Table 1.

Table 1 Course programme

Date	Topics	Lecturers
9-Apr	Introduction of the course	Kwan-Hoong Ng
9-Apr	Radiobiology of tissue interaction with radiation	Aik-Hao Ng
9-Apr	L-Q model, TCP and NTCP calculation, Lyman-Kutcher, QUANTEC, Relative serial model (Emami / Burman data) + Bioplan+Sensitivity analysis	Eva Bezak
16-Apr	Clinical application of L-Q model, Radiobiology of altered fractionation (hypo, hyper), hypoxia, extension of L-Q for SABR	Wendy Phillips
16-Apr	Reirradiation, treatment interruptions and combined therapy	Fuad Ismail
23-Apr	MIRD formalism, diagnostic procedures	Jake Forster

Date	Topics	Lecturers
23-Apr	Latest development of the biomarkers and its clinical applications	Loredana G. Marcu
23-Apr	Course wrap-up	Chai-Hong Yeong

The online course was conducted using Zoom cloud meetings software (Zoom Video Communications, Inc, California, USA) and was broadcasted on YouTube ACOMP Channel (Fig. 1) via the following links:

Session 1:

<https://www.youtube.com/watch?v=mA3ObVNwLOo&t=1791s>

Session 2:

<https://www.youtube.com/watch?v=sJgo54f4NhE>

Session 3:

<https://www.youtube.com/watch?v=TBey3ODzsho&t=225s>

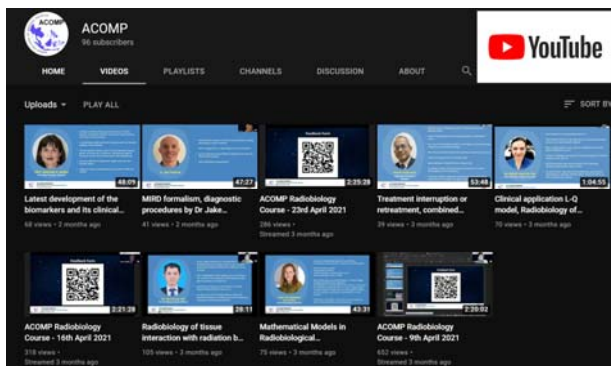


Fig. 1 ACOMP YouTube Channel containing links to access recorded lectures.

III. INVITED LECTURERS

We invited six experienced lecturers including one oncologist and five medical physicists from Australia, Malaysia and Romania. Their biographies are listed below:

Dr. Aik-Hao Ng, a senior medical physicist at the Department of Radiotherapy and Oncology, Kuala Lumpur Hospital and Nuclear Medicine Department, National Cancer Institute, Malaysia. He is the founder and current Chairman of the Malaysia Ministry of Health Medical Physics Research Task Force. He also serves as the Physics Advisory Editors for Medical Dosimetry Journal.

Professor Dr. Eva Bezak, a Professor in Medical Radiations and Director of the Translational Cancer Research Centre, University of South Australia. She is the current Secretary-General of the International Organization for Medical Physics (IOMP), Vice President of the Asia-Oceania Federation of Organizations for Medical Physics (AFOMP), former President of the Australasian College of Physical Scientists and Engineers in Medicine (ACPSEM),

and external member of the Affiliated Commission 4 (AC4) of the International Union of Pure and Applied Physics (IUPAP). Professor Bezak and her group are national leaders in radiation biology modeling using Monte Carlo algorithms. They have developed a new micro-dosimetry measurement technique for detection of alpha particles for use in targeted alpha therapy using the Timepix detector (which was developed in CERN) and became one of the most exciting micro-dosimeters in the market.

Dr. Wendy Phillips, a senior radiation oncology medical physicist at the Royal Adelaide Hospital, Australia. She served as a Radiation Oncology TEAP Public Preceptor and ACPSEM Advisory Forum in 2018–19. She was the recipient of the ACPSEM Kenneth Clarke Journal Award 2011 and Boyce Worthley Young Achiever Award 2012.

Professor Dr. Fuad Ismail, one of the pioneer radiation oncologists in Malaysia. He is the current Head of the Radiotherapy and Oncology Department at the National University of Malaysia Medical Centre. He founded the Master of Clinical Oncology programme at the University of Malaya. He is a member of the Evaluation Committee for Specialist Medical Qualifications for Oncology in Malaysia.

Dr. Jake Forster, a medical physics registrar at the South Australia Medical Imaging, specializing in nuclear medicine. He has a background in radiobiology and micro-dosimetry with interests in quantitative imaging and dosimetry for radionuclide therapies. He received the Best Medical Physics PhD award in Australia and New Zealand in 2019.

Professor Dr. Lorendana G Marcu, a Professor of Medical Physics at the University of Oradea, Romania and adjunct professor at the School of Health Sciences, University of South Australia. She is a radiotherapy medical physicist and her research interests include in silico modeling of tumour growth and response to treatment, radiobiology, targeted therapies, and the risk of second cancer after radiotherapy. She has involved in several professional activities within European Federation of Organizations for Medical Physics (EFOMP) and the International Union for Physical and Engineering Sciences in Medicine (IUPESM).

IV. PARTICIPANTS

289, 265 and 161 participants attended the live Session 1, 2 and 3, respectively. Fig. 2 shows the screenshots of the participants during the course. The ratio of Zoom:YouTube participants was approximately 2.5:1. 57% of the participants were medical physicists, 30% were students, 3% were radiographers and the remaining were oncologists, radiobiologists, regulators, radiation therapists, radiation protection officers, nuclear medicine physician, etc. Majority of the participants were from the ASEAN countries (Malaysia, Indonesia, Philippines, Singapore, Brunei, Cambodia, Vietnam) and some were from India,

Taiwan, Australia, Nepal, United Kingdom, Hong Kong and the United States.



Fig. 2 The screenshots of the participants during the course via Zoom platform

V. FEEDBACK AND COMMENTS

We received overall excellent ratings regarding the quality of the course. Details of the feedback are shown in Fig. 3-5.

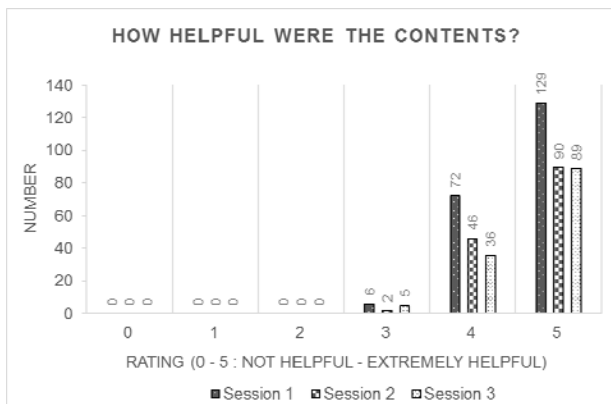


Fig. 3 Rating on the usefulness of the course contents

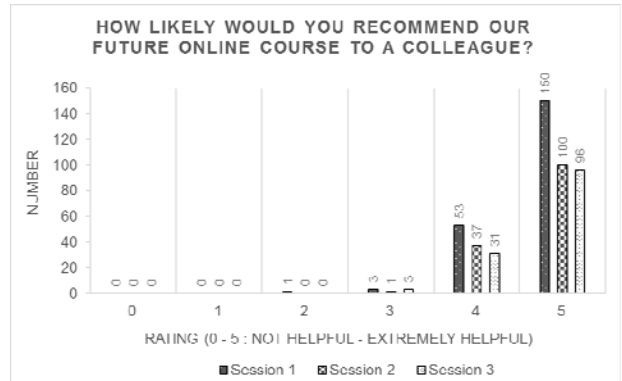


Fig. 4 Participants' feedback if they would recommend the future online courses to their colleagues

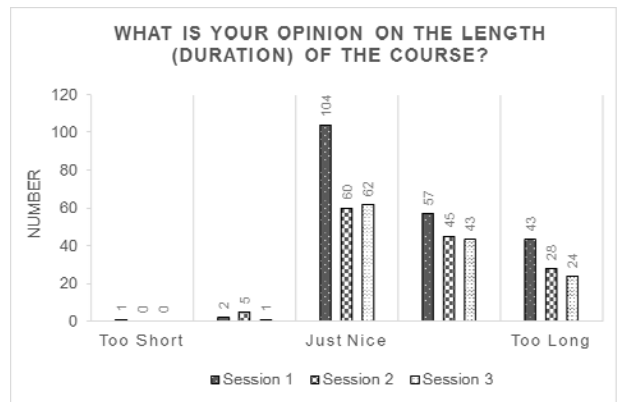


Fig. 5 Rating on the duration (length) of the course

Table 2 shows the ten most recommended topics for future courses from the participant's feedback.

Table 2 Top ten topics recommended by the participants for future courses

No.	Recommended Topics
1	Radiotherapy
2	Radiobiology
3	Stereotactic Body Radiation Therapy
4	Dosimetry
5	Quality Assurance and Quality Control
6	Brachytherapy
7	Stereotactic Radiosurgery
8	Radiation Treatments other than for Cancer
9	Gap Correction during radiotherapy treatment
10	Radiotherapy for COVID-19 Cancer Patients

We also received more than 450 comments gathered from the all three sessions of the course. The five top comments include “good presentation”, “great webinar”, “good work”, “good lecture” and “interesting topic”. In terms of recommendations for future improvements, the comments are categorized as follows:

1. Organize more such courses in the future.
2. Increase duration/length of the workshop.
3. Allocate more time for discussion.
4. Prolong the questions and answers (Q&A) session.
5. Include more animation or video to aid explanation.

VI. CONCLUSIONS

The 13th ACOMP Course has paved a new online learning platform to disseminate the knowledge and experiences in radiobiology. It has received overwhelming response from the participants. The number of attendees (averagely 250 participants per session) has far exceeded the original target of 100 from the ASEAN region. The positive response and feedback from the participants have shown that radiobiology is an important and very much sought-after topic in medical physics and radiation oncology. This information is beneficial in their routine clinical works while bridges the gap for the application of radiobiology principles in the current development of

various imaging and therapeutic procedures. The free online meeting platforms have made teaching and learning more accessible and affordable for everyone.

ACKNOWLEDGMENT

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Physica Medica – current status and future perspectives

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Physica Medica – *European Journal of Medical Physics* (EJMP) has seen a great advance during the past decade with respect to the number and the quality of the submissions that led to a well-established position among the journals in the field of medical physics and close applications. This is due to the fantastic work done by the past Editors-in-Chief, Professor Paolo Russo (Naples, Italy), who led the journal for no less than eight years, and Professor Fridtjof Nüsslin (Munich, Germany) as well as the Honorary Editor, Professor Alberto Del Guerra (Pisa, Italy). The past year brought few changes to the Editorial Board. Thus, the journal got not only a new Editor-in-Chief, Professor Iuliana Toma-Dasu (Stockholm, Sweden), but also a Deputy Editor, Dr. Claudio Fiorino (Milano, Italy) and a Managing Editor, Dr. Marta Lazzeroni (Stockholm, Sweden) joining the work to carry on the legacy of the previous editors, to maintain the high status of the journal and to raise it even higher in the endeavour to serve the medical physics community.

The current high status of the journal and its development is reflected by the increase of the impact factor (IF) to 2.685 and the 5-Year IF to 2.736. Several strategies and corresponding actions for ensuring the further development of *Physica Medica* and for better contouring and defining its scope are presented in this article.

Physica Medica is the official journal of many professional associations (EFOMP - European Federation of Organisations for Medical Physics, AIFM - Associazione Italiana di Fisica Medica e Sanitaria, IAPM - Association of Medical Physicists working in Health Care and Academia in Ireland, CSFM - Czech Association of Medical Physicists, EFIE - The Hellenic Association of Medical Physicists and SFPM - Société Française de Physique Médicale) and therefore one could define better its place among the medical physics journals by strengthening the connection with the medical physicist profession. Several actions are therefore planned in this direction including the creation of subsections in the journal corresponding to the major areas of research and professional work of medical physicists such as radiation therapy, diagnostic radiology, nuclear medicine, magnetic resonance imaging as well as closely related topics such as radiation protection, radiation and system biology, artificial intelligence in medical physics, and, last but definitely not least, educational and professional issues. Along the same line of strengthening the connection with the professional societies, a new section called “EFOMP’s Corner” was created starting already from the second edition this year, where one will find the results of the work of the various EFOMP task groups etc. Within this section, a short collection of historical reviews presenting the development of medical physics in different countries was also arranged involving the national societies recognising *Physica Medica* as their official journal.

Another strategic objective for the near future is to expand the journal toward multidisciplinary areas. There are many topics in medical physics (research and development areas) at the crossroad of various disciplines. Progress in these areas implies close collaboration with the other professional categories such as the medical doctors, nurses, technologists, and engineers, as well as radiation protection experts. Our objective should therefore be to make *Physica Medica* more visible and attractive outside the medical physics community by inviting review articles of interest across disciplines and publishing manuscripts that are within the scope of the

Journal, not strictly addressed to the medical physicists, but also to the other professional categories. A new series of invited commentaries by medical doctors, key opinion leaders in radiation oncology, radiology etc. on the expected contribution of medical physicists to the most exciting current research topics in the field was also initiated to support this strategic objective.

Due to the great work of the Past Editor-in-Chief, *Physica Medica* has become better known outside Europe, this being illustrated by the large number of submissions from China, India, Iran, Japan, Australia etc. received by the journal. His work will be continued and even intensified in order to keep pace with the rapidly growing community of medical physicists in regions outside Europe.

Another practice previously introduced that will also continue is the publication of collection of articles in the form of Focus Issues. Four article collections were produced in 2021, all focusing on highly timely and relevant topics in our field. They are listed here in the chronological order they appeared: Optimization of Medical Accelerators, Covid-19 collection, Artificial Intelligence in Medical Physics [1] and New Developments in MRI: System Characterization, Technical Advances and Radiotherapy Applications [2].

There is ongoing work on putting together four new collections of articles to be published in 2022. Two of them emerged following two scientific events organised by the medical physicists' associations: the Focus Issue "ECMP 2020" containing selected papers from contributions to ECMP 2020 - the European Congress of Medical Physics that took place online between 16th and 19th of June 2021 and the Focus issue with the topic: "SFPM 2021" containing selected papers from the 2021 congress of the Société Française de Physique Médicale. They will therefore closely reflect the complex characters of the meetings and they will mostly consist of original research papers on the main areas of professional activities of medical physicists. A third collection planned for next year will also consist of papers selected from scientific meeting, but it will be focussed on a very special topic, FLASH radiotherapy that has seen a revived interest in recent years with the proliferation of proton therapy facilities that could easily deliver the high dose rates required by this technique. Finally, the fourth collection of articles will be dedicated to quantitative magnetic resonance imaging (MRI) focusing on methods for standardisation, accuracy, reproducibility and harmonisation in the field. These are crucial aspects in the era of personalised medicine as well as for national and international collaborations in multicenter studies.

The increased importance of multidisciplinary topics in regular articles as well as those collected in focus issues reflects the continuously evolving roles and interests of medical physics and its practitioners in modern medicine. It is also a reflection of the challenges faced by our profession

which were even higher during these difficult times of the Corona-virus pandemic. The professional dedication of our authors, reviewers, and editorial team, however, helped defeating the challenges and further pave the road to progress through research and development in the field of medical radiation physics.

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PROFESSIONAL ISSUES

MEDICAL PHYSICS IN THE EFOMP REGION: HISTORY, EDUCATION, AND PROFESSIONAL RECOGNITION

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Abstract— The European Federation of Organisations for Medical Physics (EFOMP) was founded in 1980 in London. Its aims were to foster communication and coordinate activities between medical physics organisations, create such organisations where none existed, provide educational standards, content and facilitate exchange of medical physicists. EFOMP has largely delivered on these core objectives for its 9,000 members in 36 countries which are summarised in its slogan of “Communicate, Integrate and Educate”. The current focus for EFOMP remains the recognition of a common training standard, and delivery of enhanced educational offerings for medical physicists and radiation protection experts.

Keywords— Medical Physics, Education, Training, Accreditation, EFOMP, Europe

I. INTRODUCTION

The historical origins of medical physics can be traced from the first use of weighing as a means of monitoring health by Sanctorius in the early seventeenth century to the emergence of radiology, phototherapy and electrotherapy at the end of the nineteenth century. There are many origins of medical physics, stemming from the many intersections between physics and medicine. Overall, the early nineteenth-century definition of medical physics still holds today: “Physics applied to the knowledge of the human body, to its preservation and to the cure of its illnesses” [1]. Medical physics is now an established and important branch of medical science. The physical scientist applies their fundamental scientific knowledge to problems appearing in ionizing and non-ionizing radiation, radiology, nuclear medicine, radiotherapy, ultrasound, laser, physiological measurement, bioengineering, surgery, audiometry and photometry. Nowadays, the contribution of the medical physics community extends from fundamental research on the effects of radiation, proper dosimetry, to equipment and facilities design, optimisation of the benefit risk ratio in both the treatment and diagnosis of medical conditions. EFOMP plays a key role in supporting the European medical physics community in delivering these goals.

II. HISTORY OF MEDICAL PHYSICS IN EUROPE

In February 1978, the Council of the UK’s Hospital Physicists’ Association (H.P.A.) identified the need to

establish a body that would be recognised throughout Europe as representing the unified opinion of European Medical Physics, “A voice for Medical Physics in Europe”. The draft constitution of the proposed Federation was circulated to all interested national organisations and at a second meeting held in London, from 7th-9th May 1980 (Fig. 1), the constitution was formally accepted by delegates representing the medical physics organisations of fourteen countries, who thus became the founder members of the Federation. Delegates from several organisations who at that time had not approved the proposed constitution were able to express the wish of their respective organisation to join the Federation at an early date [2].



Fig. 1 Founding members of EFOMP pictured at the inaugural meeting in London

When the formalities were completed, the European Federation of Organisations for Medical Physics (EFOMP) represented about 3,000 medical physicists. The following officers were elected: President: I. Clifton (UK), Vice President: I. Chavaudra (FR), Past President: J.S. Orr (UK) Secretary General: A. Benini (IT) Treasurer: F. Welde (NO). Four EFOMP committees were constituted: Education and Training, chaired by A. Kahl (DE), Committee on Professional Matters chaired by P.K. Asard, (SE), Publications Committee chaired by C. Franconi (IT), and Scientific Activities chaired by R.E. Ellis (UK). The aims and purpose of EFOMP were defined as follows:

- Fostering and co-ordinating the activities of Member Organisations;
- Encouraging exchanges between Member Organisations and disseminating professional and

scientific information;

- Encouraging scholarships and the exchange of Medical Physicists between countries;
- Proposing guidelines for education, training and accreditation programmes;
- Making recommendations on the appropriate general responsibilities;
- Encouraging the formation of organisations for Medical Physics where such organisations do not exist.

These aims still exist today, when EFOMP represents over 9,000 medical physicists in 36 European countries (Fig. 2). Throughout the years, two committees were formed on top of the initial ones: European Matters and Projects. The governing body of EFOMP is its Council which consists of representatives of the National Member Organisations (NMOs). Each country can only be represented by one NMO. When a country has more than one eligible society there must be a formal arrangement as to which will represent the country as its NMO. The executive committee consists of the President, Past/Vice President, Secretary General and Treasurer. The executive committee and chairs of the six committees meet at least twice a year, as a Governing Committee. Its remit is to manage the affairs of EFOMP and prepare papers for the Council. In January 2021, EFOMP relocated its seat from the UK to the Netherlands.

III. EDUCATION AND TRAINING

Education and training are provided by the three main pillars of EFOMP, namely to “Communicate, Integrate and Educate”. ESMPE, the European School for Medical Physics Experts, organizes medical physics education and training events specifically targeted to Medical Physicists who are already Medical Physics Experts (MPEs) or would like to achieve Medical Physics Expert (MPE) status. These events are open to all European Medical Physicists and are accredited by an independent body, the European Board of Accreditation for Medical Physics (EBAMP) to ensure that they are at the required educational level, i.e., Level 8 of the European Qualifications Framework. Several editions have been organized jointly with COCIR, the European Trade Association representing the medical imaging, radiotherapy, health ICT and electromedical industries, driven by the need for a closer cooperation between manufacturers and medical physicists to increase the awareness of features of medical devices related to imaging and therapy. This collaboration extends in many levels such as joint actions related to the age profile of medical equipment which is installed in European countries since obsolescent equipment can undermine patient safety as well as developing guidelines for manufacturers to meet the requirements of article 78.2 of the Basic Safety Standards (BSS) Directive (96/29/Euratom) which sets out standards for radiation protection in the Member States. Indeed, having such links with COCIR allows us to assess the

Member State	Current National Member Organisation
 Albania	Albanian Association of Medical Physics (AAMP)
 Austria	Austrian Society of Medical Physics (ÖGMP)
 Belgium	Société Belge des Physiciens des Hôpitaux Belgische Vereniging Ziekenhuis Fysici (SBPH-BVZF)
 Bosnia and Herzegovina	Association of Medical Physicists in Bosnia and Herzegovina (AMPBH)
 Bulgaria	Bulgarian Society of Biomedical Physics and Engineering (BSBPE)
 Croatia	Croatian Biomedical Engineering and Medical Physics Society (CROBEMPS)
 Cyprus	Cyprus Association of Medical Physics and Bio-Medical Engineering (CAMPBE)
 Czech Republic	Czech Association of Medical Physicists (CAMP)
 Denmark	Danish Society for Medical Physics (DSMP)
 Estonia	Estonian Society for Biomedical Engineering and Medical Physics (ESBEMP)
 Finland	Finnish Association of Hospital Physicists (FAHP)
 France	Société Française de Physique Médicale (SFFPM)
 Germany	Deutsche Gesellschaft für Medizinische Physik (DGMP)
 Greece	Hellenic Association of Medical Physicists (HAMF)
 Hungary	Hungarian Society of Medical Physics (HSMP)
 Ireland	Irish Association of Physicists in Medicine (IAPM)
 Italy	Associazione Italiana di Fisica Medica (AIFM)
 Latvia	Latvian Medical Engineering and Physics Society (LMEPS)
 Lithuania	Lithuanian Association of Medical physics and Biomedical Engineering (LMPBIA)
 Malta	Malta Association of Medical Physicists (MAMP)
 Moldova	Association of Medical Physicists from the Republic of Moldova (AFM/Moldova)
 Netherlands	Nederlandse vereniging voor klinische fysica (NVKF)
 North Macedonia	Association of Medical Physics and Biomedical Engineering (AMPBE)
 Norway	Norwegian Association of Medical Physics (NFMF)
 Poland	Polish Society of Medical Physics (PSMP)
 Portugal	Medical Physics Division of the Portuguese Physics Society (PPS)
 Romania	Romanian College of Medical Physicists Colegiul Fizicienilor Medicali din Romania (CFMR)
 Russia	Association of Medical Physicists of Russia (AMPR)
 Serbia	Serbian Association of Medical Physicists (DMFS)
 Slovakia	Slovak Society of Physics and Biophysics Slovak Medical Society (SKBS)
 Slovenia	Slovenian Biophysical Society (SBS)
 Spain	Sociedad Española de Física Médica (SEFM)
 Sweden	Swedish Hospital Physicists Association (SHPA)
 Switzerland	Schweizerische Gesellschaft für Strahlenbiologie und Medizinische Physik Société Suisse de Radiobiologie et de Physique Médicale Società Svizzera di Radiobiologia e di Fisica Medica (SGSMP-SSRPM-SSRFM)
 Ukraine	Ukrainian Association of Medical Physicists (UAMP)
 United Kingdom	Institute of Physics and Engineering in Medicine (IPeM)

Fig. 2 National Member Organisations of EFOMP in 2021[3]

current and future medical physics requirements for delivery of clinical services. Currently, the numbers vary widely in each region. For example, Western Europe has of the order of 7 Linacs per million population (3.1 in Eastern Europe), 24 CT scanners per million population (15 in Eastern Europe), 20 MRI scanners per million population (7 in Eastern Europe), 2.6 PET scanners per million population (0.7 in Eastern Europe) [5,6].

Since the end of February 2020, European countries have been in the midst of an unprecedented challenge due to the COVID-19 pandemic, and this was a challenging time for the whole Medical Physics community. Thus, a series of online Medical Physics webinars and workshops were organized in order to sustain EFOMP education and training activities. EFOMP digital resources have been used to host educational and training events organized by the NMOs.

ECMP is the European Congress of Medical Physics. During the period 1987 to 2016, EFOMP has collaborated with National Member Organisations in holding regular

European Conferences of Medical Physics in conjunction with their events. In 2016, the idea of organizing a biennial EFOMP congress became a reality, thus the 1st ECMP took place in Athens, Greece and the 2nd in Copenhagen, Denmark. The 3rd ECMP was initially planned to be held in Torino, Italy but due to the pandemic was converted to a fully digital event. The 4th ECMP will take place in Dublin, Ireland in 2022 as a hybrid event.

EJMP, the European Journal of Medical Physics (EJMP), is the official scientific journal of EFOMP. The owner of the journal is the Italian Association of Medical Physics (AIFM), and it is also the official organ of the French (SFPM), Irish (IAPM), Czech Republic (CAMP) and Hellenic (HAMP) Societies of Medical Physics. In 2019, EJMP became the official publication of the International Organization for Medical Physics (IOMP) and provides an international forum for research and reviews on imaging, therapy, radiation protection, professional and educational topics as well as new emerging technologies. A volume is published every month.

The main target of EFOMP is the harmonization of Medical Physics education and training standards throughout Europe. For this purpose, two elements have been implemented:

1. NMOs National Registration Scheme (NRS), a system for education, training and registration of MPEs in place. This can be validated by the Professional Matters Committee and approved by the EFOMP governing committee. The long-term aim of the NRS is a generally accepted level of expertise, facilitating an exchange of professionals across Europe. EFOMP has published several policies concerning the education, training and registration of MPEs [7]. Four of these policies [PS2, PS3, PS4, PS6] describe recommendations which have to be fulfilled by an NRS in order to meet the EFOMP standard.
2. The European Examination board (EEB) awards the European Diploma of Medical Physics (EDMP) and the European Attestation Certificate (EACMPE) to those Medical Physicists that have reached the Medical Physics Expert level. EEB examinations are tests of excellence in Medical Physics, and they are designed to assess the knowledge, skills and competences requisite for the delivery of high standard Medical Physics services.

In 2019, EFOMP developed an e-learning platform, where video recordings of the lectures given during the EFOMP school editions, webinars and workshops, and NMOs' events have been made available to Individual Associate Members of EFOMP.

IV. SCIENTIFIC EXCHANGE

Included in the scope of the federation is to coordinate scientific activities and to support the development of

guidelines and directives. A number of Working Groups have been established and operate for a specific time period to create quality control protocols, guidance documents, harmonise practices, update core curricula in all subspecialties.

Special Interest Groups (SIG) are also formed to establish networks of medical physicists working in a specific area such as Nuclear Medicine Dosimetry, Dental Imaging etc. The SIGs aim to fulfil the need for networking, education, research and professional exchanges in this field.

Scientific exchange is also fulfilled through Memoranda of Understanding and collaborations with European and International bodies including AAPM, COCIR, EANM, ESR, ESMRMB, EFRS, EUSOMII, EURADOS, EORTC, ESTRO, HERCA, IAEA, IOMP, MEFOMP.

EFOMP's Governing Committee continuously encourages early career colleagues to take active roles in the work of the federation by being part of the congress scientific committee, the organization committee of EFOMP school editions, the editorial board of the EFOMP newsletter, or participating in programmes such as "Mentoring in Research" which aims to support early career Medical Physicists (MPs) who want to set up a research project or successfully develop or explore their innovative ideas.

V. PROFESSIONAL RECOGNITION

EFOMP recognises that training and standards are the key to assuring safety and quality for the patients who benefit from our medical physics and radiation protection expertise. It is also the key to establishing our identity as medical physicists and allowing mobility of experts throughout Europe and beyond. The IAEA Basic safety standard [8] and EU directive 13/59 mandate registration and accreditation schemes. The EFOMP accreditation for national registration scheme establishes a common platform for training. If a critical number of states achieve the EFOMP standard these can form the basis in the European Union recognition of professional qualifications and interstate recognition of these qualifications under EU directives 05/36 and 13/55. This will also act as a foundation for such recognition outside the European Union.

VI. CONCLUSIONS

EFOMP is constantly working to create a trajectory towards a standardised approach to the training of the radiation protection expert and medical physics expert, mobility and mutual recognition in the European Union and beyond.

It is also in the Organisation's objective to ensure that highest standards of scientific knowledge, training and expertise that meet considered criteria are available to patients, healthcare staff and public throughout Europe.

Although communication and medical technology may have changed in the four decades since our inception, the founding principles of the federation and the need to Communicate, Integrate and Educate are still as relevant in 2021 as they were in 1980.

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MEDICAL PHYSICS IN DENMARK: HISTORY, EDUCATION, AND PROFESSIONAL RECOGNITION

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Abstract— Since Röntgen's discovery of x-rays, medical physics has been a professional topic in Denmark, and from the very beginning physicists have been involved in the application of ionising radiation – both in research, diagnostics and treatment.

40 years ago the Danish Society for Medical Physics (DSMF) was formed. An important task for the society has always been the education of medical physicists and the Continuing Professional Development (CPD) programme.

In Denmark, medical physicists are recognized and registered, but unlike other health professionals not formally authorized. This is a position DSMF have fought for since the formation of the society and still today finds of utmost importance.

Keywords— Medical Physics, Education, Development, Accreditation, DSMF

I. HISTORY OF MEDICAL PHYSICS IN DENMARK

Röntgen's discovery of x-rays was announced in Danish newspapers [1] already within two weeks of the original scientific paper "On A New Kind of Rays" [2] having been published at the end of December 1895. As in many other countries, the announcement sparked an immediate public interest in the new fascinating technology. During January, physics professor H.O.G. Ellinger at the Royal Veterinary and Agricultural University in Copenhagen did his own experiments with x-rays, which resulted in the first public demonstration in Denmark on January 28 1896 [3]. During this talk, the professor actually tried to x-ray the hand of a member of the audience.

It was another physicist, 24-year old Martin Knudsen, who on the 12th of February 1896 at the College of Advanced Technology in Copenhagen acquired the first diagnostic radiography in Denmark, that of a broken lower limb [4]. Present was also physics professor Christian Christiansen and King Christian the 9th's royal surgeon Carl Ludvig Studsgaard [5]. Three days later, professor Christiansen published the first Danish monograph on x-rays, an 80-page book describing all the details of the technical equipment needed to generate the rays [6]. Simultaneously, engineer Paul Bergsøe did extensive work on exploring x-ray production and detection, which was published the same year [7,8].

Meanwhile, professor Ellinger joined forces with a medical doctor, Johannes Mygge, who went on to pioneer radiology in Denmark. Together, in March 1896, they installed the first x-ray equipment at a Danish hospital, Copenhagen's Municipal Hospital, and before the end of the year, Mygge had experimented with radiotherapy [9]. The same year, two private x-ray clinics appeared in Denmark, one in Copenhagen and one in Aarhus.

Though physicists and engineers thus were an integral part of the early application of x-rays in medicine, medical doctors soon dominated the field both in scientific literature and public awareness in Denmark.

In 1912, public focus switched from x-rays to radium as a means of treating cancer patients. In May, the newspaper Politiken started a fundraising campaign for a young artist whose wife had fallen seriously ill from cancer and needed to finance radium treatment abroad. The same month, King Frederik the 8th died and his successor asked that the public instead of buying funeral wreaths of silver or gold would donate money to charity. These two events sparked a debate about financing the quite expensive radium treatment in Denmark, and a national radium fundraising committee was established, resulting in the first public radium station in Copenhagen opening in 1913 and radium stations in Aarhus and Odense opening in 1914 [10].

An intense debate followed about staffing of the radium stations, mainly due to the Copenhagen station being headed by a dermatologist, which the local surgeons did not appreciate. However, no mention of physicists was made at the time.

In 1919, reports emerged about a critical shortage of radium with patient treatments being cancelled. This triggered a second national fundraising campaign, which was launched in early 1921. At the same time, professor Niels Bohr opened his famous institute at the University of Copenhagen. His brother, Harald Bohr, had just been elected into the Executive Committee of the Radium Foundation, and this led the surgeon professor Thorkild Røvsing – who had been very active in the 1914 debate about the staffing of the radium stations – to demand that a physicist from the Niels Bohr Institute should be associated to the radium clinics [11].

The fundraising resulted in the purchase of radium worth about 3.8m Euros (2020 equivalent). When the first shipment arrived in October from the US, the box was opened in the home of the chairman of the Radium Foundation with the presence of Niels Bohr. The box was quite difficult to open, but finally professor Bohr took over and cracked the lid open.

“He is used to splitting the atom”, one newspaper reported [12].

The opening of the radium box was documented in a famous photograph (see Figure 1). Close to Bohr another scientist and Nobel laureate can be seen, Hungarian George de Hevesy, who was spending the first half of the 1920s at the Niels Bohr Institute. He went on to work with radioactive tracers to study biochemical processes, thus becoming one of the pioneers in nuclear medicine.



Fig. 1 Opening of the radium box, Dagbladet, October 21 1921.

Shortly after the event, Jacob Christian Jacobsen from the Niels Bohr Institute was associated part time with the radium station in Copenhagen as the very first medical physicist in Denmark.

In 1936, the radium station in Aarhus got a similar part-time association with a physicist from the newly formed Department of Physics at the University of Aarhus. The first permanent position for a hospital physicist in Denmark was established in 1954, when J. Ambrosen became head of the new Radiophysics Laboratory in Copenhagen. In 1955, C.B. Madsen was appointed to a similar position in Aarhus [10], and in 1962 Norwegian P. Omsveen was appointed in Odense [13].

In 1928 the original radium fundraising committees merged into The Danish Cancer Society, and still today private donations are an important part of Danish healthcare technology implementation. For instance, the first Scandinavian full body CT scanner was donated by a private foundation (A.P. Møller Foundation) and implemented in Copenhagen in 1976, the first MRI scanner (1985) was donated by a businessman (Simon Spies). The Cyclotron and PET Center at Rigshospitalet in Copenhagen has from its start in 1992 and to date been generously supported by the John and Birthe Meyer Foundation, and even the very large

and expensive Danish Centre for Particle Therapy (2019) was made possible only by a large private donation by the A.P. Møller Foundation.

II. HISTORY OF THE DANISH SOCIETY FOR MEDICAL PHYSICS

Initial attempts to found a professional society for medical physicists was done in the early 1970s, but only after the founding of the European Federation of Organisations for Medical Physics (EFOMP) in 1980 was this achieved.

Before this, individual Danish medical physicists had a Scandinavian network through the Nordic Association of Clinical Physics (NACP), formally established in 1965 [14], and the radiotherapy branch of the Danish physicists had a national forum through the Danish Society for Radiotherapy and Oncology. However, with EFOMP the opportunity to establish strong international relations emerged.

After 1½ years of preparation, the Danish Society for Medical Physics (DSMF) was founded in November 1981, with K.A. Jessen from Aarhus being elected the first president. Formal membership of both EFOMP and the International Organization for Medical Physics (IOMP) was achieved in 1982. Jessen went on to become EFOMP president from 1993-1995 [15]. Over the years DSMF has had 10 presidents - the first female president being elected in 2019.

The number of members has risen continuously over the years along with the evolvement of the profession and has recently passed 200 (see Figure 2). Implementation of the 1996 Euratom BSS Directive [16] established the need for medical physicists in Nuclear Medicine and Diagnostic Radiology, and in particular, national cancer plans resulted in heavy investments into new radiotherapy equipment between 2000-2010. The result of these investments was documented in the 2014 ESTRO-HERO project where Denmark now had the largest number of treatment linear accelerators per capita in Europe [17]. All this is reflected in the number of medical physicists in Denmark.

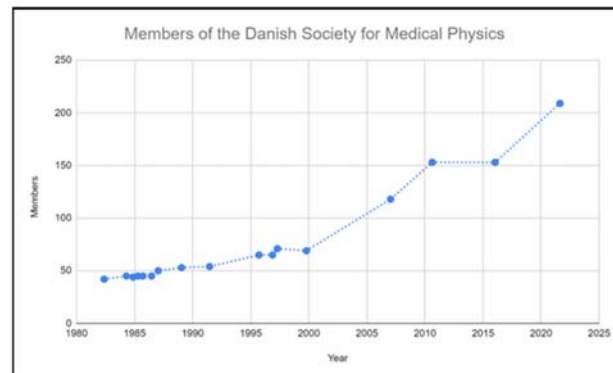


Fig. 2 Ordinary members of DSMF over time.

DSMF had their first web page in 1999 and a logo was approved in 2000 after suggestions were sent in by members. In 2010 a new professional website (www.dsmf.org) was launched where the logo played an important role in the design. The same logo is still in use today.

DSMF is also quite active on social media, with the Facebook page being launched in 2014. The goal was to increase the knowledge of both our society and also medical physics in general and give room for discussion. For several years the number of followers has exceeded our member count and news thus reaches a larger audience.

In 2018, DSMF hosted the 2nd European Congress of Medical Physics (ECMP2018). With more than 800 participants from all over Europe visiting Copenhagen, this marked a major milestone in the history of the society and for medical physics in Denmark.

III. NATIONAL EDUCATIONAL PROGRAMME

Even today, there is no formal university degree in medical physics, while an important task for the society has always been to formalise and strengthen the education of medical physicists. The first work on this was started in April 1972, before the founding of the society, when the Danish Society for Radiotherapy and Oncology established a committee with the task of assessing the need for education of radiotherapy physicists.

The report of the committee [18], which was approved in May 1973, listed all the theoretical subjects that should be mastered by a physicist working within radiotherapy. Some of these subjects would require further education after employment at a radium station. Since formal educational courses could not always be found at the universities, substantial self-study would be needed, and the report suggested that all educational activities should be documented and approved by a national educational committee under the Danish Society for Radiotherapy and Oncology. The need for education of new radiotherapy physicists from 1973-1985 was estimated to about 3 per year.

In parallel with the development of this report, work was being done to establish a committee that could evaluate the professional qualifications of candidates for chief physicist positions. The inspiration for this was the Danish Medical Practitioners Act, which stated that any chief medical doctor before employment was to be evaluated by a national committee established by the national medical societies. In a meeting with the Danish Health Authority in October 1972, this model was presented and unanimously approved, though the committee would be an advisory body and not a mandatory step in the recruitment process. The committee was subsequently formed in 1974 under the Danish Society for Radiotherapy and Oncology.

In 1985 DSMF published a new report on education of medical physicists, as an update of the 1973-report. This report focused on the demographics of current medical physicists and the future need for educating new physicists.

Again, the need for education was stressed, and it was proposed to setup a national Educational Council that could participate in the planning of individual education programmes and also in organising much needed teaching courses. This council was established by DSMF the same year.

The report was widely distributed and used as a political lobbying tool, and finally, in 1995, the Danish Health Authority issued legal guidelines to hospitals on the education of medical physicists.

The document for the first time describes the system which is still in use in Denmark, where the education is based on a Master's degree in physics or engineering with relevant levels of physics and mathematics. The education is divided into three sub-fields: 1) Oncologic Radiotherapy, 2) Diagnostic Radiology, and 3) Nuclear Medicine. The candidate is first employed in a residency position at an approved hospital department, a qualified supervisor is assigned, and an individual educational programme of at least 3 years duration is planned. The programme is approved by the Educational Council of DSMF, and a status report has to be submitted each year.

The membership of DSMF is similarly divided into the three sub-fields, with Radiotherapy being the largest group (almost 70% of all members), see Table 1. With the emerging use of MRI, DSMF hopes to formally include MRI physicists in the society in the future as well.

Table 1 Number and distribution of DSMF member physicists 2021. MPE: Medical Physics Expert

Medical Physicists	Total	Male/Female	MPE
Radiotherapy	145	93/52	74
Nuclear Medicine	34	30/4	17
Radiology	30	21/9	7
Total	209	144/65	98

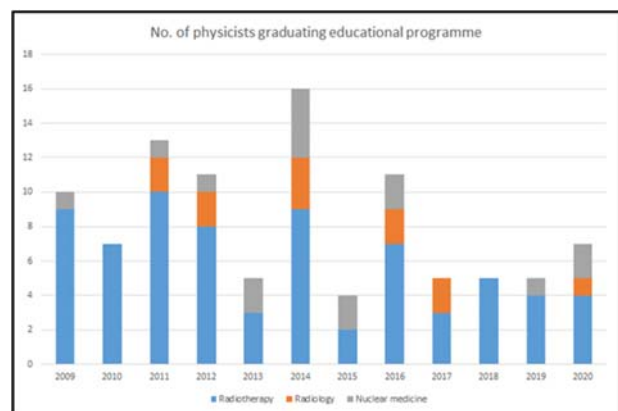


Fig. 3 Number of physicists graduating from the national educational programme per year.

In 2010 the educational structure was upgraded and consolidated into a law, but with more or less the same contents as the 1995 guidelines.

The number of new physicists annually graduating the national educational programme can be seen in Figure 3.

In parallel with the basic educational programme, a Continuing Professional Development (CPD) programme was formalized in 1997 with the formation of a CPD Evaluation Committee. This committee was actually based on the concept of a qualified medical physics expert which had emerged during the 1980s in European Economic Community directives [19], and which needed a formal evaluation system to qualify for the title.

Today, after finishing the basic educational programme, Danish medical physicists register professional development activities, which are then annually reviewed and converted into CPD points by the Evaluation Committee. With a sufficient number of CPD points, a medical physicist can obtain the Medical Physics Expert (MPE) title, which then has to be maintained and renewed every 5 years.

IV. PROFESSIONAL RECOGNITION

The educational programme described is in reality just guidelines for departments to train physicists to obtain the qualifications needed to carry out their duties at a hospital. Because medical physicists are not formally authorized by the Danish Health Authority, you can actually work as a medical physicist in Denmark, without having completed the educational programme.

This lack of healthcare authorization is in strong contrast to the Danish Authorization Act, which clearly states that the purpose of healthcare authorization is to “strengthen patient safety and promote quality through the authorization of healthcare professionals, where the activities of others in the business area in question may be associated with particular danger to patients” [20].

This obviously covers our profession but it has yet to be acknowledged by the authorities. As important as ionising radiation is for radiation therapy and diagnostics, as damaging it can be if mishandled due to lack of knowledge of the applied equipment and procedures. Quality assurance in relation to ionising radiation is of the utmost importance for patient safety. There are few other places in the healthcare system where one individual’s mistakes can make so much detriment to so many patients. Furthermore, medical physicists train and educate staff members like physicians, RTTs, and radiographers to work in the field of ionising radiation, and as such we are responsible for the qualifications of authorized personnel. The term MPE was included in Danish law with the *EU Council Directive 2013/59/EURATOM* in 2013 [21], but still no formal authorization of medical physicists exists.

For more than 30 years DSMF has fought for professional recognition like our authorized colleagues, and in 2012 the importance of this was emphasized in *The Lancet* [22].

Despite several enquiries to politicians in the Danish Parliament and especially the different Ministers for Health, the arguments have not been acted upon. In many of the countries Denmark normally compares to, medical physics is a protected profession, so this is an important position DSMF will continuously pursue.

V. CONCLUSIONS: FUTURE OF MEDICAL PHYSICS IN DENMARK

A continuous high level of education is important. Private funding and priority by healthcare decision makers continues to introduce state-of-the art equipment in Denmark shortly after release. In addition, there is a long and proud tradition for well-reputed evidence-based research in medical physics. All are important points that are worth to retain and protect in the future for the continuous development of medical physics in Denmark. Looking at the current number of Medical Physics Experts there is a genuine request to continue the professional development throughout one's work life – we need to incite this in the future as well.

As a society we shall continue the support of our medical physicist members and make awareness of our important field of expertise – both to future medical physics students and the public in general.

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CONTINUING PROFESSIONAL DEVELOPMENT FOR MEDICAL PHYSICISTS IN FRANCE

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Abstract— Since 2017, medical physicists in France have been recognized as healthcare professionals. As a consequence, they entered the continuing professional development (CPD) programme for healthcare professionals. This implies creating the corresponding CPD bodies for medical physicists and to build a continuing education offer to comply with the CPD requirements, with the aim to improve the overall quality of patient care.

Keywords— medical physics, continuing professional development (CPD), training.

I. INTRODUCTION

After the completion of a formal initial training, continuing education involves maintaining and enhancing the knowledge, skills and experience related to the professional activities.

The first initiative for a national continuing education (CE) coordination open to medical physicists was made in 1999 by the French society of medical physics (SFPM, société française de physique médicale). A registration scheme was created, based on EFOMP (European Federation of Organisations for Medical Physics) recommendations [1]. It was only opened to SFPM members and based on a voluntary process. The registration scheme was approved by EFOMP in 2001.

Since 2004, medical physicists in France have an obligation of continuing education (CE). It was first stated by ministerial order [2] that medical physicists should, as part of their CE, update their theoretical and practical knowledge in order to fulfil their missions. In 2011, a new ministerial order [3] complemented this statement by adding that professional practice analysis and evaluation could be part of a CE for medical physicists, making it similar to the healthcare professionals CPD scheme (DPC for “développement professionnel continu” in French).

The SFPM registration scheme remained the only framework formalizing and following the CE obligation for medical physicists.

In 2016, EFOMP updated its “recommended guidelines on national registration schemes for Medical Physicists” [4] and the SFPM registration scheme was once again approved by EFOMP in 2020.

In 2009 a CPD framework was established in order for healthcare professionals to maintain and update their

knowledge and skills and to improve their practices.

Since 2017, medical physicists have been recognised by the French government as healthcare professionals [5], thus entering the CPD framework.

This paper presents the different steps to enter the healthcare professionals CPD scheme as well as the progresses and the pitfalls of entering a system designed to accommodate all healthcare professionals.

II. HEALTHCARE PROFESSIONAL CPD BODIES

Figure 1 presents an overview of the different CPD bodies.

The CPD is supervised by a national agency, later referred to as ANDPC (for “agence nationale de développement professionnel continu” in French), whose CEO is appointed by the ministry of Health. Its role is to guarantee that the CPD framework is independent of any interest related to the industry and economical stakeholders.

Each profession is represented by a national professional council (CNP for “Conseil National professionnel” in French) and an independent scientific commission (CSI for “commission scientifique indépendante” in French) constituted of national representatives of the profession. The CNP and CSI must be independent to avoid any conflict of interest. Members of CNP are non-profit organisations acting in the field of medical physics and cannot be a CPD organisation (ODPC for “organisme de développement professionnel continu” in French) providing CPD courses. There are currently two members of the medical physicist CNP (CN2PM, www.cn2pm.fr): the French society of medical physics (SFPM, www.sfpf.fr) and the association of medical physicists working in private institutions (APMESSP, www.apmessp.fr). The CNP is also recognized as an official representative of medical physicists for the French Ministry of Health. CSI members are appointed by the ANDPC upon CNP recommendations.

The primary role of the CNP is to define the priority orientations for a 3-year period. It also establishes the CPD scheme to follow in order to comply with ANDPC requirements.

CPD training courses are proposed by an ODPC, an organisation or company that has been qualified by ANDPC for healthcare professionals CPD. A training course has to be approved by ANDPC to be eligible to be taken into account in the CPD scheme. The scientific content of CPD courses is

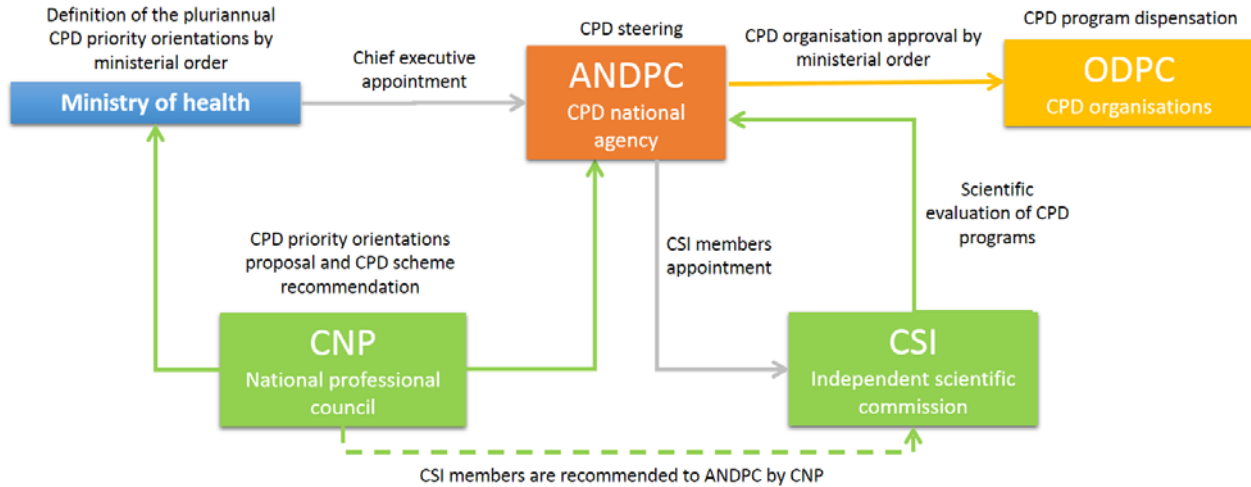


Fig. 1 Overview of CPD bodies

evaluated by the CSI of the profession to which the courses are dedicated. A CPD course can be multidisciplinary, hence the corresponding CSIs would have to be consulted by the ANDPC.

An ODPC is a training organisation that has applied to the ANDPC to become an official DPC organisation. It has to demonstrate its ability to run a programme for healthcare professionals in terms of organisation, scientific committee and to give a programme example fulfilling the agency criteria such as being about one of the priority orientations, having adequate pedagogical methods, performing prior and post assessment of the trainees, etc.

III. CNP RECOMMENDATIONS

CPD is organized as triennial periods. For each period, the CNPs are asked by the ANDPC to define the priority orientations for DPC courses and what should be the DPC scheme to follow to fulfill the requirements.

Priority training orientations are of two types: general orientations that can apply to different healthcare professions and orientations specific to the profession. They can be found online [7].

For the 2020-22 period, the medical physicists CNP (CN2PM) has selected the following general orientations:

- Risk management
- Adverse event handling
- Appropriate use of medical devices
- Artificial intelligence, data science, etc.
- Appropriate use of computerized tools for patient data
- Cancer management, in particular for children, adolescents and young adults

Specific orientations for medical physicists were also defined:

- Medical imaging techniques with a particular focus on the new technologies for image acquisition and treatment, information analysis and database, exposition estimate in diagnostic and interventional imaging using radiations.
- Therapeutic techniques involving radiations with a particular focus on the new technologies, image guided therapy, absorbed dose evaluation, modelling and artificial intelligence, and process control.

The CPD schemes have to follow the methods defined by the Haute Autorité de la Santé (HAS) [8], an independent health authority that has a scientific role in the evaluation of drugs, medical devices and professional practices. Their actions can be divided into three categories: teaching, risk management and professional practice evaluation. Training must not only target a better knowledge in a particular field but also trigger a reflection on professional practices and quality management in order to increase the general quality of care.

Medical physics CPD scheme recommendations are as follows:

- At least two of the three categories (teaching course, risk management and professional practice evaluation) must be present.
- At least one action must be part of the national priority orientations described above.

Actions can be independent or combined in an integrated programme (for example, a teaching course on a given topic with a session on risk management on the same topic).

This scheme is considered to be the minimum CPD scheme in order to maintain the overall knowledge and skills on professional practices. Nonetheless the professional can go beyond these recommendations and follow other CPD actions, if necessary for his/her professional practice.

IV. DISCUSSION

After more than 60 years of existence in France, medical physicists have gained recognition as healthcare professionals.

This allows medical physicists to enter a more structured continuing education (CE) framework called continuous professional development (CPD). This is a great opportunity to develop and maintain the quality of care. Nevertheless, it comes with several constraints.

First, there is an independence rule between CSI, CNP and its members SFPM and APMESSP: SFPM and APMESSP board individuals cannot be CNP board members. CSI members cannot be CNP members and cannot be part of the scientific committee of an ODPC. Although this rule makes perfect sense on the ethical level, it is more difficult for the small French medical physicist community (around 800 individuals) to find volunteers to be part of national professional boards.

Until now, the French Society of Medical Physics (SFPM) was the main provider of CE courses in the field of medical physics. Although it still can offer teaching programmes, these programmes cannot be CPD approved since SFPM is a member of the CNP.

The current three-year CPD period started in 2020, before all CPD institutions for medical physicists were in place and in the COVID crisis context. The first ANDPC approved trainings were only available at the end of 2021, making it difficult for all medical physicists to comply with the CNP recommendations by the end of the period. Currently it is the employer's responsibility to check the CPD compliance of healthcare professionals. No fine or enforcement actions are planned in CPD law but in case of an accident or a malpractice, it will be seen as an aggravating circumstance, although there will certainly be a tolerance for the first three-year period.

The healthcare CPD organisation applies to all healthcare professionals, from caregiver to opticians and specialized doctors. It is therefore not considering the specificities for each profession, and it is very rigid. Nevertheless, ANDPC regularly gathers all healthcare profession representatives to get feedback in order to improve the system.

Before entering the healthcare CPD organisation, SFPM had a very comprehensive CPD registration scheme set up. It was going far beyond healthcare CPD recommendations and considered a larger set of training actions. The main flaw was that it was not mandatory. Medical physicist CNP is currently working on bringing the best of the two systems in a unified registration scheme, where its members could extract the CPD actions from their registration scheme.

V. CONCLUSIONS

Being recognized as a healthcare profession by the French government was a major breakthrough for medical physicists' relationship with national institutions. It offered a better recognition of the profession and a better integration in institutional discussions. Medical physicists entered the healthcare professional CPD programme. Several bodies had to be created and a change of training content and organization had to be set up. Despite the changes, the French medical physicist community has adapted to the new system and continues working to offer the best quality of care, while complying with national regulations.

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MEDICAL PHYSICS TRAINING, EDUCATION AND PROFESSIONAL RECOGNITION IN HUNGARY

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Abstract—Medical Physics as a science is concerned with the application and development of the principles and techniques of physics to human beings, including the diagnosis, treatment and prevention of human disease. The Hungarian Society of Medical Physics was organized in 2008. The society is the professional community organized voluntarily by medical physicists working in the health care system. The great majority of the members are working in the field of radiation therapy, but medical imaging, diagnostic radiology, nuclear medicine, radiobiology and radiation protection are also represented. As a specialization of the physics MSc, the Department of Nuclear Techniques of the Budapest University of Technology and Economics launched a novel education module being the single medical physics education in Hungary in 2010.

Keywords— Medical Physics, Education, Accreditation and Certification, Hungary

INTRODUCTION: MEDICAL PHYSICS IN HUNGARY

Medical Physics as a science is concerned with the application and development of the principles and techniques of physics to human beings, including the diagnosis, treatment and prevention of human disease. The clinical use of X-ray and Ra-226 isotopes started in Hungary at the beginning of the 20th century. The first Hungarian application of isotope ²²⁶Ra was possible in a special department in a hospital of National Health Insurance Institute – now Uzsöki Hospital. The foundation of the Loránd Eötvös Radium and X-Ray Institute in 1935 can be regarded as the birth of medical physics with two famous Hungarian physicists: Dr. Johanna Toperczer (1903-1991), who was the first full time physicist in radiation therapy and Prof. Dr. László Bozóky (1911-1995) who joined in 1937. Later, in 1952 the Ministry of Health reorganized the institute and established the National Institute of Oncology.

The first patient in Hungary was treated with cobalt therapy more than sixty years ago at the National Institute of Oncology, Budapest with a fixed gantry Gravicert type equipment, which had been designed by László Bozóky seven years after the first cobalt unit installation in the world in Canada. At the beginning, the localization was performed with X-ray imaging, while the treatment planning was done manually. In 1965 a Rotacert type cobalt unit was installed at the same institute. This machine was already capable of making irradiation in multiple directions and it worked in rotating mode as well. In Hungary, more cobalt units – first the Gravicert type, then machines manufactured abroad –

were gradually installed in other radiotherapy centres. The quality of treatments was significantly improved by the introduction of the computerized treatment planning, and the foundation of the IAEA-supported National Computerized Treatment Planning Network in 1978. Moreover, the planning software donated by Van de Geijn was used on a central computer. The next important development was the commencement of the CT image based treatment planning in 1981.

The first step in July 1974 was the foundation of a Medical Physics Section (headed by Prof. Bozóky) in the Hungarian Biophysical Society (HBS). From 1994 the organization worked as the Hungarian Association of Medical Physicists (HAMP) – still part of the HBS, and became a member of the International Organization for Medical Physics (IOMP) in 1975 and of the European Federation of Organizations for Medical Physics (EFOMP) in 1980.

The first conference of the HAMP was organized in 1994 and the materials of the yearly conferences were published in English or in Hungarian as a Supplement of Radiológiai Közlemények (Radiological Communications, HU-ISSN 0133-2791, periodical of the National Institute for Roentgen and Radiation Physics, ORSI). The Hungarian Association of Medical Physicists as the Hungarian member society of EFOMP became entitled to prepare a Training Scheme, and appointed a Training and Education Committee to administer the Training Scheme in 1996 [1].

In 2008 we reorganized our society: the medical physics community left the HBS and founded the new independent Hungarian Society of Medical Physics (HSMP). The society is the professional community organized voluntarily by medical physicists working in the health care system. The purposes and activity of the Society are the following:

1. It assists the improvement of the application of medical physics (primarily ionizing radiations) and informs the public on professional issues for the interest of the population.
2. It represents specific aspects and interests of medical physics in the regulation and development of health care.
3. It assists and supports research and the education and training of its members in medical physics.
4. Through the improvement of professional conditions it assists the creative work of its members and urges toward the moral and financial appreciation of its members.
5. It represents the interests and viewpoints of the society as a Hungarian organization in international professional organizations and implements the application of the policy of

the European Federation of Organizations in Medical Physics (EFOMP) in Hungary.

The great majority of the members work in the field of radiation therapy. Today we have 13 radiation therapy centres and several nuclear medicine, X-ray diagnostic radiology and MRI (Magnetic Resonance Imaging) departments in Hungary.

GRADUATE TRAINING

In agreement with the Bologna process, the former university education has been replaced by the two-step Bachelor's and Master's level education. As a specialization of the physics MSc, the Department of Nuclear Techniques of the Budapest University of Technology launched a novel education module being the single medical physics education in Hungary. This MSc specialization offers courses on medical imaging, nuclear medicine, X-ray diagnostics, MRI and radiotherapy. Medical courses such as anatomy and medical physiology are given by lecturers from the Semmelweis University, Budapest.

The Institute of Nuclear Techniques (BME NTI) of the Budapest University of Technology and Economics is part of the Faculty of Natural Sciences. The mission of the institute is the education of physicists, environmental and power engineers in the field of nuclear measurement techniques and power generation. At the end of November in 2009 the Senate of the University approved the curriculum of the Medical Physics module.

The medical physics specialization aims at providing high level interdisciplinary theoretical and practical knowledge and readily applicable skills, which can be put into action both in the clinical and the R&D field. Strong contacts to medical institutions and to medical equipment vendors assure that the courses remain up-to-date and the skills readily applicable.

Applicants entering this profession have an appropriate degree (BSc) in a physical science or an equivalent 3-year training. The duration of the medical physics MSc programme is 4 semesters, 3 of which are intended for theoretical education while the last is for preparing the Master's thesis. The number of contact lectures are 104, resulting in a total of 120 credit points. The Module of Specific Lectures is collected on the basis of IPEN, EFOMP, AAPM and IAEA recommendations.

Module Specific Lectures (lecture/practical/laboratory work/credit): Functional Anatomy (2/0/2/4), Physiology (3/1/0/4), Ethical Aspects of Medical Research (2/0/0/2), Radiobiology (2/1/0/3), Radiation protection (2/0/2/4), Physical basis of Radiotherapy (2/0/2/4), Radiotherapy II. (2/0/0/2), Brachytherapy (2/0/0/2), Quality Assurance and Legislation (2/0/1/3), Medical Imaging (3/1/0/4), Physical basis of X-Ray Diagnostic (2/0/0/3), Nuclear medicine (2/0/1/3), Magnetic Resonance and clinical applications (2/1/0/3), Introduction to Optics (2/2/0/5), Microscopy (2/0/0/2), Physical Basis of Laser Medical Applications

(2/0/0/2), Spectroscopy and structure of matter (2/0/0/3), Neutron and gamma transport calculation techniques (2/2/0/5), Monte Carlo Methods (2/0/2/4), Ultrasound (2/0/0/2).

The interest of the students for the programme is high and it has become one of the most popular specialties of physics at the university. Institutes that are involved in the training include: National Institute of Oncology, BME, Institute of Physics, "Frédéric Joliot-Curie" National Research Institute for Radiobiology and Radiation Hygiene, Semmelweis University, Mediso Ltd.

CLINICAL TRAINING

The duration of the clinical training is 48 months (4 years) with a theoretical and practical exam at the end [2,2]. After a successful exam the physicist is qualified as a Clinical radiation physicist and registered by the Office of Health Authorization and Administrative Procedures.

To enter into the training programme, the applicant shall have an MSc (or equivalent) degree in physics, physics teacher or biomedical engineering, and basic education with a minimum 30-hour course in physiology, functional anatomy and radiobiology. The three main medical physics fields are radiotherapy, nuclear medicine and radiology. The training programme consists of 4 main parts: Practical training I. (17 months), Practical training II. (20 months), Theoretical courses (6 months), Scientific work (5 months).

Practical training I. consists of: radiotherapy (4 months), nuclear medicine (3 months), radiology (4 months), radiation protection (2 months), medical image processing (3 months), health informatics (1 month).

Practical training II consists of: radiotherapy or nuclear medicine or radiology (20 months).

Theoretical courses: 2 months in the field of interest (radiotherapy, nuclear medicine or radiology); 2 months – physical and technical module (comprehensive radiation protection, radiations, atomic and nuclear physics, nuclear measurement methods, methodology of scientific research, health informatics and biomedical statistics); 1.5 months – medical field module (basics of oncology, health organization and management, bioethics, laws in health care, basics of quality management); 0.5 month (comprehensive radiation protection).

Scientific work: The trainee conducts a scientific work in the selected medical physics field which results in a written essay or a paper for publication in a scientific journal.

The aim of life-long learning is well-known; thus, the members of our society are always encouraged to further develop their skills and improve their professional knowledge. To achieve the above-mentioned goals, the society supports its members by financing their participation in international conferences; however, the participant member is required to share the acquired information with the society members in return (in a presentation during the annual conference of the HSMP).



Fig 1 Structure of the present education system of qualified medical physicists in Hungary

Certification is awarded following a written, an oral and a practical examination.

The number of medical physics registrars enrolled in the Basic and Operational Registry of National Healthcare Service Center system is summarized in Table 1.

Table 1 Medical physics specialist registrars enrolled in Hungary in 2021

Specialty	Registrars	Female	Male
Diagnostic radiology	0	0	0
Radiation oncology	20	7 (35%)	13 (65%)
Nuclear medicine	3	0 (0%)	3 (100%)
Total	23	7 (31%)	16 (69%)

ONGOING REGISTRATION

The successful completion of the clinical training programme enables graduates to be added to the Basic and Operational Registry of National Healthcare Service Center that registers Medical doctors and Clinical radiation physicists.

In order to proceed with the registration, it is required to complete Continuing Professional Development (CPD) activities. This programme is now a web-based system (OFTEX) which extends over 5-year registration periods. Participants are awarded points for the completion of professional development activities, including attendance at scientific meetings, contributions to professional bodies, publications, teaching and supervision, and attending training courses. It is necessary to collect 250 points in total in 5 years. The points for practice are credited by the universities, based on the time spent in employment. 20 points can be collected annually, which means a total of 100 points during one

period. In order to finish a period, the collection of at least 60 points is required. The Compulsory training course is worth 50 points. The remaining 100 points can be collected from elective courses, publications and educational activities.

Registered physicists become members of the Hungarian Medical Chamber.

FUTURE OPPORTUNITIES AND CHALLENGES

Currently, the clinical radiation physicist qualification is only available on a fee-paying basis, and subsidized training is not available. The number of accredited departments is limited. There is no residency system, and no quota as there is for medical doctors. Therefore, tuition fees and course fees have to be paid by the trainees themselves. Furthermore, they are paid by their employer during the 4-year training period and are therefore expected to be at work in their home institution as much as possible. It is unlikely that they can be released for weeks or months to do an internship or a course in another institution. Therefore, many physicists from centres without an accredited training programme cannot afford to take part in the formal training. A solution to this would be to provide centrally funded training for clinical radiation physicists, as is the case with the medical doctor specialist training. With this, the number of physicists participating in the training could be greatly increased.

CONCLUSIONS

Training and certification are key activities for professional organizations and HSMP in its more than 20 years of history has been actively involved in many aspects of these tasks. The members of the HSMP have contributed to the delivery of training internationally, through organizations including the International Atomic Energy Agency (IAEA), European Society for Radiotherapy and Oncology (ESTRO) and European Federation of Organisations for Medical Physics (EFOMP).

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MEDICAL PHYSICISTS IN LITHUANIA IN THE 21st CENTURY

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Abstract— Regular university level MSc studies in Medical Physics have been established and are successfully carried out over almost 20 years at Kaunas University of Technology providing programme graduates with the opportunity to continue their career in radiation therapy, diagnostic imaging, nuclear medicine or radiation protection. The programme Medical Physics is aligned with international guidelines set by EFOMP and IOMP, is highly focused on clinical training and research and is one of the few programmes in Europe (except UK) delivered in English. Almost 100 programme graduates are daily contributing to the provision of high quality services to oncology patients in Lithuania. The article aims to show the progress in education & training of medical physicists in Lithuania during the last 20 years and discusses the medical physicist career path due to the establishment and implementation of a nationally approved recognition scheme.

Keywords— Medical Physics, Medical physicists, Education, Training and Certification, Lithuania.

HISTORICAL BACKGROUND

The history of medical uses of radiation in Lithuania goes back to 1896 when F. Dembovskis opened his first X-ray cabinet in Vilnius. Application of radionuclides for the treatment tumours was started in the third decade of the past century and the first teletherapy unit with Co-60 source was commissioned in 1954. At this time irradiation services were provided by medical doctors with the support of nurses. There is no well documented information related to contingency and education of medical radiation workers from this time, but some data related to measurements of individual doses of these workers [1] indicate that there was dedicated technical staff, performing medical physicist’s tasks.

In 1995, the newly established Lithuanian Society of Radiation therapy recognized that there was an urgent need to start regular education and training of medical physicists in Lithuania [2] and dedicated this task to Medical Physics Committee members represented by medical radiation workers of Oncology institute and Kaunas Medical University Clinics.

Despite the efforts of the MP Committee the situation did not change until a new player – Kaunas University of Technology – came to the scene via participating in the EU TEMPUS PROGRAMME Project S_JEP-12402-97, the main objective of which was: development of a new Joint Baltic Medical Engineering and Physics Master’s course (JBMEP) on the basis of developing new educational

modules and restructuring of some existing modules on Medical/Biomedical Engineering and Physics (including their teaching materials) delivered as part of various MSc programmes in the universities of Latvia, Lithuania and Estonia. Even though the developed curricula of the joint Baltic MSc programme was never realized (due to the differences in legal requirements for education and training in three Baltic countries), it inspired a new step for the development of medical physicists’ education & training and their recognition strategy in Lithuania which was elaborated following EFOMP recommendations in the frame of the National Radiation Protection programme (2001-2005) (Fig.1) [3].

Level	Actual scheme	New scheme	EFOMP
1	B.Sc. In physics, engineering or equal, 4 years		
2	Professional work in the hospital or hospital environment	M.Sc. in medical physics, KTU, 2 years	Post-graduate training: Theoretical part (300-400 hrs) Practical part (min 2 years professional work)
MEDICAL PHYSICIST			
3	On the job training (min 2 years), theoretical studies and training courses	Continuous post-graduate studies, KMU, 2 years	
	Qualification exam as medical physicist		
LICENSED MEDICALPHYSICIST			QUALIFIED MEDICAL PHYSICIST
4	Continuous professional development, 5 year cycle time, credit point system		
MEDICAL PHYSICS EXPERT			

Fig. 1 Career scheme for medical physicists in Lithuania (2003)

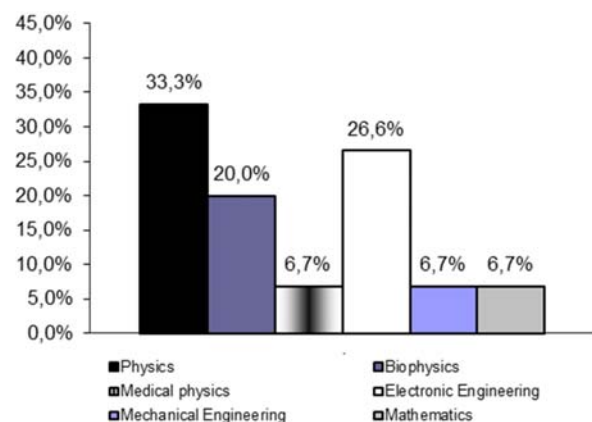


Fig. 2 "Medical physicists" staff in Lithuania's hospitals in 2003

It should be noted that the profession of medical physicist was approved by the Ministry of Health of the Republic of Lithuania in 1992. Implementing the guidelines of EC Directive 1997/43/Euratom [4], hospitals having radiology (especially radiotherapy) departments were forced to employ a number of “medical physicists” without adequate education and training. The distribution of graduates from different study programmes employed as “medical physicist” in 2003 is provided in Fig. 2 [5].

Increasing numbers of modern installations in radiology departments and new patient treatment and diagnostic methods were challenging for the existing “medical physicists” staff as they required deeper specific knowledge in the field of medical physics. The only possibility to overcome this problem was to start education and training of medical physicists at the university MSc level, creating additional possibilities for education and retraining of the staff employed in the hospitals as medical physicists.

GRADUATE TRAINING

Education and training of medical physicists at Master’s level was started at Kaunas Technological University (KTU) in collaboration with Kaunas Medical University in 2003, strictly following the recommendations of international authorities, EFOMP and IOMP. A valuable contribution to the successful opening and development of this study programme was the establishment of the Dosimetry laboratory at Kaunas University of Technology, which was financed by the Swedish Government and also supported by colleagues from Lund University, Malmö University Hospital and King’s College London.

The main goal of this two-years programme was and is to educate and train medical physicists for the health care institutions where ionizing radiation technologies are applied for the diagnosis and treatment of patients. Besides, medical physicists are additionally trained to work as radiation protection officers.

The MSc programme in Medical Physics has been successfully implemented over the years at KTU and is unique for Lithuania.

There were attempts to run an MSc study programme “Medical physics” at Vilnius University (VU) in 2010-2015, but due to the limited number of highly qualified teachers in the field in Lithuania and some discrepancies of the programme curriculum as compared to international recommendations, this programme was closed.

It should be noted that the number of students in different programmes is regulated by the Ministry of Education, Science and Sports of the Republic of Lithuania, which limits the quota for the number of MP students to 6-8. However, due to the successful implementation of education and training of medical physicists at Kaunas University of Technology, the goal of exceeding 50% of all employed medical physicists having an MSc degree in Medical physics was achieved in 2010 (Fig. 3) [3].

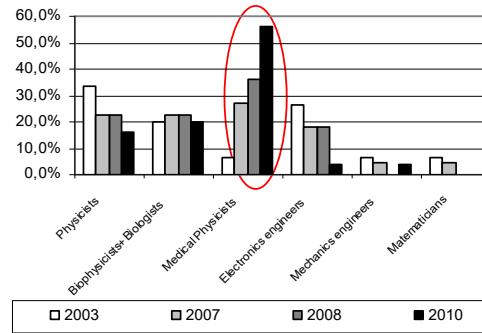


Fig. 3 Qualification of medical physicist staff employed in the Lithuanian health care system

The total number of Lithuanian graduates from the MSc study programme Medical Physics is 115: 92 graduates from KTU and 23 graduates from VU (as of the year 2021).

Since the courses are given in English, the study programme is attractive for foreign students. Programme graduates and students were/are from different countries, including: Japan, Germany, India, Bangladesh, Nepal, Iran, Iraq, Turkey, Bulgaria, Canada, UK, Egypt, Portugal, France, Spain, Lebanon, Georgia, Serbia, Nigeria. Implementation of a so-called “clinical semester” in the frame of the programme, during which the students are taught and are performing their practical and research work mainly in the clinical environment, contributed very much for making the programme relevant to recent needs and supporting integration of Medical physics programme graduates in clinical teams. There is no officially recognized clinical training programme for medical physicists in Lithuania; it runs on individual supervision basis.

The majority of programme graduates are employed in the health care system of Lithuania. The dynamics of the employment of MP programme graduates, which is one of the highest in Lithuania, is presented in Fig. 4.

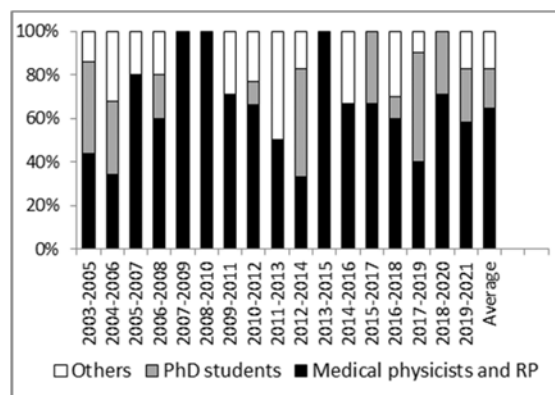


Fig.4. Employment of graduates from the MSc programme Medical Physics at KTU

There are 5 Oncology departments in Lithuania: National Cancer Institute, Vilnius University hospital “Santaros” Clinics, Hospital of Lithuanian University of Health Sciences Kaunas Clinics, Klaipėda University Hospital, Šiauliai Republican Hospital. The total number of Medical Physicists employed at radiotherapy departments in 2016 and perspective number of MPs employed at RT departments in 2021, together with a total number of MPs calculated following RP 174 guidelines in 2013 are provided in Table 1 [6].

Table 1. Numbers of MP in Lithuania 2013-2021*

Hospitals	Requested total number of MP (calculated following RP174 guidelines, 2013)	Number of full time positions for MP in RT, 2016 (fact)	Number of full time positions for MP in RT, 2021 (perspective)
University Hospital of Lithuanian University of Health Sciences Kauno Klinikos	15MPE+22MF	10.25	12
National Cancer Centre	11MPE+22MF	10	12
Republican Šiauliai Hospital	3MPE+7MF	3.5	4.5
Klaipėda University Hospital	6MPE+12MF	6.5	8.5
	98 (35MPE+63MP)	30.25	41.5 (37)???

* table with calculation mistake is taken from original document (6).

The real total number of MPs employed in the clinical environment in 2021 was 41: 29 MPs in radiotherapy, 8 MPs in Radiology and 4 MPs in nuclear medicine. They were involved in the operation and preparation of dose treatment plans for patients at 12 Linacs, 5 HDR/LDR brachytherapy units, 3 X-ray therapy units, 1 Gamma knife, and also were carrying out QA and calibration work in different radiology departments or performing their duties working with two 2 PET/CT units. It is worth pointing out that installation of a medium energy cyclotron is underway.

Due to a very strong involvement of the KTU Research group “Radiation and Medical Physics” led by Prof. Diana Adliene and researchers from Clinics during preparation of MSc thesis by the programme students, a relatively large number of medical physics graduates are continuing their PhD studies. There is no PhD programme in Medical

Physics due to the lack of professors in this field, however there are possibilities for programme graduates to enter PhD studies in Physics or Materials engineering and work on topics related to the medical physics field: dosimetry (materials and devices), phantoms (materials), modelling of radiation induced processes in materials, etc.

The remainder of the graduates are working in the radiation protection field or are choosing different pathways for their career.

NATIONAL RECOGNITION SCHEME OF MEDICAL PHYSICISTS CLINICAL TRAINING

With the successful implementation of MSc studies, the knowledge and skills gained by programme graduates raised a question regarding non adequate professional recognition of medical physicists among health care workers and their role in clinical work. Following ILO (2008) recommendations it was suggested that MP professional recognition should be assigned to the group of physicists working in the medical environment. However, the profession of MP in Lithuania was often misinterpreted, assigning medical physicists to supporting staff or engineers in the clinic.

With the establishment of the national Medical Physicists Society in 2007 it was decided to initiate development of a national strategy for recognition of medical physicists, as medical professionals working in the clinical environment. The idea was supported by the Radiation Protection Centre, Kaunas University of Technology and Vilnius University and a working group was created at the Ministry of Health of the Republic of Lithuania. The newly established representative Lithuanian Association of Medical Physics and Biomedical Engineering joined the working group by the end of 2008. It took 10 years until 2017 to get an officially approved National Registration Scheme which defines the requirements and procedures for the recognition of medical physicists in Lithuania (Table 2) [7].

Table 2. National recognition scheme of Medical Physicists in Lithuania

Junior Medical Physicist
4 years of BSc studies in physical, biomedical, technological sciences + 2 years of MSc studies in Medical physics. Working in clinical environment is allowed under supervision of medical physicist specialist (MPS) or Medical physicist expert (MPE)
Medical Physicist Specialist
2 years working experience in clinical environment under supervision of MPS and MPE and clinical training and research. After obtaining MPS in one of fields of medical physics (radiotherapy, imaging and diagnostic, nuclear medicine, lasers and non-ionizing radiation), MPS in another field can be awarded after one year of clinical training in relevant field. When the requirements are fulfilled, MPS is recognized as a person who is legible for license of work in the ionizing radiation environment.
Medical Physicist Expert
At least after 3 years of clinical work as MPS in a selected field + at least 100 hours of professional training, + minimum of 200 hours of participation in research and teaching experience. The expertise of MPE shall be approved by State Commission for Recognition of medical physicist expert. Re-certification of MPE is mandatory every 5 th year following the procedures set by Radiation Protection Centre of Lithuania.

All requested achievements for the obtaining any Medical Physicist's category must be approved by corresponding documents. The qualification of Junior Medical Physicist and Medical Physicist Specialist in one or more areas is assigned to a person for a life-long period, however the Medical Physics Expert category may be withdrawn if the person fails during the re-certification procedure, which is mandatory every 5th year.

The responsibility for registration of Medical Physicists as persons working in an ionizing radiation environment is delegated to the Radiation Protection Centre, which maintains a National Register of the sources of ionizing radiation and occupationally exposed persons.

A small confusion remains, speaking about the profession of Medical Physicists. In general, medical physics studies are assigned to the study direction "Medical technologies", which are covering both medical and physics fields; however, according to the diploma, programme graduates are assigned directly to the health care workers.

Since 2020, MSc diploma in Medical physics holders, as health professionals, are obliged to apply for the stamp with individual number at the State Accreditation Service for Health Care Activities under the Ministry of Health, before they are able to start to provide health care services [8]. It should be noted that 29 medical physicists have already applied for and got their individual stamps in 2020/2021, thus being included into the data base of health care workers in Lithuania.

The national recognition scheme is already being applied for the evaluation of Medical Physicists. They must show their knowledge, skills and abilities during discussion with the members of the accreditation board, which is created by a special order of the Minister of health of the Republic of Lithuania. The first 8 MPEs are already recognized and the recognition process is going on with support from the very active Medical Physicists Society which is organizing different seminars and training for young medical physicists, supports their training abroad, encourages colleagues to perform research in the medical physics field and present their results at the International Conference "Medical Physics in the Baltic States" which is organized every second year by Kaunas University of Technology, Lund University and the Medical Physicists Society.

CONCLUSIONS

The education & training, recognition and career pathways of medical physicists in Lithuania have been discussed. It was indicated that the training and certification of medical physicists must be key activities for the professional organizations while education should be left as a priority for the University.

It was also shown that, even having two professional organizations in the country: Lithuanian Association of Medical physics and Biomedical Engineering which has only a representative role at the international organizations

and Medical Physicists Society which is the main driver of ideas and activities related to the medical physicist's profession, it is possible to move forwards. A network established by both societies allows reaching of every Medical Physicist in Lithuania, to provide them with advice and to consult him/her by solving specific problems or support (if requested) regarding the career pathway.

The national recognition scheme of medical physics professionals is already implemented and seems to work properly, however there some problems left. The most important question for Lithuania is the establishment of officially regulated and recognized clinical training of MSc graduates from the university. Contribution to the recognition of Medical Physicist's profession at the European level is another priority for Lithuanian Medical Physicists, since it would allow movement of medical physicists around Europe.

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MEDICAL PHYSICS IN MALTA: PAST, PRESENT AND FUTURE

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Abstract— The Medical Physics profession is a very young profession in Malta. However, in the few years of its existence it has organized itself in a very effective manner. The profession is legally recognized, we have excellent Bachelor's and Master's degree programmes and now we are setting up our own training programme. Notwithstanding being a small association, we involve ourselves fully in EFOMP activities and we have contributed to the development of the profession in Europe.

Keywords— Medical Physics, Education and Training, Certification, Professional Recognition

INTRODUCTION: MEDICAL PHYSICS IN MALTA

The Medical Physics profession is a very young profession in Malta. Discussions to work towards the establishment and recognition of the profession started in 2007 through a collaboration of a single university academic at the University of Malta and the three clinical Medical Physicists at the time. At the time the profession was practically unknown, not legally recognized and clinical Medical Physicists were employed under the generic title of 'scientific officers'. A major breakthrough happened in 2012 when the Ministry of Health recognized the importance of Medical Physicists and through a grant of the European Social Fund and a strong collaboration between the Ministry of Health and the Medical Physics Department of the University of Malta, 14 trainee Medical Physicists were employed, read for a Master's in Medical Physics at the University of Malta and underwent two years supervised clinical training in the United Kingdom [1]. In 2014, the Maltese Government, through a legal notice, included Medical Physics as a regulated profession within the Council of Professions Complementary to Medicine. Medical Physics Experts in Malta are also legally recognized and certified by the national Commission for the Protection from Ionising and Non-ionising Radiation. As part of its national activities, the Malta Association of Medical Physics (MAMP, <https://mamp.org.mt/>) organizes meetings and seminars, some of which include members presenting the clinical challenges and successes achieved in our hospitals. MAMP has always encouraged members to get involved within the Association and EFOMP. Meetings are held in collaboration with other institutions, including the University of Malta, the national Commission for the Protection from Ionising and Non-ionising Radiation and

the Allied Health Care Services Directorate. MAMP also has a students' chapter. The number of clinically qualified Medical Physicists in Malta presently stands at 20.



Fig. 1 2020 Annual meeting of the Malta Association of Medical Physics

ROUTE FOR REGISTRATION

The standard route for certification as a clinical Medical Physicist is: (a) first degree in Physics or Engineering, (b) Master's in Medical Physics and (c) two years supervised clinical training.

EDUCATION IN MEDICAL PHYSICS: PAST, PRESENT, FUTURE

In the past the Master's in Medical Physics was a two-year full-time programme. The curriculum (shown in Table 1) was comprehensive and served the profession extremely well. Unfortunately, in the past few years this system has been found to be no longer attractive as students are insisting on a single year Master's degree programme, owing to their reluctance to forego two years of salary. The Medical Physics profession has had to face the contradictory situation when we needed to reduce the duration of the Master's programme at a time when the knowledge, skills and competences required to be an effective and safe Medical Physicist are increasing owing to the rapid expansion in medical device technology. In addition, we have been facing the dire situation of having low numbers of entrants to the Master's owing to the low number of undergraduate students in physics and engineering.

Table 1 Curriculum for the Master's in Medical Physics

Subject	ECTS Credits
Biophysics and Basic Biomedical Sciences for Medical Physicists	10
Clinical Medical Devices & Protection from Physical Agents	5
Research Methods and Statistics for the Physical and Health Sciences	5
Principles of Biomedical Signal Processing for Medical Physics	5
Principles of Biomedical Image Processing for Medical Physics	5
Professional, Ethical, Legislative and European Issues in Medical Physics	10
Service Quality Development, Health Technology Assessment and Innovation in Medical Physics	10
Clinical Medical Physics Practices and Procedures	10
Medical Physics in Diagnostic and Interventional Radiology (Major/Minor)	20 / 5*
Medical Physics in Nuclear Medicine (Major/Minor)	20 / 5*
Medical Physics in Radiation Oncology (Major/Minor)	20 / 5*
Dissertation	30

*Students were to choose one major area of specialization at 20ECTS and two minor areas at 5ECTS each.

After much thought we are pleased to report that we have found a solution. Our programme now involves an alternative route which involves a new undergraduate programme: a *B.Sc. (Hons) Physics, Medical Physics and Radiation Protection followed by a one-year MSc Medical Physics*. The new bachelor programme is an inter-faculty programme between the Physics department of the Faculty of Science and Medical Physics at the Faculty of Health Sciences. Students join physics, mathematics and statistics classes with the physics students of the Faculty of Science, and anatomy, physiology, pathology, ethics and health services management classes with the students of the Faculty of Health Sciences. These study units are then followed by study units in Medical Physics and Radiation Protection. Since our entrants to the bachelor's programme rarely have a background in biology, we offer an online free Summer School in which we provide a comprehensive overview of human biology. The programme also includes a total of 336 hours of clinical hospital experience. We are pleased to report that the bachelor undergraduate degree has been a huge success and we do not depend on entrants from physics or engineering any more (although of course these are still welcome). We now have enough students to easily provide all the future Medical Physics trainees the country would need. We are also hoping that some will go overseas for some years and bring much needed know-how back with them once they return. Further information on the new bachelor's programme can be found here: <https://www.um.edu.mt/courses/overview/UBSCHPMRFT-2021-2-O> whilst the full curriculum can be found here: <https://www.um.edu.mt/courses/programme/UBSCHPMRFT-2021-2-O>. This new pathway has enabled us to transfer a

chunk of the Master's in Medical Physics curriculum to the undergraduate course and is permitting us to include new future-oriented study units in the curriculum of the Master's proper (e.g., we have introduced a 10 ECTS credit in Machine Learning and Pattern Recognition).

CONTINUOUS PROFESSIONAL DEVELOPMENT TOWARD MEDICAL PHYSICS EXPERT STATUS

As part of the transposition of directive 2013/59/EURATOM into Maltese legislation, the recognition of an MPE in Malta has been defined to include an additional two years documented full time work experience following registration as a Medical Physicist and documented continuous professional development (CPD). The Association has taken the lead in supporting CPD through various activities, national and international.

INTERNATIONAL ACTIVITIES

Although a small organization by European standards, our members involve themselves as much as possible in EFOMP activities. We have a member on every EFOMP committee, our President Sam Agius is secretary of the Professional Matters committee and Carmel Caruana our EFOMP delegate was in the past Chairperson of the Education and Training Committee. Carmel is also well known for his initiatives in promoting leadership in Medical Physics both at the European and global level and his involvement in the European Guidelines on the MPE, the EUTEMPE project and Medical Physics education at the European level and at the global level with IMPCB are well known [2-7]. MAMP members are also involved in different working groups endorsed by EFOMP: Eric Pace is a member of the Working Group on "the involvement of MPEs in the life cycle of medical devices" and Sam Agius and Nadine Napoli are involved in the Special Interest Group for Radionuclide Internal Dosimetry.

We also organize international courses. Our EQF Level 7 EBAMP accredited course on Data Analysis with Python for Medical Physicists was designed to address a skills gap in the area of programming and formal understanding of principles of general purpose programming languages. The aim is to help Medical Physicists work with large datasets and to provide a foundation for the further expansion of the Medical Physicist's role in clinical applications of AI and machine learning. So far, we have held two successful courses with a combined attendance of more than 90 international participants. This course is also being taught as part of the new B.Sc. (Hons) Physics, Medical Physics and Radiation Protection as we believe that all future Medical Physicists need to have strong programming skills [8, 9].

FUTURE OPPORTUNITIES AND CHALLENGES

The great majority of Maltese clinical Medical Physicists have been trained in the UK. This has been good for the profession because we learned from some of the best Medical Physicists around. However, it is now time to set up our own training scheme. The Maltese authorities had insisted with the UK trainers that our training should follow the IAEA training schemes in all three specialty areas. We are now in the process of setting up our training scheme in Malta and we will be following the IAEA training scheme to be in line with international standards.

A major opportunity ahead is the expansion of our profession to other specialties, in particular that of the General Hospital Physicist (physiological measurement, lasers etc.) on the basis of the Dutch model.



Fig. 2 Poster of the international Python course for Medical Physicists

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MEDICAL PHYSICS IN NORWAY – HISTORY, EDUCATION, CERTIFICATION AND NORDIC COLLABORATION

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Abstract— The Norwegian Association of Medical Physics (NFMF) was established in 1976 and celebrates its 45th anniversary in 2021. The main aim for NFMF is to support the medical physics community. The mandate of NFMF is also to initiate, encourage and facilitate the exchange of knowledge and cooperation across professions and country borders. An important focus is to continuously evaluate and develop the educational programme in order to improve and standardize the professional level of medical physicists in Norway.

Keywords— Medical Physics, Education, Certification and Collaboration.

I. INTRODUCTION

Medical physicists in Norway are primarily employed in hospitals within the fields of diagnostic radiology (X-rays, MRI), nuclear medicine and radiation therapy. In addition, active research groups in physics departments at Norwegian universities work in close collaboration with the hospitals, especially within radiation therapy and radiobiology.

In this paper we will focus on the history of medical physics in Norway; how physicists initially worked with radiation therapy and over the years evolved into being medical physicists actively involved in interdisciplinary teams in charge of the preparation, delivery and evaluation of the diagnostic imaging and treatment of patients. Medical physicists are today the spearhead in the development and implementation of new technology in order to improve the patient outcome.

II. A BRIEF HISTORY OF MEDICAL PHYSICS IN NORWAY

The first medical physicist in Norway was Nelius H. Moxnes who was hired during the initial phase of the building process of the Norwegian Radium Hospital in Oslo in 1929. As a part of this work, Moxnes established a physics laboratory to ensure that the dosimetry and treatment methods would be ready for the opening of the hospital in 1932. Moxnes was later asked to build a governmental laboratory in 1939. This laboratory is today the Norwegian Radiation and Nuclear Safety Authority (DSA) [1]

Since 1972, radiation therapy departments have been established outside the capital of Oslo in order to be geographically close to the patients. The establishment of radiation therapy departments across the country led to a demand for medical physicists within radiation therapy.

There are currently 10 radiation therapy departments in Norway: Tromsø, Bodø, Trondheim, Ålesund, Bergen, Stavanger, Kristiansand, Ullevål (Oslo), Radiumhospitalet (Oslo) and Gjøvik.

In the 1970s computer assisted medical technology was introduced, primary as a result of worldwide advancement within medical physics. This demanded more advanced physics service at the hospitals. Norway has always been an early adopter of new and cutting-edge medical technology. The first computed tomography (CT) machine in Norway was installed at Ullevål University Hospital, Oslo, in 1975. CT based radiation therapy planning was established in Bergen in 1979 and the first magnetic resonance imaging (MRI) machine was installed in Stavanger in 1986. This led to a steady growth in the number of diagnostic physicists at the university hospitals across the country. The diagnostic physics group at the university hospitals acted as a physicist pool, serving the smaller peripheral radiology departments.

As a result of the diagnostic and radiation therapy advancements in the 1970s, the medical physics community established the Norwegian Association of Medical Physics (NFMF) in 1976. Today, NFMF has 223 members and the number is increasing each year. The NFMF holds an annual meeting for the Norwegian medical physics members with invited speakers, proffered papers, poster sessions and vendor exhibition. The annual meeting typically attracts 120 members and is one of the cornerstones in the Norwegian medical physics “family” where the social programme and mingling during the coffee breaks is just as popular as the scientific programme.

III. LEGISLATION

The Norwegian radiation law was established in 1938, one of the first radiation legislations in the world. Today, the EU basic safety standards (2013/59/Euratom) are implemented in the Norwegian radiation protection regulation where appropriate and feasible. An update in the Norwegian radiation legislation stated that the number of scientists with an MSc degree should reflect the complexity and number of the modalities available in the hospital. In the notes of the current legislation it is stated that a scientist certified by the NFMF meets the necessary requirements to work in a Norwegian hospital. This implies that a certification as a medical physicist or medical physics expert is recommended, but not mandatory in order for a scientist to work in a hospital. A scientist working in a hospital is not defined as

“authorized health personnel” in the Norwegian health legislation, which restricts the scientist from working directly with patients.

IV. EDUCATION

In the medical physics community, a typical requirement in order to work as a physicist in a hospital in Norway is to hold an MSc degree within either nuclear physics, biophysics or medical technology. Four universities in Norway offers a complete Master’s programme or separate Master’s level courses within these topics: The Norwegian University of Science and Technology (Trondheim), the University of Oslo (Oslo), the University of Bergen (Bergen) and the Arctic University of Norway (Tromsø). The Master’s thesis can be conducted in collaboration with hospitals and with clinical physicists as supervisors.

Several universities and colleges in Norway work closely together with the hospitals and have active research groups and PhD programmes within medical physics.

V. CERTIFICATION AND SPECIALIZATION

In 2001 the DSA set down a work group to establish a Norwegian training programme for medical physicists working within radiation therapy, based on European guidelines. The Norwegian training programme was published in 2005. In 2009, the NFMF established a certification programme for medical physicist and a specialization programme within X-ray imaging, MRI, nuclear medicine and radiation therapy. The certification and specialization programmes are based on EFOMP and other international recommendations.

The certification as a medical physicist requires a minimum of 2 years of training after accomplishing an MSc degree in physics. The certification process is based on recommended literature, courses (hosted by e.g. ESTRO or Royal Marsden) and shorter internships or “sit-ins” to learn about typical tasks of other professions such as the technical staff, oncologists, radiologists and radiographers. A medical physics expert or a senior medical physicist acts as a supervisor who guides the process and approves the certification application that is later assessed by the NFMF. Today, 166 medical physicists are certified by the NFMF.

A certified medical physicist can apply to be become a medical physics specialist (equivalent to medical physics expert) within X-ray imaging, MRI, nuclear medicine or radiation therapy. The specialization to become a medical physics expert is based on CPD points (Continuous Professional Development) according to the EFOMP standards. Since 2009, 72 medical physicists have been accredited as a medical physics expert. The accreditation is valid for 5 years before it must be renewed.

It is a goal that the certification process is relevant and feasible in the everyday clinic at Norwegian hospitals. The

NFMF certification process is therefore under continuous evaluation and development. The educational resource bank established by the NFMF education council with recommended courses and literature is highly appreciated and works as a stamp of approval and quality for physicists in training. However, out of 72 accredited medical physics experts there are currently only 19 medical physics experts with valid accreditation in Norway, see Table 1 for details. The NFMF board are currently looking into why so few medical physics experts renew their accreditation.

Table 1 Number of NFMF members, certified medical physicists and medical physics experts with valid accreditation in Norway as of October 1st 2021

NFMF members		223
Certified Medical Physicists		116
Medical Physics Experts	Specialty	
	X-ray imaging	8
	Nuclear Medicine	3
	MRI	0
	Radiation therapy	8

VI. NORDIC COLLABORATION

The first Nordic medical physics meeting was held in 1962 in Örebro, Sweden. The Nordic Association of Clinical Physics (NACP) was formally founded in 1965, only a few years later than e.g. the Association of Physics in Medicine (AAPM). At the time, NACP established highly acclaimed workgroups and publications within topics such as dosimetry, radiation protection, treatment planning, education and simulation techniques [2].

The triannual NACP symposia was revitalized in 2008 in Aarhus, Denmark. The role as hosting nation rotates between the Nordic countries. The next NACP symposium will be held in 2023 in Reykjavik, Iceland, and will be organized in cooperation with the Danish society of medical physics (DSMF) and NFMF.

There are two specialty committees under the umbrella of the NACP: The Radiological Physics Committee (RPC) and the Nuclear Medicine Physics Committee (NMPC). The mandate of the specialty committees is to initiate Nordic networks and collaborations within their field of medical physics to meet the demands from the community. The committees organize courses that are relevant for their community. The committees consists of one member from each of the Nordic countries.

VII. INTERDISCIPLINARY COLLABORATION

The NFMF closely collaborates with the Norwegian Oncology Association, the Norwegian Radiology Association, The Norwegian Society of Radiographers and the DSA.

Within radiation therapy, a national quality assurance group (KVIST) was established in 2000 by the DSA in order to harmonize and strengthen the field of dosimetry and radiation therapy. KVIST consists of representatives from physics, oncology and therapists from each radiation therapy department in Norway. KVIST is continually working to improve the quality and communication between the radiation therapy clinics and across the different professions working within radiation therapy. Each year an interdisciplinary meeting within radiation therapy is held in collaboration between KVIST, NFMF, the Norwegian Oncology Association and The Norwegian Society of Radiographers.

VIII. CONCLUSIONS

We have given an overview of how the fields within medical physics have developed since its infancy in 1929. Since 1976 the NFMF has been instrumental in the development of the medical physics community, especially the annual meeting for the members of NFMF and the establishment of the educational programme to improve and

standardize the professional level of medical physicists in Norway. In addition, supporting and facilitating communication and collaboration across professions and country borders continues to be one of the key activities for the NFMF in the years to come.

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MEDICAL PHYSICS EDUCATION AND TRAINING IN POLAND

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Abstract— Medical Physics in Poland has a relatively long tradition. To say that Maria Skłodowska-Curie was the very first Polish medical physicist would be a simplification. However, she had a huge contribution to the development and understanding of medical physics in Poland. The training of human resources initiated by Marie Curie was passionately continued by her followers, even in spite of the economic difficulties typical of the economy of communist countries. Also today, there is in Poland a dynamic development of medical physics observed, both in clinics and at the academic level. Poland has a very clear National Registration Scheme, which is fully compliant with EFOMP recommendations. It covers all recommended topics and fields of study. The Polish NRS was one of the first six approved by EFOMP.

Keywords— Medical Physics, Education, Accreditation and Certification, Training

I. INTRODUCTION: HISTORY AND DEVELOPMENT OF MEDICAL PHYSICS IN POLAND

It should be said that medical physics in Poland from the very beginning, i.e. from the beginning of the 20th century, found fertile ground for development. Young physicists, inspired by the successes of our great compatriot Maria Skłodowska-Curie, willingly decided to continue her work. Development continued despite the dark period of World War II and the long years of the Iron Curtain.

Maria Skłodowska-Curie, living in exile in Paris, actively supported her countrymen who remained in her homeland. Her dream was to establish the Radium Institute in Warsaw. For this purpose, the Radium Institute Society was established in 1921 and Maria became its honorary chairman.

Maria Skłodowska personally participated in the conceptual work on the Institute's project as she had considerable experience in organizing research laboratories. It was intended to be an institution in which therapy should be carried out in conjunction with scientific work. Clinical activity was to have a status equal to that of research. It was a very innovative solution for those times [1].

The construction of the Institute at Wawelska Street in Warsaw (it still exists today) began in 1925 [1,2]. Apart from supervising the construction works, Maria made efforts to obtain the necessary research staff for the

Institute. For this purpose, close cooperation with the University of Warsaw was established. One of the first delegates for an internship in Paris, to the laboratory run by Curie, was Cezary Pawłowski, who had just defended his PhD dissertation in physics.

The purchase of the laboratory equipment was financed by the Polish state and numerous donations from private individuals, including Maria Skłodowska's family: Dr. Bronisława Dulska (sister) and Irena Curie-Joliot (daughter) [2]. The primary radioactive source of radium, on the other hand, came directly from Marie Curie. In 1934, Pawłowski became the head of the Physical Laboratory at the Radium Institute. Following the solutions observed in Paris, Pawłowski established two sub-laboratories: the Calibration Laboratory and the Laboratory for Measurements of Radioactive Substances. The intention was that both laboratories were to perform dosimetric measurements for other treatment facilities in Poland. The Calibration Laboratory is still operating with the SSDL (Secondary Standard Dosimetric Laboratory) status. It was the only scientific institution in occupied Poland to operate legally, also during the war (from the beginning of its activity in 1937 until the end of the war, over 640 calibrations were performed). The Radium, prepared chemically, survived the war, hidden by Pawłowski underground in the garden adjacent to the Institute.

In 1946, Pawłowski became a professor at the Warsaw University of Technology. Thanks to his efforts, a new field of study was created at the Faculty of Communications: electromedicine, as a specialization after three years of general studies. Graduates of these studies for many years expanded the staff of the Maria Skłodowska-Curie Institute of Oncology (nowadays National Institute of Oncology), which was established on the basis of the Radium Institute.

The Polish Society of Medical Physics (PSMP), named after Prof. Cezary Pawłowski, continues the ideas promoted by the Radium Institute Society. In 2020, the Society had nearly 400 active members, the vast majority of whom deal with the use of ionizing radiation in medicine.

II. EDUCATION AND TRAINING

In order to become a Medical Physicist in Poland, one needs to complete a master's degree (EQF 7) in physics, medical physics or related studies, such as biomedical

engineering, technical physics and biophysics. It is an absolute condition for starting work in the clinic and next for commencing postgraduate education. This “specialization education” is carried out in accordance with EFOMP and EU recommendations. Education at the master's level may take place at several universities, both colleges and universities of technology. Students have the opportunity to undergo practical classes and internships in a selected oncology centre.

After completing the 3.5-year training, which consists of theoretical and practical modules, the physicist must pass the state examination. Specialization in the field of medical physics in Poland has the same rank as medical specialization and it is for life.

Specialization training in Poland in the field of medical physics was first established in 2011. Since then, the teaching programme has been updated twice. Currently the educational programme covers theoretical education (specialization courses) at 536 hours and practical training (internships) at 880 hours [3]. During the specialization, the candidate should complete a basic internship of 580 days of professional activities in the workplace in accordance with the specialization programme. The content of the curriculum is provided in Table 1.

Table 1 Content of the curriculum

Content	Days	Hours
MODULE I General module		
- specialization courses	23	138
MODULE II Radiotherapy		
- specialization courses	22	132
- directional internships:		
1. external beams radiotherapy	50	400
2. brachytherapy	20	160
MODULE III Imaging diagnostics		
- specialization courses	14	84
- directional internships:		
1.X-ray and ultrasound diagnostics	15	120
2. magnetic resonance imaging	5	40
MODULE IV Nuclear Medicine		
- specialization courses:	8	48
- directional internships:	20	160
THE ONE COURSE		
Medical law	2	12
Basic specialization internship	480	4640
Self-education – evidenced by supervisor	18	144

The teaching courses are conducted by experienced specialists employed in accredited oncology centres. Postgraduate education of medical physicists and other medical professions in Poland is regulated and supervised by the Medical Centre for Postgraduate Education. After completing the specialization training, a medical physicist passes the state examination. The institution responsible for conducting specialization exams in areas applicable in health care in Poland is the Medical Examinations Centre.

The state examination is carried out twice a year, i.e. in the spring and autumn sessions. The examination committee appointed by the Medical Examinations Centre consists of representatives of the Ministry of Health (National Consultant in the field of medical physics), outstanding specialists appointed by professional institutions supervised by the Minister of Health and representatives of the Polish Society of Medical Physics.

The Society actively contributes to the scientific and professional development of medical physicists in Poland by organizing courses, conferences, scientific conventions and congresses. Points are awarded for participation in individual activities, which are the basis for the evaluation of professional development. Active participation of specialists in Continuous Professional Development (CPD) is the basis for applying for the title of Medical Physics Expert at the PSMP.

The most recognizable meeting in the country organized by the PSMP is the Congress of PSMP, which is organized every two years. The second one is the Autumn School of Medical Physics (ASMP). The School was founded in the late 1980s. The meeting was initially a local event organized by the Oncology Center in Bydgoszcz, but quickly gained the status of a national event. Nowadays it is organized every two years and deals mainly with radiotherapy, x-ray diagnostics and nuclear medicine topics. ASMP plays an important role in the medical physics community in Poland by integrating the community and providing an opportunity to exchange professional experiences.

Regional branches of PSMP organize their own events. Some of them host not only colleagues from their neighbourhood, but also from all over the country. It is worth mentioning, for example, the Silesian Medical Physics Seminars organized in cooperation with the University of Silesia. The Seminars are held every two years in the Beskid mountains. The programme of the event covers the full scope of medical physics. MP students have also an opportunity to present their MSc or PhD theses here.

The PSMP also acts as a partner of several events organized by universities, scientific centres and independent hospitals. These are, inter alia, the “Young Scientists Forum” organized since 2001 by Greater Poland Cancer Center in Poznań and “Physics for a Medic” held at AGH University of Science and Technology in Kraków. The YSF is held in English, usually about 15 speakers present projects in radiobiology, medical physics and clinical radiotherapy to an international competition committee. The Physics for a Medic conference is organized on the initiative and by the Student Scientific Association KERMA. The event attracts a large number of students (almost 200) from 20 Polish universities.

As PSMP brings together medical physicists from various fields, such as radiation protection, nuclear medicine, brachytherapy or radiotherapy, each profession also meets in its own group within the so-called section meetings.

The Society publishes its own periodical, the Polish Journal of Medical Physics and Engineering, which is available at <https://sciendo.com/journal/pjmpe>. [3,4]

III. INFRASTRUCTURE

Poland, with almost 40 million citizens, has exactly 50 radiotherapy centres – including public and private ones (data for the beginning of 2020). Several of them additionally have smaller satellite facilities located in smaller towns.

The total number of linear accelerators used in external beam radiotherapy is currently 168. Four centres in Poland have additionally installed Cyber Knife accelerators and two centres possess Gamma Knife units. There is also one proton therapy centre. In brachytherapy, HDR units are mainly used (57 devices), but LDR and PDR devices (5 and 3 units respectively) are also used [5].

About 500 medical physicists are employed in radiotherapy. Physicists also work in x-ray diagnostics, MRI and non-ionizing imaging, radiation protection and nuclear medicine throughout Poland – 29 PET scanners (including PET-MRI) and 22 SPECT-CT scanners operated in nuclear medicine departments in 2020.

Nearly 67% of medical physicists in Poland have the title of specialist or they are in the process of specialization training.

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MEDICAL PHYSICS IN SPAIN: CURRENT STATUS AND CHALLENGES

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Abstract— Medical Physics is officially recognized as a healthcare specialty in Spain with the same status to that of other medical specialties. Regulation at national level together with the activity of organizations such as the SEFM (Spanish Society of Medical Physics) and the work of medical physicists have brought the profession to a high level of qualification. This paper describes the current situation of Medical Physics in Spain and summarizes the challenges it is currently facing: the need to update and expand the official teaching programme and the accreditation criteria for hospital training units, to promote research activity and to increase the social visibility of Medical Physics.

Keywords— Medical Physics, Spain, SEFM, training programme.

I. INTRODUCTION

The first medical physicists in Spain, mostly women, began working in the hospital setting in the early 1960s because of the need to ensure the safe and controlled use of ionizing radiation in health care.

Throughout the 80s and 90s, a series of events took place that marked the development of our profession. In 1980, the Nuclear Safety Council (CSN) was created as the sole regulatory body in the field of Radiation Protection. Subsequently, in 1982 and in accordance with Directive 80/836/EURATOM [1], the role of the Qualified Expert in Radiation Protection (RPE), called “Head of Radiation Protection Department”, appeared in the first regulation on health protection against ionizing radiation.

In the 1990s, Radiation Protection Services (SPR) were created in large hospitals of the public network of the National Health Institute of the Ministry of Health, while CSN started to require that such departments be organized in some hospitals with Radiotherapy, Nuclear Medicine and Diagnostic Radiology facilities.

A milestone towards specialization/regulation of training and accreditation was the first call for medical physics residents in 1993. Finally, Royal Decree 220/1997 [2] of 14 February, created and regulated the official title of Specialist in Radiophysics (Medical Physics Expert, MPE), based on regulated three-year theoretical-practical residency.

With this Royal Decree, physicists and physicians were given the same status as specialists.

Medical Physics is currently a health profession in Spain, regulated along with the rest of the health professions by Law 44/2003 [3] and Royal Decree 183/2008 [4], and for whose professional practice it is required to be in possession of the corresponding official title of specialist in Medical Physics.

The MPE degree in Spain qualifies the holder to work in the field of ionizing radiation in any hospital setting. The activity is mainly clinical, including the areas of therapy, both in radiotherapy and nuclear medicine, diagnostic imaging, interventional radiology and radiation protection.

In addition, teaching and research are regular activities of Medical Physics departments, although, due to the clinical workload, the latter must often be reduced.

Regarding institutions, there are currently more than 100 centres in Spain, both public and private, where more than 650 MPEs work. According to a survey conducted by the Spanish Society of Medical Physics in 2016 [5], the average number of MPEs in public centres was 5.2, and 2.5 in private ones. Although these numbers have certainly increased, it can be said that Spain is a country with a wide network of centres with relatively small MPE teams.

The historical ratio of men to women was approximately 2, but this value has been balanced to approximately 1.5, according to data on new residents in the last decade.

II. SEFM

The Spanish Society of Medical Physics (SEFM) was born in 1974 from the dissolution of the Spanish Society of Medical Radiology and Electrology (SEREM), which combined Electrology, Radiotherapy, Physiotherapy and Radiology. SEREM, created in 1930, had only physicians as full members, although it admitted physicists, manufacturers and others, but without voting rights.

The development and specialization of the discipline of Medical Physics in Spain, boosted by the creation of national societies of Medical Physics by IOMP (International Organization for Medical Physics), eventually led to the founding of SEFM. In this context, the nearly twenty medical physicists who were spread all over the country, in either universities or hospitals, were linked through a society with its own statutes, dependent on the Spanish Ministry of the Interior.

The number of members of SEFM, which started with only two women and two men in 1974, has progressively increased to the current 960 members, of which 600 (67%) are MPEs.

Its development has been driven by the organization of 23 congresses, which have been held since 1977 on a biennial basis until the last one held in 2021, this one completely virtual due to COVID-19 restrictions. The last 7 congresses have been held jointly with the Spanish Society of Radiological Protection. It should be noted that the 1993 congress in Tenerife coincided with the 2nd EFOMP congress, which demonstrated the support that Spanish Medical Physics received from the international community.

The aim of the SEFM is the development and promotion of Medical Physics in scientific and professional aspects, with training activities and working groups. An accredited training course (12 ECTS, European Credit Transfer System) in Fundamentals of Medical Physics (Baeza Course) is given annually to provide a common theoretical basis to most of the medical physicists in training (it is not mandatory, but most attend). It is a blended course, with a six-month online phase (but requiring 4-5 hours per week) and a three-week face-to-face phase, although in 2020 it was online-only due to COVID-19 restrictions.

Continuing Professional Development of medical physicists is another of the SEFM's strategic objectives for which there is a permanent commission with a wide range of accredited courses covering all areas of the specialty. This activity has been strongly affected by COVID-19 and SEFM has had to reorient its teaching activity to online mode, which has been a great challenge. It is likely that the training will continue to have an online component allowing for greater flexibility.

Among the different activities in which SEFM is working through its members and working groups, two projects in particular should be highlighted: GAIN (Support Group for New Researchers), aimed at enhancing the research role of medical physicists in Spain with the support and collaboration of colleagues with consolidated research experience, and the REM project (Network of Spaniards in the World), which will put in contact all Spaniards who carry out activities outside our borders to create a network of support and feedback that strengthens our work, both individually and as a professional group.

Since the year 2000, SEFM has been publishing periodically a journal, the yellow journal, which is currently in the process of being indexed.

At present, it continues its scientific development in close collaboration with other Spanish Societies, such as Radiation Protection (SEPR), Radiation Oncology (SEOR), Nuclear Medicine and Molecular Imaging (SEMNUM) and Medical Radiology (SERAM).

SEFM is also involved in all aspects of Medical Physics through its representation in relevant national organizations, such as the National Commission of the Specialty, the Spanish Professional Association of Physicists, the Forum of the Nuclear Safety Council and the Spanish Society of

Radiological Protection, as well as in international organizations, namely, EFOMP, IOMP and ESTRO.

All information about SEFM can be found at <https://sefm.es/>.

III. MEDICAL PHYSICS EDUCATION AT UNIVERSITY

Until 2007, Physics was a licentiate's degree (5 years), equivalent to a master's degree. To apply for the 3-year Medical Physics residency programme, a Licentiate degree in Physics or other scientific-technological degrees were required.

After joining the European Higher Education Area, aimed at homogenizing university degrees in Europe, the old licentiate's degrees disappeared and the Physics degree was reduced to a 4-year graduate's degree, equivalent to 240 ECTS credits.

A Physics degree (240 ECTS) is taught by 24 universities in Spain and 8 (33.3%) offer a specific subject of Medical Physics as an elective (mostly of 6 ECTS). Two more universities (8.3%) offer a subject related to the applications of radioactivity, touching on some topics of Medical Physics, such as radiation protection or radiological equipment.

In summary, less than 50% of universities offer content related to Medical Physics. Students are required to do an internship (6 ECTS) in companies or institutions related to Physics degrees. Some students choose a Medical Physics department of a hospital to carry it out and, in this way, establish a first contact with this field.

A Master in Medical Physics (determining a total of 300 ECTS, EFQ7) is not required to become a MPE, but it provides the basic background to prepare for the national exam to apply for the residency programme. It is also a valuable profile for some companies looking for a profile related to Medical Physics (application specialists, sales representatives, research, etc.). Only 3 out of 24 universities offer a specific Master's degree in Medical Physics.

As for the PhD, only one university offers a specific programme on Medical Physics. However, topics in this matter are included in different programmes, such as Nuclear Physics, Applied Physics, Medicine, Biophysics or Engineering. PhD students must have a master's degree or, failing that, the second year of residency in Medical Physics.

The PhD degree is a prerequisite for directing a research project and it is often taken into account for career promotion. There are some well-established research groups on Medical Physics in Spain, especially in brachytherapy, functional imaging, in-vivo dosimetry, Monte Carlo or IORT, whose work is often published. Most of them are composed of medical physicists working in hospitals and researchers from universities or other public institutions, such as IFIMED (Valencia), CIEMAT (Madrid), CSIC, i3M (Valencia), Complutense University of Madrid, UNED, University of Granada, University of Barcelona, University of Santiago, etc.

Finally, it is worth mentioning that there are different centres dedicated to the calibration and traceability of ionizing radiation measurements, such as Ionizing Radiation Metrology Laboratory- CIEMAT (Madrid), Institute of Energy Techniques (Barcelona), National Dosimetry Center (Valencia) or the Radiophysics Laboratory (Santiago).

IV. SPECIALISED HEALTH TRAINING

As mentioned above, the specialty of Medical Physics is recognized as a specialty in Health Sciences by Royal Decree 183/2008 [4]. Therefore, the specialized training in Medical Physics (Fig. 1) is regulated and governed by the same rules of access, structure, monitoring and evaluation as the rest of the healthcare specialties, as established by the Law 44/2003 [3].

Training in Medical Physics is carried out in accredited institutions through a residency system that follows an official 3-year teaching programme. The training framework foresees the provision of paid professional services by the medical physicists in training, while they acquire the competences of the specialty through the professional practice programmed and supervised by the tutor and the collaborators of the teaching unit.

Access to the training system is by means of a national examination, held annually along with the rest of the health specialties. This exam consists of a test-type exercise mainly on physics and to a lesser extent, in mathematics.

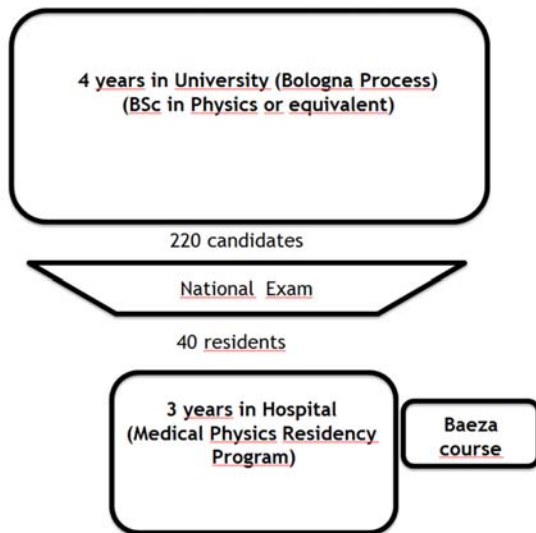


Fig. 1. Scheme of Spanish system of specialized training in Medical Physics. Data for 2020-2021 Spanish Ministry of Health [6].

The number of applicants varies over the years but usually hovers around 200. According to a study conducted

between 2015 and 2019, approximately 95% of the candidates had studied Physics and of the remaining 5%, most had studied Industrial Engineering.

There are currently 40 accredited teaching units in Spain that could offer a total of 43 training positions, although the number offered annually by the Ministry of Health varies according to the proposals of the Spanish Autonomous Communities, which have healthcare competencies. In the last 5 years the number of positions offered has increased (Fig. 2) due to the 7 new teaching units accredited in recent years and the need for a greater number of MPEs to cover the latest investments in radiotherapy in Spain.

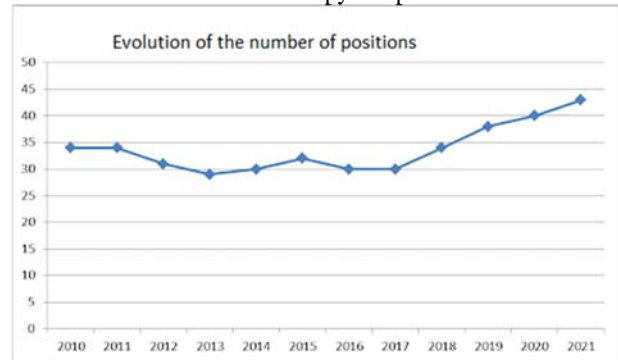


Fig. 2. Evolution of the number of training positions offered in recent years.

The Ministry of Health is advised by the National Commission of the Specialty, which issues a justified report recommending the number of positions appropriate to the current need for MPE.

The National Commission is made up of 11 members with specialist degrees, representing the Ministry of Education and Professional Training, the Human Resources Commission of the National Health System, the national scientific societies SEFM and SEPR, the Spanish Professional Association of Physicists and the specialist in training. Its main functions, as an advisory body on specialized training, are to draw up the training programme and the evaluation criteria, to propose the creation of specific training areas and to establish the criteria for accreditation of teaching units.

Summarizing, specialized training in Medical Physics in Spain follows a training programme drawn up by the National Commission of the Specialty, informed by the regulatory authority for Radiological Protection (Nuclear Safety Council, CSN) and approved by the Ministries of Health and Education.

The current official training programme was approved in 1996 when the specialty was created. It established the teaching objectives, the specific theoretical and practical content and the recommended time to be dedicated to each area: Radiotherapy (18 months), Diagnostic Imaging (12 months) and other uses of radiation and Radiation Protection (6 months). Activities such as teaching and research were also taken into account. The National Commission has been

working on updating this programme and has proposed to the Ministry of Health to extend the training period from 3 to 4 years in order to: i) adequately develop the responsibilities established for MPEs and RPEs referred to in Directive 2013/59 EURATOM of 5 December 2013 [7], ii) incorporate the recommendations expressed in the “European Guidelines on Medical Physics Experts (MPE)”, published by the European Commission in 2014 [8], which include competencies that reflect the updating of new technologies and clinical procedures in the field of Medical Physics.

V. CHALLENGES

The scientific challenges of Medical Physics in Spain are linked to those of the community worldwide in this field. Spanish MP and research groups related to this discipline contribute and participate in the evolution of Medical Physics. This is the result of individual efforts but also of the existing infrastructure at the clinical, administrative and research level.

The official recognition of Medical Physics as a healthcare specialty by the national authorities is a fundamental step for its consolidation and development. This goal, together with the existence of a regulated training system that guarantees the competence of professionals and researchers, are two of the main objectives of our profession in all countries. Both milestones were accomplished in the last decade of the last century in Spain [2].

Over time, these foundations have allowed the consolidation of an important scientific community dedicated to Medical Physics in Spain. SEFM has been key in this evolution as an integrating element of the different needs and initiatives. It is also worth mentioning the contribution of the administration through the creation of bodies such as the National Commission of the Specialty [4]. In addition to them, the Spanish Professional Association of Physicists also plays a major role for legal matters concerning professional issues.

Despite the achievements made, major structural challenges that Medical Physics in Spain must face in order to continue growing:

- The current official training programme is in urgent need of updating, as it has become obsolete both in content and in duration. Since its approval 25 years ago, there have been important advances in clinical procedures that have been accompanied by an increasing complexity of technologies in the therapeutic and imaging fields. In addition, new legislation has established new responsibilities and new specific roles for MPEs. Consequently, the competencies to be acquired have increased significantly in both number and complexity.
- The harmonization of accredited programmes in hospitals requires a constant effort on the part of those in charge. Special attention needs to be paid to the existence of new techniques and technological

advances, due to the impossibility of their existence in all training centres. To make up for this, stays are organized during the training process in those centres that have the latest developments.

- Special attention should be paid to the figure of tutor. Tutoring is a voluntary activity that is not recognized in salaries. The recognition and training of tutors must be a constant challenge, as they are a fundamental part of achieving quality training.
- The requirements for access to Medical Physics training should be modified. Firstly, it should be limited to those with a solid background in physics and mathematics. Secondly, the required university education should be increased to a minimum of 300 ECTS, which is the equivalent level of education to that required prior to the entry into force of Royal Decree 183/2008 [4]. These rules would guarantee the appropriate level of knowledge of the applicants, as well as equal opportunities for specialists in the field of free exchange of professionals in the EU.
- To increase the research participation of MPEs, especially in clinical trials where they have very limited participation. Although there are several competitive research groups in Spain, there are few commitments with clinical trials and the participation of MPEs in clinical trials is residual and mostly related to quality assurance. One way to increase the inclusion of MPEs in clinical trials could be to improve the collaboration with clinical societies (SEOR, SEMN, SERAM, EORTC and ESTRO).
- The presentation in October 2021 of the ESTRO-EFOMP Core Curriculum for Medical Physics Experts in Radiotherapy [9, 10] will represent a new challenge consisting of the incorporation of its new features into the official training programme for Spanish medical physicists.

We would also like to stress the importance of the improvements in the integration and participation of the SEFM in the EFOMP and IOMP, as a natural framework for development in the future of Medical Physics in Spain.

In conclusion, Medical Physics in Spain is in good health but requires some actions to maintain its positive evolution over time. Particularly, it is worth noting that there is a growing concern among medical physicists about the still poor social outreach of our profession in Spain. This is not only a matter of social recognition, but rather a strategic issue that would help to resolve some of the pending challenges already mentioned in this paper. SEFM should lead this initiative.

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MEDICAL PHYSICS IN SERBIA – TRAINING, EDUCATION, RECOGNITION AND EMPLOYMENT OPPORTUNITIES

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Abstract— Profession of medical physics in Serbia is not recognized as health care profession. The training and education are provided through university studies on BSc, MSc and PhD level, as well as specialization and through training in hospitals. The recognition of profession is a task for current generation of medical physicists. Medical physicists are employed in hospitals, and currently there are 70 colleagues who support all radiotherapy, nuclear medicine and diagnostic radiology patients all over Serbia. They also cover radiation protection issues in hospitals within their regular duties.

Keywords— Medical physics, education, training, medical physics expert, radiation protection

I. INTRODUCTION: MEDICAL PHYSICS IN SERBIA

The Republic of Serbia has a population of approximately 7,350,000 inhabitants, and the official language in Serbia is Serbian. Its capital Belgrade has almost 1,700,000 inhabitants, and the three following major cities are Novi Sad (~ 400,000 inhabitants), Nis (~ 260,000 inhabitants) and Kragujevac (~180,000 inhabitants).

There are eight radiotherapy centres in the country, with five brachytherapy machines, 25 linear accelerators and one gamma knife machine, while the purchase of an additional five linear accelerators is in process. The country has 15 nuclear medicine centres, also housing two PET machines. Two nuclear medicine centres are private. Diagnostic radiology departments are equipped with CT, MRI, mammography units, X rays etc.

Radiation protections in clinics are covered by employees whose main job is radiotherapy or nuclear medicine. There are also a number of medical physicists working in institutions of occupational health.

Medical use of ionizing radiation in Serbia actually started with the first X-ray unit, brought in 1897, more than 120 years ago, to the hospital in the small Serbian city of Sabac. This machine arrived to Serbia thanks to the close friendship of Dr Avram Vinaver, medical doctor, with Wilhelm Roentgen. Dr Avram Vinaver was born into a Jewish family in Krakow, Poland, where he finished studies

of medicine. He lived and worked in Sabac, Serbia where he developed his private practice.

The second X ray unit was purchased in 1901 for a hospital in Zemun (at that time a part of the Austro-Hungarian empire), and the third X ray for the General hospital in Belgrade in 1905. One of the first patients at that time was the Serbian king Petar I Karadjordjevic, whose hand was imaged by the machine.

Dr Avram Vinaver organized the “First Congress of Serbian physicians and naturalists under the highest protection of His Majesty King Peter I”, held in Belgrade in September 1904, which was one of the first conferences with a session dedicated to the use of X rays in the world, and the first in the Balkans [1-3]. Dr Avram Vinaver prophesied that X-rays and X-ray diagnostic application were the method of the future. In his study “Five years of treatment with Roentgen rays” [2] Dr Avram Vinaver presented therapeutic options of X-ray used on 62 treated patients where he cited Prof Holzknrecht from Vienna who was one of the eminent radiologists of the world at that time. Dr Avram Vinaver concluded that “it would be an unforgivable sin against our patients to remain indifferent to the Roentgen-therapy and not make it possible for them to be treated and cured by means of X-rays”.

At that time, characteristics of ionizing radiation were not known, and there was no room for medical physicists. Many years after, in 1939 the Royal hospital for cancer treatment and diagnosis was founded in Belgrade, and its building was funded by the queen Marija Karadjordjevic. Unfortunately, the Second World War postponed all the plans for nearly 15 years.

The first ever physicist employed in Serbian medicine was Mr Veselin Vujnic, a young and ambitious nuclear physicist, who was working at the Institute of nuclear sciences Vinca on the nuclear reactor installation. His previous knowledge and experience in dosimetry enabled safe implementation of the first external beam treatment unit – cobalt 60 – in Belgrade. The machine started clinically in 1960.

The first Society that gathered people interested in biomedical sciences was formed in Belgrade in 1984. Later on, a Society for biomedical engineering and medical

physics (BIMEF) was formed in 1996. This Society was closed in 2011.

The Serbian Association of Medical Physicists was established in 2012, gathering all medical physicists working in hospitals. The Association is a member of EFOMP (European Federation of Organisations of Medical Physicists) and regularly organizes annual professional and scientific meetings and workshops, and keeps close connections to other regional medical physics organisations through the Alpe-Adria network.

It is a non-profit organization with the task of raising awareness of the importance of the profession, taking part in research and teaching in the field of medical physics, and giving advice on the safe application of physical methods in medicine. Also, the task of the Association is to help in the recognition of the profession, work on roles and responsibilities, and conduct educational and training sessions.

Since the foundation of the Association, the medical physics profession has grown together with other medical specialties, and nowadays there are over 70 medical physicists in Serbia, serving annually more than 13,000 radiotherapy patients and over 50,000 nuclear medicine patients.

Medical physicists in Serbia are employed in hospitals and provide services to radiotherapy departments, nuclear medicine departments, diagnostic radiology and radiation protection in their hospitals. The number of academic staff, also employed in hospitals, is still very low, but due to the future need for education of medical physicists, radiation oncologists, nuclear medicine specialists and radiologists, the number of academic staff will have to increase.

However, the medical physicist profession, although recognized within the Serbian Ministry of labour and approved in the official Serbian catalogue of jobs, still lacks recognition from healthcare institutions and the Ministry of Health. The aim of this paper is to discuss the challenges that medical physicists in Serbia is faced with in everyday work, explain the scheme of training and education, and provide opportunities for future recognition.

Roles and responsibilities of medical physicists are defined by the Serbian Law on radiation and nuclear safety and security, brought in 2018 (Act 84). The definition of medical physicist in the Law (Act 5) describes a medical physicist as a person working in a clinical environment, specialized and qualified to work independently in one of the areas: radiotherapy, nuclear medicine or diagnostic radiology.

There is also a definition of medical physics expert in the Law (Act 103), but this is not yet implemented.

The number of medical physicists, and spread over different areas, is given in Table 1.

Table 1 Medical physicists in Serbia

Item	Total	Diagostic Radiol	Radiat. Oncol	Nuclear Medicine
Univ.Clin.Center Kragujevac	12	1	10	1
Univ.Clin.Center Nis*	7	0	6	0
Univ. Clin.Center Serbia, Belgrade	12	0	8	4
Univ.Clin.Center Vojvodina, Novi Sad	2	1	0	1
Institute of oncol&Radiol Serbia, Belgrade	17	0	16	1
Inst.Oncology Vojvodina, Sremska Kamenica	12	0	12	0
Inst.Pulm.Diseases Vojvodina, Sr.Kamenica	2	0	2	0
Military Medical Acad. Belgrade	4	1	2	1
Health center Kladovo	4	0	4	0
General Hospital Cuprija	1	0	0	1
Total	73	3	60	9

* one physicist works solely as radiation protection officer

II. ACADEMIC EDUCATION

The established pathway to become a medical physicist in Serbia starts with the university education in the field of physics or technical sciences, and gaining the EQF 6 (European Qualification Framework level 6). There are currently five university centres (Belgrade, Novi Sad, Nis, Kragujevac and Kosovska Mitrovica) where a candidate can obtain a BSc degree at Faculties of Physics, Natural Sciences, Physical Chemistry or Faculty of technical Sciences).

According to the current catalogue of jobs in Serbian healthcare, a medical physicist must have a master's degree in physics or equivalent (EQF 7). There is also a possibility in two university centres to obtain a master's degree in medical physics.

After obtaining an MSc degree, one can go for a PhD degree. One university centre (Novi Sad) offers a PhD programme in medical physics.

All courses are accredited by the National accreditation body in higher education of Serbia.

The first master's programme in Serbia, in the field of medical physics, was offered in 1995 by the Association of Centres for Interdisciplinary and Multidisciplinary Studies and Research (ACIMSI), University of Novi Sad, but in 2010 it is closed down and moved to the Faculty of Sciences.

Students from university centres can select to work on their final diploma work, or MSc thesis or PhD thesis, and it requires very close cooperation with the hospital and good

logistics. It is not always easy, as still only a few medical physicists are also employed by the University. Currently, this is the case with only one person with a university and clinical professional background. This should be changed in the coming year.

III. PROFESSIONAL/ CLINICAL TRAINING

A Medical Physics training programme in clinics was established in 1992, by the Faculty of Medicine, University of Novi Sad. The training programme was approved by the Ministry of Health of Serbia, and was a part of the rulebook of all healthcare specializations. It was written in the form of descriptive text, giving short information on what topics must be learnt and skills obtained. The training lasted for three years, and after the final exam, defence of the research project done during clinical employment in hospital, a candidate obtained a title “specialist in medical nuclear physics”.

During 2012, the Ministry of Health required reformation of all healthcare specializations, and the old specialization was terminated while a new one was established in 2013, based on IAEA Guidelines of clinical training of medical physicists as well as ESTRO recommendations on training of medical physicists. The new title that the specialists obtained was “specialist in medical physics”. It covers all three areas of medical physics.

This programme is now conducted in two university centres (Novi Sad and Belgrade). It comprises of theoretical lectures and clinical training.

But the main condition to enter clinical training and specialization is that a candidate is employed by the hospital in the field of radiotherapy, nuclear medicine or diagnostic radiology, and that the Ministry of Health approves the candidate’s entrance, based on documentation provided by the hospital, describing the need for a medical physicist.

Currently, the number of specialists in medical physics (qualified) and in training is given in Table 2.

Table 2 Qualified and in training medical physicists in Serbia

Specialty	Qualified Medical Physics Specialists	In training
Diagnostic radiology	0	3
Radiation oncology	21	40
Nuclear medicine	7	2
Rad.Protect	0	1
Total	28	46

IV. ONGOING WORK

The Serbian Association of Medical Physicists is active in national, regional and international activities.

On a national level, it established cooperation with the Ministry of Health and the Directorate for Radiation and Nuclear Safety and Security.

The liaisons of the Directorate as regulatory body in Serbia and the Serbian Association of Medical Physicists are related to generation of regulatory documents, liaised with the Law on ionizing radiation and nuclear safety in the field of radiation medicine. They contain:

1. Set of national quality control and quality assurance documents for the safe use of radiation generators and radioisotopes in diagnostic and nuclear medicine as well as radiation oncology
2. Implementation of EU directive [4] into national laws, as well as implementation of professional recommendations (IAEA, EFOMP, ESTRO) into local legal framework

The work with the Ministry of health has the following directions:

1. Recognition of profession of medical physicist in the healthcare system as healthcare professional
2. Equalizing of status of medical physicist with the status of radiation oncologist, radiologist and nuclear medicine specialist
3. Accordingly change of salary, as it is currently 30% lower than that of medical professionals
4. Employment of more physicists as recommended by IAEA staffing calculator [5]

The Serbian Association is also trying to find its place within professional organisations in Europe, and is acquiring fruitful connections to the International Atomic Energy Agency, EFOMP and ESTRO.

V. FUTURE WORK

The Serbian Association of Medical Physicists marks its 10th anniversary in 2022. We are also hoping to close very important chapters for us: recognition as healthcare professional and improved staffing levels.

Currently, the lack of medical physicists worldwide reflects the national picture in Serbia. The number of physicists is generally very limited in hospitals, due to regulation that has not been changed for decades (staffing levels). On the other hand, less and less students are starting physics studies each year, thus contributing to the future lack of professionals.

Another future task is establishment of national regulation regarding the QA in medical use of radiation sources. Our Association, together with the Ministry of Health and the Directorate, started working on it, by creating dedicated workgroups for different topics related to radiotherapy QA, nuclear medicine QA and diagnostic radiology QA. This is planned to be adopted on a national level and implemented into Serbian regulation.

We plan more involvement in international projects and activities, in the field of radiation protection and medical physics.

VI. CONCLUSIONS

Training, education and registration are the most important tasks for a professional association of medical physicists.

The lack of medical physicists worldwide is reflected in Serbia; contributing to this is also the fact that physicists are widely neglected in healthcare, as well as other non-health professions (biologists, chemists, etc).

Physicists in Serbia contribute substantially to implementation of new techniques as well as training of all staff, but their value is not acknowledged through their status and salary. This might lead in future years to the dramatic failure of the Serbian healthcMPI_issue_final_versionsare system relying on ionizing radiation, as the students will turn to more profitable jobs.

The career of medical physicists is very exciting, requires constant education and improvements in knowledge and skills, also enables travelling and meeting new people, but it has to be valued and recognized.



Fig. 1 Members of the Serbian Association of Medical Physicists during the annual meeting in 2021

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MEDICAL PHYSICS HISTORY, EDUCATION AND PROFESSIONAL TRAINING IN SWEDEN

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Abstract — Sweden has a long tradition of using ionizing radiation within health care. In the span of more than 100 years, the applications within Medical Physics have grown to include many areas within diagnostics and treatment. Today, the usage of ionizing radiation is strictly governed by laws and the Hospital (or Medical) Physicist plays a central role within radiation safety. In order to work as a Hospital Physicist in Sweden, one has to undergo adequate training which leads to an MSc in Medical radiation physics and be legally entitled as a Hospital Physicist. The Swedish association of Hospital Physicists has for several years worked actively for a so-called specialist education, where Hospital Physicists have the opportunity to further educate themselves in the profession and after completing the education may call themselves a Specialist.

Keywords— Medical physics, ionizing radiation, training, education, Sweden

I. INTRODUCTION – THE LEGACY OF SWEDISH PIONEERS WITHIN MEDICAL RADIATION PHYSICS

Sweden has a long tradition when it comes to various applications of radiation within medicine and healthcare. Not least with regard to Rolf Sieverts' (1886-1966) pioneering efforts within dosimetry for measuring radiation doses in radiation treatment and diagnostics [1]. In addition, much of his later research focused on the biological effects of radiation and much of today's work in medical radiation physics bears traces of his spirit. His work is considered to have laid much of the foundation on which our modern radiation physics and protection stands. Despite Sievert's extensive work, he is not credited with all successes in Swedish radiation physics. The world's first successful radiation treatment was performed in Stockholm in 1899 by Thor Stenbeck, who is considered by many to be the Swedish father of X-ray technology [2]. He was also the first in Sweden to take an X-ray picture of a skull in 1896, the same year as Wilhelm Conrad Roentgen's great discovery of X-rays.

Radiation as a useful tool in healthcare grew rapidly during the first half of the 20th century, and medical applications were expanded and refined as radiation technology developed. In the wake of the growing field of radiation physics, the need for radiation protection grew and in 1941 Rolf Sievert's laboratory became the Department of Radiation Physics at Stockholm University, with a responsibility for national radiation protection. In parallel

with this, the first radiation protection law in Sweden was adopted and Rolf Sievert's department was responsible for ensuring that this law was complied with until the National Institute for Radiation Protection was established in 1965. Departments of medical and academic radiation physics were also established at Lund University, the University of Gothenburg and the University of Umeå, and are still closely integrated with the clinical activities and applications of medical radiation physics [3]. With this development, the need for academic and clinical exchange within the profession increased, and the idea of a formal association emerged during the 50s. In 1954 The Swedish Hospital and Health Physicists' Association was formed and in 1961 it was split into The Swedish Association of Radio Physicists and The Swedish Association of Radio Physics. In 1976, the Swedish Hospital Physicists Association (SSFF) was formed as a section in the then Natural Scientists' Association.

II. EDUCATION AND TRAINING

The usage of ionizing radiation in Sweden is strictly governed by laws and statutes, and in order to be able to legally practice the profession as a Hospital Physicist, one needs to have undergone adequate training and have applied for, and received the title of Hospital Physicist. The formal title of Hospital Physicist was recognized in Sweden as a credentialing profession in 1998, mainly as a result of the work that The Swedish Association of Radio Physicists put into the matter. The 5-year education leading to an MSc in Medical Radiation Physics, and thus the title as a Hospital Physicist, provides the student with the necessary theoretical and practical training needed to work in the profession. The education is currently offered at four universities and the content of the education is largely controlled by the Swedish National Board of Health and Welfare (Socialstyrelsen) together with professions in healthcare and universities. Even though the education can differ between the universities, the courses cover the same basic knowledge requirements required of a Hospital Physicist in Sweden today.

During the first years, the students will learn basic physics, mathematics and programming, as well as being trained in problem solving and laboratory work. The latter part of the education focuses on medical radiation physics and includes in-depth studies in, among other things,

radiation's interaction with tissue, How radiation detectors work, dosimetry, the basics of medicine and tumour biology, radiation biology, medical imaging and programming, ultrasound physics, x-ray physics, magnetic resonance physics as well as nuclear medicine and radiation therapy. Also, during the latter part of the education, typically shortly before the degree project, the student completes a clinical hospital internship where the student gets to learn how the Hospital Physicist works side by side with other professional categories in a hospital environment.

III. THE SWEDISH ASSOCIATION OF RADIATION PHYSICISTS

Today, The Swedish Association of Hospital Physicists (SSFF) is a professional association within The Swedish Association for Natural Scientists (SACO) and is a member of the European Federation of Organizations for Medical Physics (EFOMP). SSFF connects the country's Hospital Physicists in an organized way. Through the exchange of knowledge between Hospital Physicists, and further training, SSFF plays an important role in the Swedish Hospital Physicist society and the daily work of its members. SSFF should not be confused with the Swedish Association for Radio Physics, which is a section belonging to the medical society such as for doctors. But both associations cooperate in a wide range of matters concerning the development of professions working directly or indirectly with medical physics, radiation safety and dosimetry.

IV. THE PROFESSION AND FURTHER EDUCATION

The Swedish Hospital Physicists work at around 35 hospitals spread over the country, as well as at some private companies. Today there are roughly 7 trained physicists per 100,000 capita and there are over 600 trained physicists in Sweden. Most of the hospitals have nuclear medicine departments, whereas external radiation therapy only is given at 18 hospitals. There are diagnostic radiology departments in more than these 35 hospitals, and these are tended to by Hospital Physicists working in adjacent hospitals. There are seven on-site cyclotrons in Sweden, but PET/CT cameras in at least 12 hospitals and PET/MR cameras in four. The Swedish Hospital physicist may also work at other places where ionizing radiation can be found, such as nuclear power plants and within the industry.

The Swedish Medical Physicists Association (SSFF) together with the Swedish Society of Radiation Physics together have a programme for Hospital Physicists to become specialists, corresponding to Medical Physics Experts (MPEs). To apply to this programme, one first must work clinically for two years and after that, together with practical work under supervision, attend several courses on advanced level. There are currently 216 graduates trained according to the programme. This programme is today not yet validated by the Swedish Government and Swedish National Board of Health and Welfare. There is a work in progress by the Swedish National Board of Health and Welfare to make the programme for becoming an MPE more similar to the physician's residency.

V. CONCLUSIONS

The field of medical physics, as well as dosimetry and radiation safety, is under constant development. There are a vast number of projects around the country, pushing applications further into the future. With this, a great responsibility lies with the health care system and hence the Swedish Hospital Physicist, to always stay up to date and educated within their fields. Therefore, there is a real and urgent need for the Specialists programme for Hospital Physicists to be accepted by the Swedish Government and the Swedish National Board of Health and Welfare.

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MEDICAL PHYSICS TRAINING, EDUCATION AND PROFESSIONAL RECOGNITION IN UKRAINE

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Abstract— Although the history of medical physics in Ukraine is decades old, the profession itself is very young and is just beginning to develop. Successful steps have been taken to establish an association of medical physics and to introduce a Master's degree in medical physics, although the University programmes need to be significantly adjusted in accordance with international and national recommendations. A major challenge for the coming years is the recognition of the medical physicist as a healthcare professional, followed by the establishment of a national registration scheme.

Keywords— Medical Physics, Education and Training, Ukraine.

I. INTRODUCTION

The use of X-rays in Ukraine began in 1896, and two years later the first medical rooms with X-ray machines were opened [1]. The widespread use of radiology began during the First World War, when in 1914 the “Commission for the Relief to the Wounded with X-ray Examinations” was established. After the war, after several reforms, the Kyiv X-ray Institute (now the National Cancer Institute) was established on the basis of the commission in 1920, where the X-ray physics department began to operate from the first years. At the same time, the All-Ukrainian X-ray Academy (now the Grigoriev Institute for Medical Radiology and Oncology of the National Academy of Medical Sciences of Ukraine) was founded in Kharkiv. These two centres were the main bases for the development of diagnostic radiology and therapy in the country. Although many physicists worked in these institutes and participated in research, as such there were no clinical medical physicists, or a professional organization of medical physicists. With the restoration of Ukraine's independence in 1991, the first attempts to create this organization began. Thus, in the 1990s, the first Association of Medical Physicists of Ukraine was established (AMPU, President Sitko S.M.). But the main goal of the organization, to unite the community of medical physicists, was not achieved and gradually the organization ceased to exist. During the 2000s, the problem of the lack of a functioning organization of medical physicists was repeatedly expressed. A significant impulse to the development of medical physics in Ukraine were the I and II International seminars “Medical physics - the current state, problems, ways of development. Latest Technologies” (2011 and 2012, Kyiv) conducted at the Taras Shevchenko National University of Kyiv with the support of the Swedish Radiation Safety Regulatory Authority (SSM, within the project

“Support to the development of quality assurance and quality control in medical radiology, phase 2”) [2, 3]. Thus, in 2012 at the II Seminar a discussion was started on the “Necessity in the existence of the organization of medical physicists of Ukraine” [4] and as a result, in January 2013, the Initiative Group of Medical Physicists was established. The first task of the group was to try to resume the activities of AMPU, which ended in failure, so it was decided to create a new organization. In July 2013, the Constituent Assembly of the All-Ukrainian Association of Medical Physicists and Engineers (UAMPE, the first president Makarovska O.A.) [5] was held, to which 3 members of the Initiative Group (Clinical Medical Physicists) were invited. Despite the participation of clinical medical physicists in the Constituent Assembly, their suggestions and comments were not taken into account, so most medical physicists and members of the Initiative Group did not join the organization, waiting for the results of its work. Seeing no other possibility than the establishment of a new organization, members of the Initiative Group of Medical Physicists and other medical physicists in 2017 at the 2nd Forum of Medical Physicists (October 20, 2017, Kyiv) created the Ukrainian Association of Medical Physicists (UAMP, the first president Zelinskyi R.M.) (6). Since its inception, UAMP has 73 medical physicists as members.

Most medical physicists in Ukraine work in hospitals and provide services in radiation oncology, with a smaller number working in diagnostic radiology and nuclear medicine. The exact number of medical physicists is difficult to calculate because there is no register and often the duties of medical physicist can be performed by engineers, physicians or technicians. The estimated number of medical physicists in Ukraine is shown in Table 1.

Table 1 Estimated number of Medical Physicists (MP) in Ukraine

Specialty	MP
Diagnostic radiology	15
Radiation oncology	170
Nuclear medicine	4
Total	219

At the same time, the quantity of equipment [7], especially in diagnostic radiology, far exceeds the number of available medical physicists (Table 2).

Table 2 Available medical equipment for medical imaging and radiation therapy in the country (2020)

Equipment	Total
LINACr	28
Co-teletherapy	45
Brachytherapy	38
X-ray therapy unit	50
MRI	195
PET	3
SPECT	14
CT	372
Mammography	338
Fluorography	1240
X-ray Radiology	7209

II. GRADUATE TRAINING

There are two universities in Ukraine that have a Master's degree programme in medical physics: Kharkiv National University named after VN Karazin (Faculty of Physics and Technology, programme started in 2013) and Taras Shevchenko National University of Kyiv (two programmes: Faculty of Physics (2021) and Faculty of Radiophysics, Electronics and Computer Systems (2013)). Some other departments and universities have separate courses in their Master's programmes in medical physics. Nevertheless, the content of the programmes and the list of courses do not fully correspond to the knowledge and skills that medical physicists need. An important problem is a lack or a small number of practical classes in the curriculum for medical physicists and a lack of established cooperation between universities and hospitals.

In 2019, UAMP based on international documents, developed recommendations for Master's programmes [8]. The purpose of this document was to assist Universities in adapting their programmes to the knowledge and skills needs of future medical physicists.

There is a worse situation with PhD programmes: today, there is no PhD specialization in medical physics. So the research must be done in biophysics, engineering, radiation physics, nuclear physics, etc. That may sometimes lead to difficulties in submitting the work to the appropriate scientific commission for further consideration.

III. CLINICAL TRAINING AND POSTGRADUATE EDUCATION

Today, there is no structured clinical training of medical physicists in Ukraine as well as the legislative requirements for a qualified clinical medical physicist and their certification. The vast majority of medical physicists receive their "clinical training" in the hospital after graduation, starting to work as a medical physicist without any experience or even specialized training in medical physics. Some representatives of manufacturing companies provide

additional opportunities to attend short internship trips to hospitals in Europe and various courses in medical physics. Another opportunity to gain the necessary knowledge is various IAEA projects, ICTP with a variety of courses, schools and the opportunity to visit hospitals with well-developed medical physics department (3 medical physicists graduated from ICTP & University of Trieste Master of Advanced Studies in Medical Physics with residency in an Italian hospital).

IV. FUTURE OPPORTUNITIES AND CHALLENGES

There are still many challenges, most notably the recognition of medical physicists as health professionals. In order to unify with other medical and non-medical specialties in health care, medical professionals must have clinical training (residency), with subsequent licensing and registration and continuous professional development. The UAMP is currently working on the development of clinical training recommendations with examples of residency portfolios. The licensing / certification raises the question of who can conduct it and from whom to set up a commission. Fortunately, today there are several international certification commissions, such as the IMPCB [9] or the EEB [10]. After certification in these commissions, several medical physicists can create their own commission in Ukraine.

By signing the Association Agreement with the EU, Ukraine has committed itself to normalizing its legislation to the current European one, including Euratom Directive 2013/59, in which the critical role of the medical physicist (expert in medical physics) in medical radiological procedures is emphasized. Thus, this harmonization of legislation is also a good opportunity to develop national registration scheme for medical physicists.

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MEFOMP 2021 VIRTUAL CONFERENCE: EXPANDING KNOWLEDGE AND MEETING CHALLENGES

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Abstract— Virtual conferences in light of COVID-19 pandemic raise challenges for organizers, attendees and speakers. Nevertheless, they offer several advantages and have revolutionized the way professionals interact and how conferences of the future might look, even after the pandemic. The Middle East Federation of Organizations of Medical Physics (MEFOMP) in cooperation with the International Atomic Energy Agency (IAEA) organized a virtual medical physics conference that took place between 5 and 7 of April 2021. The conference was endorsed by leading international medical physics organizations and accredited with continuous medical education credits.

The conference enabled attendees to have interactive free access to an in-depth view of future directions, latest advancements and lessons learned from COVID-19 pandemic delivered by internationally renowned leading experts in the field. To facilitate the conference technological demands and connect effectively with the remote audience, a special dedicated website was designed and developed with Zoom Webinar as a virtual platform and an experienced IT technical support team to manage the whole event. The virtual conference opened new possibilities in panel discussion and Q&A sessions. Attendees were asked to answer real time MCQ questions submitted at the end of each lecture. This resulted in a better quality of question and interaction with the attendees. In addition, recordings of presentations were available for download on the conference website. While the in person MEFOMP conference that took place in January 2020 just before the pandemic attracted just about 200 local participants, the virtual 2021 MEFOMP conference registered over 2,900 individuals from 81 countries. This indicated that MEFOMP virtual conference has succeeded to spread knowledge and updates, and made them accessible to a larger and more diverse audience. Some of the MEFOMP first virtual conference experiences, results and lessons learned are shared in this article.

Keywords— Medical Physics, Education, Accreditation, Conference and MEFOMP.

I. INTRODUCTION

COVID-19 virus has had an unparalleled impact on all aspects of our lives [1] it has affected clinical practice, education, and research in medical physics. The Middle East Federation of Organizations of Medical Physics (MEFOMP)

has encouraged medical physicists to play a leading role in fighting this pandemic. Through its website, 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 [2]. Furthermore, building on the success of the MEFOMP conference that took place in Kuwait in January 2020 just before the pandemic, MEFOMP decided in cooperation with the IAEA to organize the "2021 Virtual MEFOMP Medical Physics Conference" that took place between 5 and 7 April 2021 [3].

The conference aimed to provide professionals and scientists with an in-depth view of future directions, innovations and techniques in the field, overview on latest advances in medical imaging and radiation therapy, artificial intelligence in medical imaging, updates on radionuclide therapy and dosimetry, and to discuss lessons learned from the COVID-19 pandemic. Twenty international leading experts in the field and six speakers from MEFOMP region participated in the conference.

II. ENDORSEMENTS AND ACCREDITATIONS

The conference was endorsed by leading international medical physics organizations, namely: the International Organization for Medical Physics (IOMP), the Asia-Oceania Federation of Organizations for Medical Physics (AFOMP), the European Federation of Organizations for Medical Physics (EFOMP) and the Federation of African Medical Physics Organizations (FAMPO).

The conference was accredited with continuous medical education credits for 15 IOMP Continuous Professional Development (CPD) points and by the Commission for Accreditation of Medical Physics Educational Programs (CAMPEP) for 16 CAMPEP Medical Physics Continuing Education Credit (MPCEC). CAMPEP is the accreditation body for Medical Physics Education program in the United States, which aims to promote consistent quality education of

Medical Physicists by evaluating and accrediting continuing education programs such as conferences. CAMPEP credits is one of the prerequisites for the maintenance of medical physics certificates from the professional organizations such as American Board of Radiology, American Board of Medical Physics and The Canadian College of Physicists in Medicine.

The conference organizing committee was honored to have world class experts and pioneers in various medical physics related fields delivering lectures virtually, through live or recorded presentations and to participate in the live discussions and Multiple Choice Questions (MCQs). At the end of each lecture, MCQs were presented for different purposes: (1) to make sure that the participants attended the sessions; (2) for active interaction between participants and the presenter; (3) for the participants to obtain credits from attending the lecture. As such, participants were required to answer at least 50% of the MCQs to receive the credits. These MCQs represented also a tool to assess the quality of the lecture and the understanding of the participants. Review sessions for recently published medical physics books by their authors took place each day during the conference first breaks and participants were offered to buy these books at 50% discount.

III. REGISTRATION AND ATTENDANCE

With free registration for all countries, the conference had an outstanding registration record with more than 2900 registrants that rival the big and established international meetings. The number of participants attended the conference were over 1900 from 81 countries mainly from the Middle East region (See Figure 1). The healthy percentage ratio of 54% females and 46% males indicates that medical physics field is becoming popular among females in the region. The participants who fulfilled the accreditation criteria (answered 50% of the MCQs generated

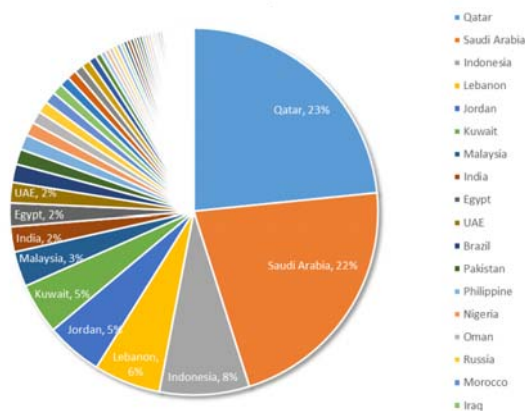


Figure 1 Distribution of conference participants per country

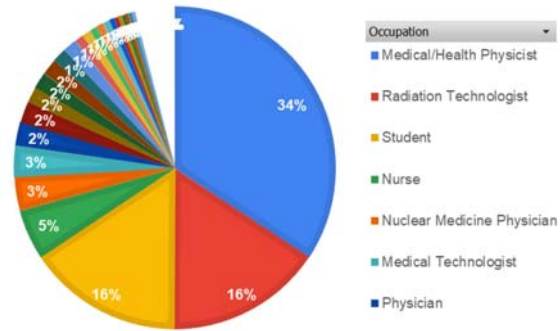


Figure 2 Distribution of conference participants per occupation

at the end of each lecture) and received certificates were about 500 participants from 48 countries.

This indicates MEFOMP’s great success in bringing together medical physics and health professionals from the region and across the globe.

The largest groups of participants were medical/health physicists, radiation technologists, students, nurses, Nuclear Medicine physicians, medical technologists and physicians with 34%, 16%, 16%, 5%, 3%, 3% and 2%, respectively (see Figure 2). It is clear that about third of the participants are Medical or Health Physicists. On the other hand, Figure 3 shows that the largest group of participants were working in the fields of diagnostic radiology, then Radiotherapy, Nuclear Medicine, Students and Radiation Protection with 31%, 18%, 14%, 10% and 10%, respectively. Figure 4 shows a group photo taken during the virtual conference.

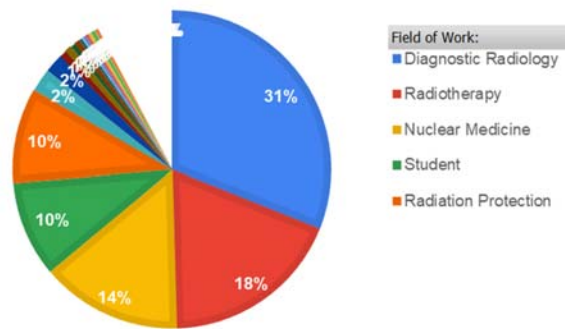


Figure 3 Distribution of conference participants per field of work

IV. PROGRAM AND MAIN TOPICS

The conference highlighted topics in different fields of medical physics including Medical Imaging, Radiation Protection, and Therapy in addition to the current and future



Figure 4 Group photo taken during the virtual conference

directions in this field including Artificial Intelligence, particle therapy, and others. As the fight against COVID-19 is still of the highest priorities for health professionals, the conference further highlighted topics related to the pandemic and its impact in medical sector especially the management and roles of Medical Physics in this crisis.

The conference program was designed to cover general subjects, medical imaging subjects and therapy subjects on daily basis. The general subjects included lectures discussing current and future directions of radiation physics in medicine, IAEA support to medical physics profession and status of medical physics in the Middle East. COVID 19 pandemic effect on running an effective service was also covered including its impact on nuclear medicine and radiology departments. Another lecture was presented exploring the contribution of medical physicists in the Middle East during the pandemic. Radiation protection subjects were also covered in the general sessions, they included lectures about new developments in personal dosimetry and radiation protection of patients and dosimetry of eye lens.

The range of topics in medical imaging were diversified including recent advances in PET/CT and PET/MR and NEMA PET acceptance testing procedures. Using Gallium-67 as theranostic SPECT imaging agent in addition to latest developments in quantitative SPECT/CT were also highlighted. Radiation safety when using Y-90 for hepatic carcinoma and its PET imaging was also covered. Lectures

on artificial intelligence in medical imaging and establishment of diagnostic reference levels in the Middle East were also delivered. Other lectures in medical imaging discussed; Angiographic and Fluoroscopic systems QC protocols, Precise CT dosimetry in diagnosis and radiotherapy, digital breast tomosynthesis and PET/MR in clinical practice.

The lectures in therapy discussed the latest advances in this modality, it included lectures about; novel radiotherapy technologies, recent advances in SGRT, latest advancements in proton therapy, MRI-guided radiotherapy and radiobiology from radium to particle therapy. Conventional radiotherapy subjects were also covered such as dose calculation, small field dosimetry and radiotherapy for pediatric and bariatric patients. Radionuclide therapy subjects had a good space in the program, they discussed updates on radiobiology of radionuclides, towards personalized dosimetry in liver SIRT and updates on radionuclide therapy and dosimetry.

V. CONFERENCE SPONSORS

The main sponsors for the conference were Kuwait Foundation for the Advancement of Sciences (KFAS) and Hamad Medical Corporation (HMC) - Qatar. The gold sponsors were Sedeer Medical, Varian and Ali Bin Ali

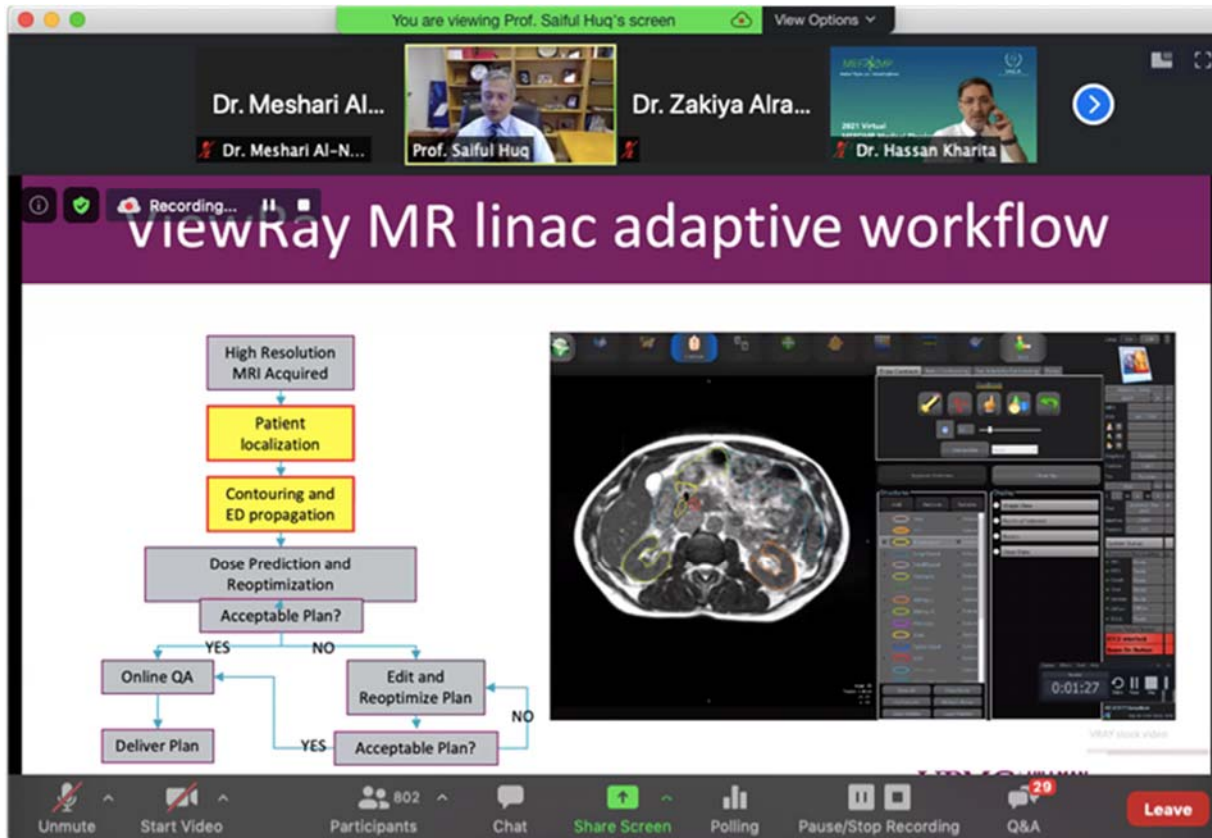


Figure 5 One of the presentations during the virtual conference

Medical & Siemens Healthineers. The silver sponsors were Al Zahrawi Medical, GE Healthcare, Barzan Medical Supplies and IBA – Ion Beam Applications S.A.

The fact that the main sponsors were well-established research foundations such as KFAS and one of the largest medical corporation in the Middle East such as HMC is a strong indication that medical physics seems to gain some momentum in the Middle East.

VI. CONFERENCE CERTIFICATES

For authentication purposes, all certificates issued in relation to this conference were provided with QR code linked to a webpage (https://www.mefomp.com/2021-MEFOMP-Virtual-Conference-Certificates_a7079.html) on MEFOMP website that contains all lists of all:

1. Members of Organizing and Program Committee awarded Appreciation Certificates
2. Names of Speakers awarded Appreciation Certificates
3. Names of sponsor awarded Certificate of Appreciation for Platinum, Gold and Silver Sponsors

4. Names of Session Chairs awarded Appreciation Certificates
5. Names of Participants awarded Participation Certificate

VII. WEBSITE AND PLATFORM

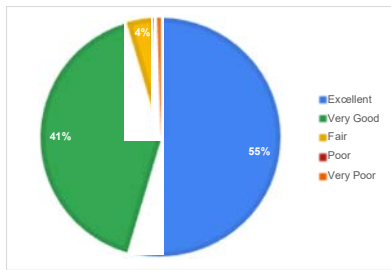
In addition to the official website of MEFOMP, a special dedicated website (link: <https://mefomp-conference.com/>) was designed and developed to manage the conference and to provide all the needed information; about the conference and its committees, program, speakers, partners, sponsors, registration, etc. Zoom Webinar was used as the virtual platform to host this virtual event and manage all meetings, recordings of lectures, managing MCQs through its polls, in addition to the interactive discussion and question and answer sessions.

The conference’s poster, program, sponsors and endorsers can be seen on the conference website. All recordings of the conference presentations and certificates information are available on MEFOMP official website: www.mefomp.com.

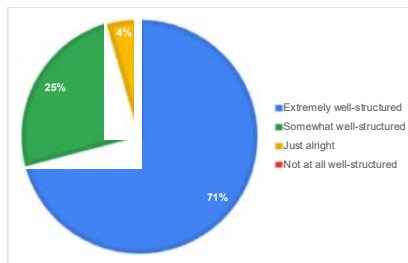
VIII. PARTICIPANTS FEEDBACK

A feedback survey was sent to the participants of the conference. Below are the results of the feedback from of about 600 participants who answered the questions of the survey:

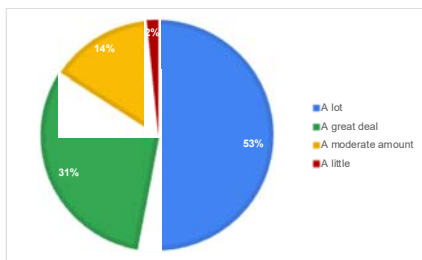
- How was your total experience with 2021 MEFOMP Conference?
55% of participants responded to the survey answered “Excellent” and 41% answered “Very Good”.



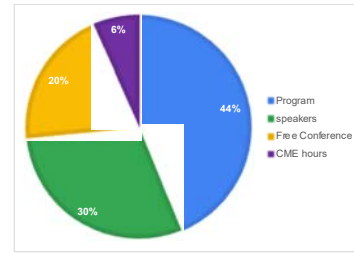
- How well-structured was the conference program?
Over 71% answered “extremely well-structured” and 25% answered “somewhat well-structured”.



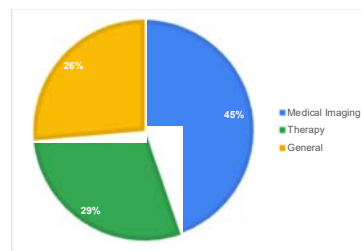
- How much have your knowledge improved after the conference?
Overwhelming positive response with over 53% replied “A lot” and 31% replied “A great deal”.



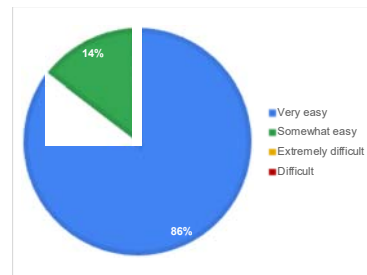
- What attracted you most to the conference?
44% of the participants said the program, 30% for the speakers and 20% for the free conference whereas only 6% for the CME or CPD points.



- Which session attracted you most during the conference?
The answers were 45% for medical imaging, 29% for therapy and 26% for the general sessions.



- How easy was it to access and use Zoom platform?
86% of the participants answered “Very easy” while 14% answered “Somewhat easy”.



IX. CONCLUSIONS

The virtual 2021 MEFOMP Medical Physics conference attracted over 2,900 individuals from 81 countries. This indicated that this virtual conference has succeeded to spread knowledge and updates and made them accessible to a larger and more diverse audience. The conference has put MEFOMP firmly on the medical physics world map. The large number of participants that rival the big and well-established international meetings; the world class speakers; and the excellent IT infrastructure were essentials to the phenomenal success of the conference.

Furthermore, the accreditation and endorsement granted by international and regional medical physics bodies were an important boost to popularity of the conference.

In addition to vendor's support, the participation of large medical and research institutions such as HMC and KFAS is a clear indication that medical physics is gaining more momentum in the Middle East Region.

Finally, the feedback from participants showed that the majority had excellent experience with the conference. Most participants said that the program is well-structured, it has improved their knowledge. Mostly the program, then the speakers and the free registration attracted participants.

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Medical Physics History, Professional and Educational Development in Pakistan

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Abstract— Aim of this article is to discuss the historical background, current status and available and possible available resources for education and professional development of Medical Physicists (MPs) in Pakistan. Medical physics is a unique profession and acknowledged one of the vital part of healthcare that needs an immediate intension to improve professional skills of MPs in developing countries. In Pakistan, first radiotherapy centre was established in 1958 at Mayo Hospital Lahore. Pakistan Nuclear Regulatory Authority (PNRA) was formed in 1956 to regulate the clinical institutes and handle nuclear safety issues. There was no formal training or education facility available for MPs in Pakistan till 1980. According to regulation on Radiation Protection (PAK/904) published (2004) by PNRA, only six months on job training is sufficient to work legally as an independent clinical MP. On job training program in Pakistan varies from institute to institute. In Pakistan, very limited annual professional's development courses are organised by PNRA for MPs. Pakistan Institute of Engineering and Applied Sciences (PIEAS) was the first chartered university by the government of Pakistan which offered a two years MS Medical Physics degree Program in 2001. Most of the clinical MPs rely on international funding scheme for professional development. Presently, MPs develop and enhance their professional expertise through attending national and international conferences, workshops, fellowships programs and educational scholarship in medical physics. Currently, PNRA and Pakistan Organisation of Medical Physics (POMP) are working with federal government of Pakistan to set up a certification program for MPs under International Atomic Energy Agency (IAEA) RAS6077 Regional Cooperation Agreement program. There are also few options to achieve certification as a qualified MPs form international certification bodies. A brief survey was conducted to study the professional and educational development needs in Pakistan.

Keywords—Medical Physicist, education, professional development, accreditation

I. INTRODUCTION

In last five decades, revolutionary development took place in the field of diagnostic imaging (DI) and radiation therapy (RT), where medical physics had played an extremely important role to optimize and regulate the ionisation radiation used in medicine. Now a day, radiation therapy and diagnostic examinations are routinely performed in medical clinics under the supervision of qualified medical physicists (MPs) [1, 2]. In radiotherapy, MPs play a vital role in clinical decisions and considered to be the back bone of radiotherapy department. Scope of medical physicist is not limited to the radiotherapy but also have a great contribution in DI and nuclear medicine (NM). The clinical MPs are responsible to design and implement quality control and quality assurance programs, radiation shielding requirements, radiation protection, implementation of clinical protocols, personal and radiation equipment dosimetry and treatment planning. Along with these expertise, MPs also actively participate in research, establishing training programs for MPs, radiation therapist (RTs), doctors and nurses which further include the practical implementation for their professional growth.

There is no cancer registry program in Pakistan. Every year, 1.48 million new cancer cases were reported [3]. With respect to population, cancer incidence, cancer deaths and cancer prevalence rate (in millions) are 17.6, 1.48, 0.1016 and 0.00274 respectively [4]. According to IAEA Directory of Radiotherapy Centers (DIRAC) only 30 cancer centers are operational in Pakistan [5]. Pakistan has 60 Radiation Oncology Medical Physicists (ROMP) [6].

History

In Pakistan, development of medical physics profession was started in 1958 when first radiotherapy centre was established at Mayo hospital Lahore, Pakistan. Pakistan Atomic Energy Commission (PAEC) established first cancer centre (Nuclear Medicine Centre for Cancer Treatment) in 1960 at The Jinnah Medical College Karachi [7]. Now more than 18 cancer centres are working under the umbrella of PAEC till 2018 [8]. These cancer centres are spread geographically throughout the country and provide diagnostic as well as therapeutic services to cancer patients at very nominal charges. First private cancer facility was

established at Shifa International hospital, Islamabad, Pakistan in 1995. In Pakistan, there are 30 radiotherapy centers running privately and under provincial and federal government. Pakistan has 27 linear accelerators, 31 cobalt-60 Teletherapy units, 3 Computed Tomography (CT) simulators, 10 conventional simulators, 9 treatment planning system (TPS) and 11 brachytherapy units [9]. Currently, more than 120 clinical MPs are working in private and government cancer centers [10]. The concept of nuclear regulatory and infrastructure existed since 1965 in Pakistan. In 1984, the Nuclear Regulatory Authority was upgraded to Directorate of Nuclear Safety and Radiation Protection (DNSRP). After signing the Convention on Nuclear Safety in 1994, PAEC has established Nuclear Regulatory Board (PNRB) within PAEC. DNSRP was dissolved in 2001 and created Nuclear Regulatory Authority (PNRA) in Pakistan to look after radiation protection and nuclear safety issues [7].

Education

There was no formal education facility available for clinical MPs in Pakistan till 1980, only requirement was MSc. Physics (16 Years of education) to work as clinical MP. Centre for Nuclear Medical Studies (CNS) under the umbrella of PAEC conducted first medical physics course (6 months) in 1967. Currently, CNS is known as Pakistan Institute of Engineering and Applied Sciences (PIEAS). PIEAS was the first chartered university by the government of Pakistan who started offering two years MS Medical Physics degree Program since 2001. PIEAS has produced 174 graduated in medical physics so far but most of them are working in the nuclear power plant, research and development at Pakistan Institute of Nuclear and Technology (PINSTECH) and PNRA. Other than PIEAS, there is no university or institute offers MS degree program in medical physics in Pakistan. Secondly, there was no formal training or education facility available for MPs in Pakistan till 1994. Shifa International hospital started one year on job training program for MPs in 1995. Higher Education Commission (HEC) of Pakistan also started Overseas Scholarship Program (OSP) since 2003. More than 5000 Ph.D. scholarship are awarded for study in technology and 3000 indigenous Ph.D. scholarship are awarded 2002 to 2008. HEC also has designed a Faculty Development Program (FDP) for capacity enhancement and teaching skills for the non-Ph.D. faculty members. In 2010, International Islamic University Islamabad has started MS Radiation Physics degree program. In last few years few more universities has started MS and PhD programs in medical physics.

Professional Development

Whereas, according to regulation on Radiation Protection (PAK/904) published (2004) by PNRA, only six months on job training is sufficient to work legally as an independent clinical MP. Mostly, trained MPs work under the supervision of a qualified MP [11]. On job training program

in Pakistan varies from institute to institute and strongly depend upon the institution formwork, resources and needs. Currently, government of Pakistan is working with International Atomic Energy Agency (IAEA) to implement formal training program in all specialties of medical physics under the project RAS6077 [12].

In Pakistan, limited professional's development activities are organised by PNRA for MPs to update their skills and knowledge and equipped themselves with new techniques technologies. Most of clinical MPs rely on international funding schemes (Union for International Cancer Control (UICC) fellowship program, International Atomic Energy Agency (IAEA), IAEA-International Centre for Theoretical Physics (ICTP), Australian Endeavour Executive Fellowship Award (AEEFA), ELEKTA Travel award etc.) for professional development [13-17].

Pakistan Organisation of Medical Physics (POMP) was established in 2012 to improve the quality, efficiency and professional development of MPs in Pakistan [18]. POMP has engaged Pakistani MPs in developed countries and planning to organise professional development activities (workshop, short courses, Symposiums etc.) for medical physics community on regular bases.

Australian College of Physical Sciences and Engineering in Medicine (ACPSEM) has established the Asia Pacific Special Interest Group (APSIG) in Australia. The purpose of this group is to encourage and assist ACPSEM members to work with similar overseas organisations and institutions in the advancement of medical physics and radiation engineering, in developing countries of the Asia-Pacific region. POMP is also planning to collaborate with APSIG and set up special training program for clinical MPs.

Certification/Accreditation Program

There are a few options available for Pakistani MPs to achieve accreditation or certification as a qualified MPs e.g. experienced ROMP path way through Australian College of Physical Sciences and Engineering in Medicine (ACPSEM), International Medical Physics Certification Board (IMPCB), Regional Cooperative Agreement (RCA) certification and Accreditation program (under process), Health and Care Professionals Council (HCPC) registration United Kingdom (UK) and European Attestation Certificate for Medical Physics Expert (ESCMPE).

A. ACPSEM Registration/Certification

ACPSEM has introduced new policy called ACPSEM Register of Qualified Medical Physics Specialists and Radiopharmaceutical Scientists [19]. In this policy a complete process is explained to achieve ACPSEM certification as a qualified MP. According to this policy, each application is process individually depending upon the individual applicant application. Most of the Pakistani MPs do not have any international certification (IPEM, COMP, ABR or HPC), due to this reason, the certification process

will be longwinded (sign off level 3 competencies of all core modules or equivalent, written examination plus oral and practical examination) and difficult. This certification process is very costly and also having difficulty to arrange oral and practical examination in Australia which has similar equipment as you have at your home institution. Otherwise, if you are interested to arrange oral and practical examination in your own centre than you have to bear the travel and accommodation cost of two examiners. One of the main requirements for the international applicants is the ability to communicate effectively in English and should pass the International English Language Testing System (IELTS) as per ACPSEM criteria. A structural diagram is summarising the certification process adopted by ACPSEM (figure 1).

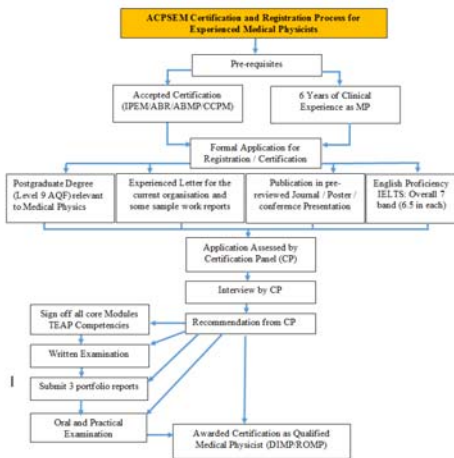


Fig. 1 ACPSEM certification process for overseas experienced applicants.

B- International Medical Physics Certification Board (IMPCB)

IMPCB was formed on May 23rd 2010 by eleven charter member organisations in medical physics.

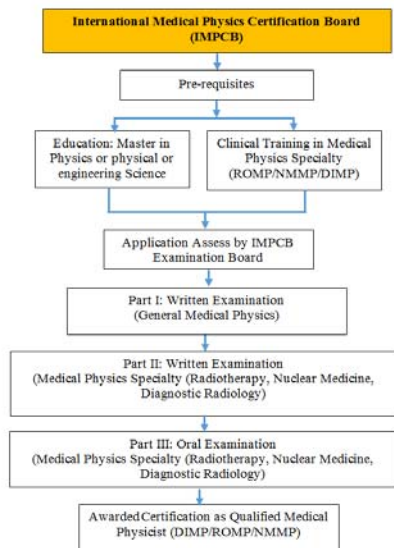


Fig. 2 IMPCB certification process for all applicants.

The main objective was to support the practice of medical physics through certification program in accordance with International Organisation of Medical Physic (IOMP) guidelines and establish a continuing education and professional development who achieve the certification in medical physics. The model is simple and cost effective. IMPCB arrange an examination every year during the conferences or ICTP medical physic summer school. This certification process consists of two written examinations (Part-I and part-II). Part-I is about general medical physics and Part-II is about the specialized medical physic (Radiology, Nuclear Medicine and Radiation Oncology). After successfully completing the Part-I and II, candidate will be eligible to sit in Oral examination. Examination fee is very nominal (\$550 USA for Part-I, II and Oral). But in addition to that, there is travelling cost involve to sit in these examinations. A structural diagram is summarising the certification process adopted by IMPCB (figure 2).

C- Health and Care Professionals Council (HCPC) registration United Kingdom

Health and care professions council (HCPC) in United Kingdom (UK) regulates the qualified members of different professions including medical physicists. This council maintains high standards of education and trainings outside the UK for international applicants. After registering with HCPC, MP is eligible to work in clinical applications.

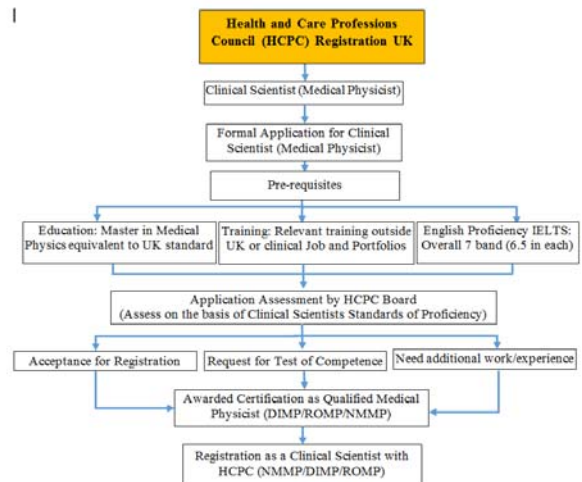


Fig. 3 HCPC certification process for overseas experienced applicants.

For international applicants HCPC has its own specific criteria for assessment that includes the proficiency of different elements. Applicants are further assessed through their education, relevant trainings and experience in specific area of profession. One of the main requirements for the international applicants is the ability to communicate effectively in English and should pass the International English Language Testing System (IELTS) as per HCPC criteria. HCPC registration is revised after every two years while maintain the quality standards of the council.

D- Regional Cooperative Agreement (RCA) certification and Accreditation program

IAEA has initiated a project RAS6077 under Regional Cooperation Agreement on “Strengthening the Effectiveness and Extant of Medical Physics Education and Training” [10]. The outcome of this project was to agree on a set of minimum standard and recommendations to be utilised to train medical physics in each subspecialty. IAEA held number of meeting to established recommendations on accreditation and certification for MPs. This document guides the professionals and administrators to develop, implement and manage education and training program in the Asia Pacific Region for MPs.

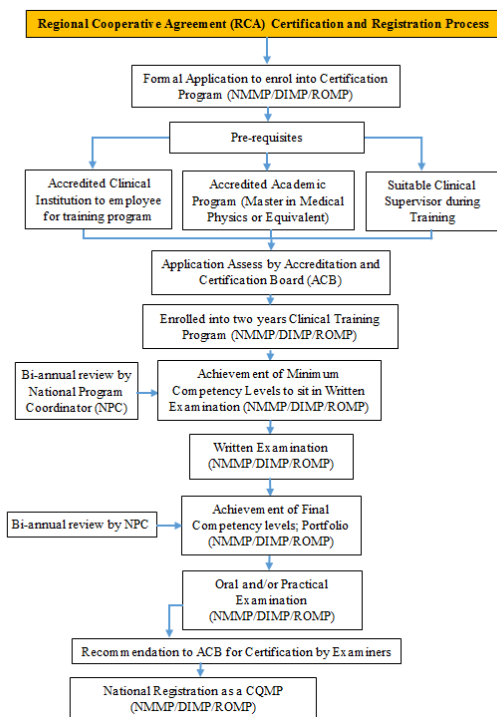


Fig. 4 RCA Accreditation and certification program for newcomer Medical Physicists.

According to this document, each country should have its own National Responsible Authority (NRA) who looks after accreditation and certification process for MPs. NRA will be responsible to develop the formwork for accreditation of a training institutes, academic programs and supervisors. NRA also will be responsible to designed guidelines for experience MPs to achieve certification and also designed a clinical training program for the new registrars. Those registrars who registered in RCA can also have access of Advanced Medical Physics Learning Environment (AMPLE) e-learning platform. Each registrar should achieve level 2 competencies in all core modules before sitting in written examination. For oral and practical (Practical examination is depending upon the accreditation and certification board (ACB)) examination, registrar

should have level three competencies including the portfolio reports. Currently, NRA is not established in Pakistan but extensive efforts has put together to established it. An AMPLE training program is followed similar process as ACPSEM has adopted for MPs registrars in Australia.

E- European Attestation Certificate for Medical Physics Expert (ESCMPE)

European Attestation Certificate for Medical Physics Expert (ESCMPE) program was designed to facilitate the harmonisation of education and training of MPs to medical physics expert (MPE) level among the member states aiming at an improvement in cross border mobility [20].

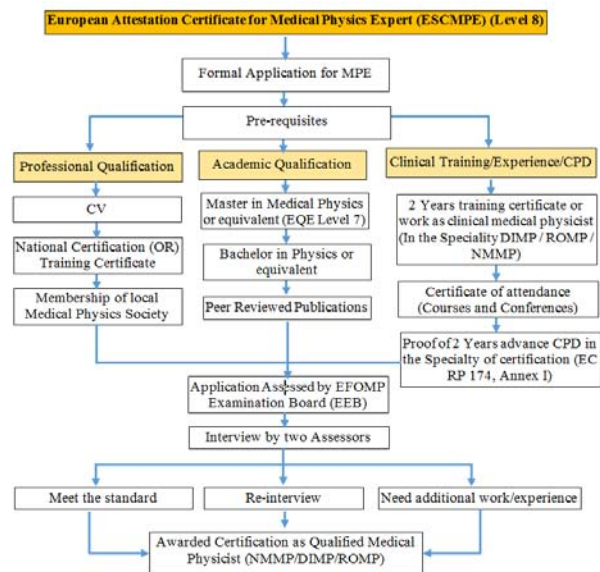


Fig. 5 ESCMPE certification process for overseas experienced applicants.

According to ESCMPE program any MP can apply for this certification. According to European Federation of Organization for Medical Physics (EFOMP) examination Board (EEB) guidelines, application is assessed on the basis of professional Qualification (CV, national certification or training certificate in the field of specific field of medical physics (NMMP/DIMP/ROMP) and membership of professional body), Academic Qualification (Mater in Medical Physics or equivalent according to European standard) and clinical training or experience (2 years clinical training certificate or worked as clinical MP in any field of medical physics (NMMP/DIMP/ROMP)). In addition to that applicant should have proven record of continuous professional development (CPD).

F- Proposed Certification Program for Pakistani Medical Physicists

MP training and certification program is a key to established world class services for the cancer patients. In this article, few key recommendations are given to the authorities who

will guide them to establish a sustainable certification program for MP community in Pakistan.

i- Regulatory Body

POMP was established in 2012 but it has no legal authority to regulate medical physics profession because it is not recognized by government of Pakistan like other organisation or societies e.g. Engineering Council, College of Physicians and Surgeons Pakistan etc. First of all, POMP writes a constitution with the collaboration of medical physics community which includes the framework to establish a certification program for MP and accreditation program for universities and clinical institutes. This constitution structure under the guidelines set by Pakistan government (Act of the parliament 1976) to establish as a body corporate. After completion of the constitution submit a documentation to get the approval from the government to establish a regulatory body for medical physics profession. It is very hard and long process to establish a regulatory body. It is suggested to establish a self-regulatory profession like ACPSEM in Pakistan for the time being to set a solid ground toward the regulatory body. POMP will responsible to self-regulate medical physics profession but at the same time POMP establish a committee who will be responsible to keep working and negotiating with the government to establish a regulatory authority for MPs like engineering council of Pakistan for engineers.

ii- Education

All over the world, for Medical Physicists, an accredited medical physics degree program is compulsory prior to enrol in the certification program. This education program not only reduces the training duration but it also helps to provide the fundamental base to construct a clinical certification program. Currently, PIEAS is offering a Master in Science (MS) in Medical Physics degree program which is accredited by International Organisation of Medical Physics (IOMP). Similarly, two years post graduate accredited degree program should introduce in government and private universities. According to the load of the patients, Pakistan government should established master program in the existing four universities which are geographically distributed among the provinces. The curriculum should be designed as per IOMP guidelines so it will be easy to get the accreditation for this master program form IOMP or in-house in future when a proper certification program is established in Pakistan.

iii- Residency Program

Internship or residency program help to groom clinical significance to the fresh medical physics graduate. Clinical environment in hospital setting is quite different form academic. Regularity body (or self-regulatory) is responsible to design a training program for each speciality, its duration, routine assessment procedure and pass and fail criteria. These graduate who complete their education form the accredited universities are eligible to enroll in this

internship or residency program. Currently, PIEAS and PNRA are working with IAEA to set up Medical Physics Training program under RAS6077 Regional Cooperation Agreement program. POMP is also supporting PIEAS and PNRA to establish national training program. It is an excellent initiative to develop a well organised training program under the governance of PNRA.

iv- Proposed Certification program Structure

Medical physics certification program is regulated by National Responsible Authority (NRA) which regulates the medical physics profession in Pakistan. It is responsible to establish a certification board (CB) for each modality of medical physics (ROMP, DRMP and NMMP). CB will be responsible to conduct the routine assessment of registrars, held examinations and designed pass and fail criteria. At the same time, NRA will also responsible to regulate the academic and clinical training institutes. Any graduate who finish his Master degree from the accredited institute will be eligible to enroll his/her clinical training at a NRA accredited clinical institute. During the training, CB will appoint a clinical supervisor who will be responsible to look after the registrar during the training and make sure registrar achieve the required competencies on time. To monitor the training progress, national and program coordinators (NPC) or regional program coordinator (RPC) are available to mentor and help the registrars during their training program. In addition to that, independent progress review (IPR) should be conducted by RPC or NPC semi-annual or annual to assess the registrar progress independently. NPC or RPC will responsible to submit a report after the assessment to CP. After achieving the required competencies and successful IPR, registrar will be eligible to sit in the examination. After successful completion of training, CB will provide recommendations to NRA for certification. After achieving the certification, NRA will offer registrar a qualified MP registration. All qualified MP are responsible to keep their continuous professional development (CPD) activities up to date to comply with the NRA registration policy. A schematic diagram is shown in the figure 6.

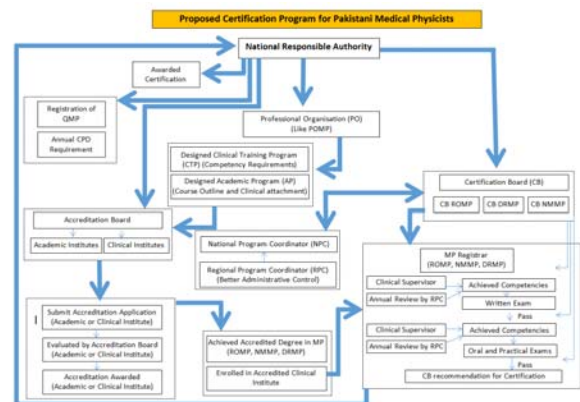


Figure 6: Proposed certification program for medical physicist in Pakistan.

II. CONCLUSIONS

A certification program is vital to maintain the standard of medical physics services throughout the country. PIEAS makes very strong contributions for the medical physics education in Pakistan. The demands of the medical physics services are increasing rapidly due to the increasing number of patients and growing population in Pakistan. The country needs specialized education in Medical Physics to produce high quality medical physicists. More universities need to introduce a medical physics degree program which is directly attached to a clinical institute to complete the research component of the degree. PNRA and POMP can play a vigorous role in developing more infrastructures and facilitating cooperation within the medical physics community. The introduction of a certification program can bring more development in this field; Pakistan can attain more recognition in the field of medical physics. A structure of a certification program is proposed and discussed in this paper which could provide a ground for establishing it in Pakistan. The author's direct experience working within the Pakistani medical physics community has informed this proposal.

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HOW TO

EMBRACING ULTRASOUND QUALITY CONTROL

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Abstract - This paper discusses the success of the ultrasound quality program that was developed and instituted at a large tertiary care busy ultrasound imaging department with some 30 ultrasound scanners and over 120 transducers regularly in use. There is a continuous steady growth in patient ultrasound imaging exam volumes with increases in the daily number of ultrasound scanners in use along with advanced application use transducers. All levels of management were involved and passionate in the development of the ultrasound quality program. Meetings were held regularly to discuss tests to be performed, the method for reporting and tracking of service repairs, the best phantom to be used, selecting of quality control sonographers, and development of databases to track ultrasound scanners, probes, repairs, replacements and upgrades. These were determined to be of outmost importance to begin the program. Adherence to the program continues successfully with slight occasional changes in order to improve the overall program effectiveness and efficiency. It is possible to institute a high quality program in a busy imaging environment where QC sonographers are vigilant and management is onboard. The system we developed was also transitioned to smaller one scanner clinics as the core of the program is independent on the number of ultrasound scanners or probes.

Keywords – quality control, quality assurance, quality improvement, ultrasound quality programs

I. INTRODUCTION

Ultrasound quality control programs are in their infancy. In the authors' opinion and past experiences, the best, and perhaps the only way image quality optimization can occur in radiology is by instituting quality programs, whether they be mandated regulations or by following recommendations from accreditation bodies or using common sense derived from experience. The best programs are those that embody the principles of quality improvement with personnel embracing and being committed to those activities. The goals are always to ensure that patients have access to the best image quality and that providers can have the confidence the images produced are of the highest quality.

Accreditation organizations such as the American College of Radiology (ACR) certify facilities for specific diagnostic imaging equipment if the facility can provide the required satisfactory documentation such as clinical and phantom test images and provider qualifications, for example [1]. This is a voluntary program associated with a certain amount of prestige with equipment being ACR accredited. The facility can certainly use this fact in their marketing collateral, as a place where patients can feel confident the equipment, personnel, physicians and the images produced are at a high level. The only way one can maintain such high levels of image optimization is if robust and regular quality programs exist.

Ultrasound quality assurance (QA) and quality control (QC) programs have not had the visibility of other diagnostic imaging modalities such as computed tomography (CT), magnetic resonance imaging (MRI) or

nuclear medicine (NM) imaging. National and international scientific regulatory bodies control ionization radiation modalities, and along with the American College of Radiology (ACR) accreditation requirements provide for comprehensive daily, weekly, monthly and yearly tests. Depending on other accreditation bodies the hospital would adhere to, there might also be further requirements.

Ultrasound is one of the diagnostic imaging modalities to have few, if any, regulations associated with the continued optimal performance of ultrasound exams, if any. Both the ACR and the American Institute of Ultrasound in Medicine (AIUM) have proposed over many years, quality programs [1-3]. The ACR, in its 2017 recommendations for ultrasound accreditation, required a quality control program be in place for institutions where ultrasound units are accredited by the ACR, but does not recommend a specific phantom or set of phantoms [1]. The document further does not stipulate any upper or lower boundary values by which specific imaging parameters should reside within. It is up to the individual site to setup a procedure to monitor and track performance levels and when to initiate a service call. Even though the ACR and AIUM advise that each scanner be acceptance tested before first clinical use, it is not necessarily a task perceived as being necessary. The Joint Commission (TJC) does not mention ultrasound imaging separately as a modality to have specific guidance or image requirements [4]. The Technical Standards Committee of AIUM issued in 2014 a set of measurement guidelines for gray scale scanners [5], which only addresses B-mode imaging. The Intersocietal Accreditation Commission (IAC) only accredits for vascular and echocardiography, though a

facility could be accredited by both IAC and AIUM for a complete range of ultrasound services. The IAC does not offer any recommendations regarding phantoms, nor regular testing procedures to ensure continued quality [6, 7]. International organizations, such as the International ElectroTechnical Commission (IEC) does have specific guidelines for pulse-echo scanners [8-12], which are periodically reviewed and revised as necessary.

In this paper, we examine the ultrasound quality assurance program developed for a large hospital and an adjoining large outpatient clinic. This is not a report on equipment efficacy nor a vendor scanner comparison, but rather a discussion on the implementation of a simple program developed in such a way that it is easy to follow and maximizes the outcomes while minimizing the time spent conducting the tests. It is a program that can be easily deployed in institutions with a large number of scanners or in a small one scanner outpatient clinic. Resistance to ultrasound QC programs is more of an ad-hoc issue, possibly due to previous sonographers' negative experiences with complicated and lengthy tasks to perform. We set out on the premise that as long as the program did not require an inordinate amount of time or complex measurements, ultrasound quality programs can be viable and provide useful information as to the quality of the scanners and probes and eventually to pro-active measures in making better purchasing and negotiating decisions. It was also seen that empowering the ultrasound technologists as the custodian of the equipment would only enhance any type of quality program.

In the authors' opinion, poor image quality does not benefit anyone, least of all the patient. Lengthy downtimes benefits no one and the longer a machine is non-functional plus the cost of repairs, if not covered by some form of warranty or service contract only delays patient imaging. Empowering the ultrasound technologists who perform the regular QC to call out defective monitors, probes, and systems only benefits the patient with the desired outcome of optimally performing scanners at all times.

II. METHOD

A. Development of the QA/QC program

A year or so before the new hospital was to open, circa 2014, discussions occurred between Radiology management, the ultrasound imaging section and medical physics. A plan needed to be developed with standardized procedures that could be implemented and followed for the optimal performance level of the clinical ultrasound scanners.

Previously, the medical physicist conducted annual physics performance evaluations on all units with an all-purpose ultrasound phantom (ATS Model 539). In addition, ultrasound technologists imaged this identical phantom twice a year, but found it unmanageable and

complicated with compliance being an issue. In many instances, failures were not addressed and never communicated to service personnel. The phantom was burdensome, had several surfaces that could be imaged leading to confusion as to which surface to use, and exactly what feature to measure as there were no formal procedural steps to follow.

Scanners were normally serviced in-house or, if necessary, by the service provider for that institution. New scanners are under some form of contractual warranty, and thereafter in-house technical service staff took over the repair and maintenance. Probes were replaced when physically damaged or when image quality was deemed clinically unsatisfactory; though a threshold for determining this defective image state had no quality metrics associated with it.

With the opening of the new hospital, a new ultrasound QA/QC program was developed. The ultrasound imaging manager selected a QC coordinator, the person who micro-manages the ultrasound QC program, and QC personnel, that is, the ones who perform the testing and report on the testing results. Selection of personnel is not a decision taken lightly. There is a need for personal internal commitment and dedication from QC personnel for the program to be successful.

Medical physics developed a standard procedure to encompass the type of tests, the frequency of those tests, who was responsible for the testing to be completed and the ensuing training required. Meetings with stakeholders were held until consensus was reached. Management was supportive, with encouragement given to implement this program at all levels starting with providing time to ultrasound technologists to perform the required testing.

A series of written directives were drafted and circulated, including a proposed set of instructions for the technologist performing the physical checks. The focus was to ensure the steps were simple, but high yield with results entered into a spreadsheet.

B. Selection of the Phantom

The next step was determining the appropriate phantom to use at the sites to image uniformity as none of the accrediting bodies requires a specific ultrasound phantom to be used. At the time, only a few suitable phantoms were available or could be used to test uniformity. An investigation determined that one model (Gammex Model 416) was the most versatile as it could image linear, curvilinear and endo-cavity probes across a uniform volume. Other phantoms were tested but proved less than robust and not as versatile or easy to use when it came to image curvilinear or endo-cavity probes. As the phantom was not costly, one was bought for the main hospital and additional ones for the outpatient clinics. Building our own phantom was not feasible at the time, but certainly could be entertained in another iteration in the development of this program.

C. Sonographer Training Program

Medical physics trained the ultrasound technologists carrying out the QC during a one hour session. Discussions revolved around the reasons for performing QC, the factors that contribute to image failure and the correct procedure to perform all the checks. It was also emphasized that if a failure is noted, the QC coordinator and the ultrasound imaging manager need to be informed so that a service ticket can be placed. Training attendance certificates were issued after the onboarding session and signed by both the medical physicist and the ultrasound technologist. These are kept as a permanent record within the ultrasound technologist’s continuing education file. Table 1 lists the main points that are brought forward during this discussion, which is also the basis of the regular QC testing program.

Table 1 Sonographer Training

Training Tasks	1. Identification of scanner parts
	2. Where to locate serial numbers of probes and scanners
	3. Identification of stress points in power cord and probe cables
	4. Examination of control panel integrity
	5. Ensure cleanliness of the complete system
	6. Brakes working
	7. Monitor can be locked in any position
	8. Any peripherals secured
	9. Locating and displaying test images either SMPTE or TG18
	10. Identifying the 0/5% and 95/100% contrast patches
	11. Looking for unsharp transitions
	12. Identifying monitor resolution pattern aliasing
	13. Identify monitor pixel defects
	14. Imaging uniformity phantom
	15. Identification of image artifacts

D. QC Testing

The simple QC program incorporates the tests recommended by ACR [1]. At this time, QC is performed quarterly by the designated QC trained staff, and the medical physicist performs a yearly comprehensive performance evaluation of the system. In addition, the in-house service bioengineers inspect each ultrasound scanner at a minimum of once per year. If planned properly, the quarterly checks performed by the ultrasound technologist, the physicist once a year, and bioengineering once a year can amount to testing each unit almost every other month. It is worth noting that bioengineering would evaluate the scanner and not necessarily all clinical probes. Records of all tests performed and any remedial actions are kept centrally in an electronic database.

Only the ACR accredited ultrasound units are part of this program, for a total of about 30 scanners across the

hospital and outpatient clinics spanning general abdominal imaging, vascular imaging, breast imaging, pediatric imaging, and with advanced applications such as contrast enhanced ultrasound, 2D/3D, and elastography being offered. There are approximately 120 ultrasound probes in the complement of clinically active probes used daily. The total number of patients imaged in the ultrasound department is approximately 50,000 per year and steadily growing. Most scanners are portable, that is, each scanner does not necessarily have an assigned imaging bay or imaging suite. Even if a scanner is in a particular bay or suite, it does not imply that same unit will be located in the same bay or suite every day. At the main hospital location, many patients are scanned bedside on the hospital floor. At the outpatient clinic, since the patients are ambulatory, there are dedicated ultrasound imaging suites.

Determining who monitors the program at all sites, who can take action when a test deficiency is noted, who is responsible for modifying the procedure or instructions when needed, how often the management team meets to discuss program results, and who can implement change are all part of the broader QA program. The broader program also addresses auditing the task of cleaning and disinfecting the ultrasound scanner and probes after each use, that endocavity probes are properly disinfected after each use, filters are cleaned regularly, and the general safety of the ultrasound scanner is checked.

Table 2 lists the elements of the quality control program performed by the ultrasound technologists. The procedure is to test all ports on the scanner along with the most clinically used probes. Updates to the probe inventory list is an ongoing task with probe additions and deletions kept up-to-date in a centralized database.

Table 2 Sonographer quarterly QC tests

Visual Inspection	Visual assessment of monitor, power cord, probe cables, and control panel
Brakes	Machine doesn’t move when brakes engaged
Electrical safety	Power cord intact
Uniformity	Phantom image from each probe and each port for artifacts
Monitor display	Evaluation of test image for pixel defects, and artifacts

QC is also performed on new probes that are put into service, and probes that are loaned to us while others are being serviced. Probes that are used only occasionally are also QC’ed before patient imaging to ensure artifacts are not present and that the integrity of the probe is intact and still safe to use. Images acquired from all probes are permanently stored for the lifetime of the probe, and then archived for future comparisons. The length of time the archive is kept has yet to be determined and is maintained

at a centralized location. A digital record, which includes pictures of all system serial numbers including the probes serial numbers, ensures the database is always current. Defects noted during the annual medical physics testing can be also be tracked. Artifact images are included in the report, as are images of any breaks or cracks of any of the probes or the unit itself. In essence, each probe and each ultrasound scanner has a complete digital history.

Acquisition display monitors are also checked during the routine QC. Resolution patterns, 0/5% and 95/100% contrast patches, looking for pixel streaks or defects, noise, and unsharp transitions are all part of monitoring displays for degradation. The medical physicist plots the luminance values of the eighteen targets from the TG-18 test pattern for display range and non-uniformity. Comparisons are made year to year to track monitor degradation.

Other aspects of the quarterly QC program is to ensure brakes are functioning properly, the power cord and probe cables are intact and not intertwined, and all peripheral devices are properly affixed to the scanner.

III. DISCUSSION

The QC program has been in place since 2017. There has been 100% testing compliance; no quarter has been missed since implementation. Sonographers have been trained by the Medical Physicist, with others trained as necessary with staff changes. Other clinical sections with ultrasound devices, interventional radiology and vascular interventional radiology, are being looped into the ultrasound quality program as word has spread about this initiative and the desire to have a program that can maintain image quality. Table 3 delineates initial and ongoing costs of the program. Improvements are being considered to streamline the sending and receiving of QC images, signing off on the quarterly QCs by using more automation. We are also looking into only using in-air images to track transducer failures as an even more economical and time-saving procedure.

Table 3 Implementation and time costs

Item	Approximate time spent
Training of QC technologists	1 hour per technologist and 1 hour medical physicist per group
Phantom	1 per site
QC checks	5-10 minutes average per machine, quarterly
Annual medical physics check at site	1 hour per machine
Medical physicist off site evaluation of images and report writing	1 hour per machine – normal 2 hours or more for acceptance testing and reporting
Updating QC database – ultrasound technologist	1 hour per quarter on average
Quarterly review of QC – medical physicist	4 hours per quarter: looking at all QC uniformity images, evaluating for artifacts, updating database

As older equipment is replaced, new ultrasound scanners are logged into the QC database. Acceptance testing is conducted on all probes, irrespective of whether the probes will be used daily. Acceptance testing starts the overall QA process with the benchmarking of all probes with the most likely clinical protocol. In-air images are also acquired at acceptance testing and annually. These images provide another layer of data in determining transducer failures.

Table 4 indicates the major problems encountered with the ultrasound scanners such as control panel breakage and the monitor arm not holding in place. When troubleshooting the control panel breakage, it was noted that sometimes patients used the side of the control panel to raise themselves from the scanning bed. This was discouraged as much as possible.

Table 4 Most often downtimes/repairs

Problem Category	Part	Failure/Reason
<i>Manufacturing Defects</i>	Monitor Arm	Unstable – Failure to maintain position
	Control Panel	Tension caused severe cracks on both sides needing replacement to all units to a more robust panel.
<i>Normal Usage</i>	Control Panel	Keys need replacement
	Probes	Probe housing coming apart Damaged probe heads High frequency probe transducer element failures Persistent noise
<i>Upgrades</i>	Software/Hardware	Image artifacts caused by hardware/software upgrade-boards replaced
<i>Electrical</i>	Power cord	Stress at both ends of power cord requiring replacement Outer rubber sheath cracking/fraying due to running over cord with scanner – cords replaced
<i>Acquisition Monitor System</i>	Clinical Image	Gray scale image displayed in color
	Connectivity	Intermittent – unknown origin – communication with RIS, PACS or pulling from Worklist disabled

One has to be diligent in selecting equipment that meets the needs of the service. As mentioned previously, most ultrasound scanners are portables and need to be moved from one location to another. The handgrips on the control panel broke on all scanners deemed portable and had to be replaced with a sturdier, improved version. Obviously, one may not be aware when purchasing that

this will occur. As a result, next purchases will include actively investigating certain features of ultrasound scanners.

Because radiology and ultrasound management embraced the program from the beginning, quality control is conducted as originally designed with few changes. Coordinating timing of the checks can sometimes be problematic due to clinic constraints or other uncontrollable events such as scanner having issues with connectivity, software or upgrades, and inclement weather such as hurricanes or tornadoes, and of course any type of contagion that would necessitate segregating the ultrasound fleet. Other minor areas requiring sporadic attention, is ensuring that ultrasound technologists are properly trained, that service tickets are promptly sent, and records timely updated.

The length of time the tests actually take is minimal, from 5 to 10 minutes per scanner once the sonographer is comfortable with the procedure. The time it takes ultrasound technologists to become comfortable is dependent mostly upon experience.

One aspect of the overall QA program identified as needing attention, is to develop a process or procedure when personnel changes occur. This is not a problem until staff changes occur. Because ultrasound QC is not as entrenched as with other diagnostic imaging modalities where technologists and managers are very much aware of regulatory requirements, anyone who would come from outside the hospital or clinic would not necessarily be aware the program exists and, more importantly, know what to do. Addressing this has become a priority.

Improvements, resulting from the deployment of the same program and processes across all hospitals and clinics are not always easily quantifiable. There are three components at play when looking at ultrasound equipment: the probe, the unit (including hardware and software), and the acquisition monitor. All three can independently contribute to image degradation. The ultrasound technologist visually checks the display monitor quarterly, as part of the QC but also daily as part of patient imaging. The medical physicist, once a year, generates a luminance graph of the TG18 gray scale pattern from each ultrasound scanner. The same criteria for CT acquisition monitors is our baseline for evaluating each monitor [13] (Table 5), as well as incorporating the 9-point luminance deviation from the median (LUDM) from AAPM Report 270 [14].

Table 5 Minimum criteria for ultrasound display monitors

Parameter	Threshold Value
Maximum Brightness (L_{max})	$\geq 100 \text{ cd/m}^2$
Uniformity – 9 point	$LUDM = \max(100 \cdot \frac{ L'_n - L'_{med} }{L'_{med}})$
	Where: L'_n is the luminance value at each point L'_{med} is the median value of the 9 luminance measurements

Because the same program exists everywhere, we now have a database of quality measures to compare the performance of the systems for the same make/model/software version. The expectation is that all machines with the identical version of software on the same make and model should be performing at the same level given a specific clinical protocol. We can now track clinical image quality throughout the system using the data collected.

Table 6 delineates simple steps one can take to begin an ultrasound quality assurance or more generally a quality improvement program at any imaging facility whether a small clinic with only one scanner or a large imaging department with a substantial ultrasound fleet.

Table 6 Suggested steps for ultrasound QC implementation

1.	Link/network with others who have successfully implemented an ultrasound QC program at their facility
2.	Summarize the best points for future internal discussions
3.	Organize meetings with all stakeholders (radiologists, managers, lead ultrasound technologists)
4.	Demonstrate value of QC testing by providing papers delineating positive results and summarizing results from your network
5.	Prepare simple QC test requirements based on your clinical/hospital requirements
6.	Propose frequency of testing that is manageable and achievable.
7.	Determine how QC data will be collected, who will monitor, where stored, who has access, etc
8.	Make necessary changes as program matures based on data collected

IV. CONCLUSION

Because this was a simple program to follow, compliance has been very high. In fact, compliance runs at 100%. Ultrasound technologists feel more empowered and in control in determining whether to place a service request for repairs to either probes or the ultrasound systems. The criteria for artifact identification that could cause image quality degradation is now firmly entrenched. A metric was developed to determine the point at which the probe housing would require resealing as opposed to replacing, as probe replacement is becoming more and more expensive with each new generation of probe development. The generation of a common failures list will help in future purchases and negotiating service agreements. Even after several years of compliance, the quality technologists are enthusiastic about the program. Equipment is repaired sooner and malfunctioning probes replaced more often providing for the best quality patient imaging.

ACKNOWLEDGEMENT

The author wishes to warmly thank all those, past and present, who participated and contributed in the development and execution of this quality initiative. The program would not have been successful without the full support and commitment of everyone involved.

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TEST OBJECTS AND METHODS FOR VISUAL ASSESSEMENT OF THE GAMMA CAMERA INTRINSIC RESOLUTION DURING QUALITY CONTROL

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Abstract - The spatial resolution of a gamma camera may be measured either subjectively or objectively. Objective assessment of resolution are simple to perform and reproducible, but usually give an insight into part of the field, while subjective methods usually cover entire UFOV. A common approach is the visual evaluation of the image of a test pattern that involves recording the smallest features which can be seen on the image. Transmission test patterns have been developed over the years for a simultaneous evaluation of intrinsic resolution of the entire field.

The present review paper discusses the capabilities of only those phantoms who, on visual inspection, assess resolution in a relatively short time and are suitable to today's cameras with rectangular detector and spatial resolution of 3.8 mm: four quadrant, Hine-Duley, PLES, UB, BRH and LRP phantoms.

Subjective methods should give similar or at least close assessments of these from objective methods. The criteria to choose a particular set, the size of the step between adjacent sets (quadrants) and coefficient for quantification are discussed. A new phantom for visual examination of camera resolution is proposed.

Visual evaluation phantoms offer a convenient and quick way to test a GC performance, but in its current form are not suitable for acceptance or routine testing. Most of the phantoms for visual inspection has been developed almost 30 years ago for the assessment of GC performance of that time. Today's GC has significantly improved features that can't be accurately evaluated with old time phantoms. They need to be updated.

Keywords: intrinsic resolution, subjective, quality control, phantom,

INTRODUCTION

The gamma camera detector is a sophisticated complex of a large area scintillation crystal and several dozen PMTs, which must work together so that the detector field (52x39

cm) has the same sensitivity and resolution at each point, as well as a high degree of linearity. In order to keep these three basic parameters under control, appropriate methods are needed (subjective and objective as well) for their assessment. While online correction methods have been developed for sensitivity and linearity throughout the entire field, there is no such method for intrinsic spatial resolution.

Without being explicitly stated, many papers - relating to quality control - note that resolution is probably not the same throughout the field, and therefore it is necessary to evaluate it at more points in the field - or at least in the central field of view (CFOV) and in the useful field of view (UFOV). That's why a lot of attention is paid to phantoms who assess resolution in different parts of the UFOV.

The spatial resolution of a gamma camera may be measured either subjectively or objectively. Objective measures are based on the point or line spread function, spatial resolution often being quoted as the Full width at half maximum (FWHM). Objective assessments of resolution are simple to perform and reproducible, but usually give an insight into part of the field, while subjective methods usually cover entire UFOV. A more common approach is the visual evaluation of the image of a test pattern that involves recording the smallest features which can be seen on the image. Subjective methods should give similar or at least close assessments of these from objective methods.

The purpose of this paper is to make a review and comparative analysis of phantoms and methods of visual evaluation of resolution over the UFOV.

Transmission test patterns have been developed over the years for the simultaneous evaluation of intrinsic resolution of the entire field. By default the width of the lead bars in these patterns is equal to the space between them while the center-to-center spacings of the holes may vary. For such patterns, the spatial frequency of either bars or holes increases as the width of the bars or spacing between holes decreases. The minimum perceptible bar spacing is used as an index of camera spatial resolution. It can be quantified using the following relationship

$$\text{FWHM} = 1.75 B$$

where B is the width of the smallest bar that the camera can resolve.

In assessing the qualities of phantoms for resolution assessment, it is often noted as an advantage the ability to assess linearity as well, since the configuration of holes or bars in most cases allows this. In the context of the quality control (QC) it is better for the phantom to give an accurate assessment of the resolution - which covers the entire field - than to give a good estimate of linearity at the same time. For linearity assessment, there are enough good specialized phantoms – ortho hole transmission phantom (OHTP) (1), parallel line equally spacing (PLES) (2) etc.

Present paper discusses the capabilities of only those phantoms who, on visual inspection, assess resolution in a relatively short time and are suitable to today's cameras with a rectangular detector and 3.8 mm resolution. Anger's first two phantoms were added as a tribute to his invaluable contribution to the creation and development of the gamma camera, a major tool for nuclear- medicine diagnostics.

REVIEW OF VARIOUS PHANTOMS

The ingenious inventor of gamma camera H. Anger created the first phantom (3) to evaluate the resolution of the detector field (Fig. 1). The phantom is a group of 4 tungsten bars with a width of 1/8" to 1/2" (3.2 – 12.7 mm) located symmetrically on the detector. Width of bars is equal to space between them. This phantom gives a good idea of camera resolution and launches development of bar phantoms.

Anger's later development is the so-called Anger "pie" phantom (4) - a lead disc with hexagonal arrays of holes with a diameter of 2, 2.5, 3, 3.5, 4 and 5 mm. (Fig. 2). In each case the hole diameter is one fourth of the center-to-center distance. This configuration is suitable for visual evaluation of the resolution of a circular detector because it allows with 5 rotations of the phantom through 60° all sectors of the phantom to pass through the entire field of the detector.

In the following years, new phantoms were already created (5), some of which are suitable for assessment of a camera resolution: 90° Bar Quadrant phantom, Hine-Duley phantom and PLES phantom.

90° Bar Quadrant phantom (later renamed to 4 quadrant bar phantom) (Fig. 3) consists of four sets of bars arranged so that each set is rotated 90° with respect to the adjacent set (5). In each set the bar width is equal to the space between bars. The smallest bar width in original pattern is 4 mm while

in the present-day commercially available phantoms it is 2 mm. The width of the bar increases in step of 0.5 mm – 2, 2.5, 3 and 3.5 mm. 4 quadrant bar phantom with different bar width and steps are available on the market. The choice of the bar width should be matched to the resolution of the camera.

To obtain a complete evaluation of camera resolution the smallest bar width has to be imaged in all 4 quadrants of the useful-field-of-view (UFOV) i.e. the phantom must be inverted 3 times to achieve this. Note also that for rectangular detector acquired images show the smallest bars only in one direction – X or Y. For older round detectors, it's possible to get images of the smallest bar width in X and Y direction with one phantom that's inverted and rotated (6). In this case 8 images in total are obtained for the final evaluation!

The following images are shown with educational purpose, their sources being cited at each figure.

The Hine-Duley bar phantom (Fig. 4) consists of 5 sets of lead bars (5). In each set the bar width is equal to the space between bars. The widths of the bars are 4 mm, 4.8 mm and 6.4 mm. The center section consists of 8 bars each 4 mm wide. On either side are 2 sets of 6 bars each 4.8 mm wide and the endmost set of 6.4 mm wide. A probable reason why this phantom does not get development is the limited number of sets - 3 that give an estimate of the limited portion of UFOV.

The Parallel Line Equal Spacing (PLES) bar phantom (Fig. 5) consists of an array of lead bars (5). The widths of the bars are equal to their separation being 3.2 mm or 4.8 mm. Later, the PLES phantom undergoes a significant modification and becomes the well-known today's main phantom for quantitative assessment of resolution through FWHM of line spread function (LSF). In addition, the PLES phantom is also known as Slit mask (7) and as Intrinsic spatial resolution and linearity phantom (1).

The UB Gamma Camera Test Pattern (Fig. 6) developed at University of Buffalo (8) consists of four sets of parallel line equally spaced bars (0.25, 0.19, 0.16, and 0.1 inch) (6.4, 4.8, 4.1 и 2.5 мм) arranged in an "L-shaped" configuration in each of its quadrants (1998). It is attractive because perform routine quality control tests of gamma camera spatial resolution and spatial linearity in approximately one quarter of the time presently spent with four-quadrant phantom.

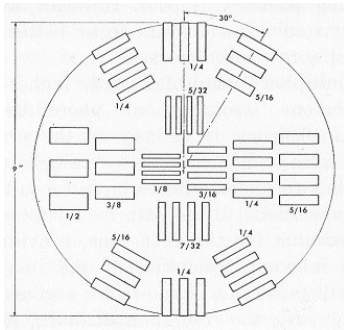


Fig. 1 Anger test pattern

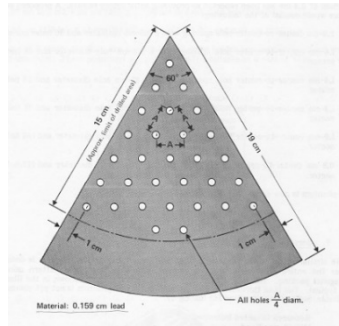


Fig. 2 Anger pie phantom

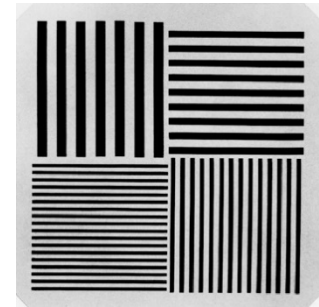


Fig. 3 Four quadrant phantom

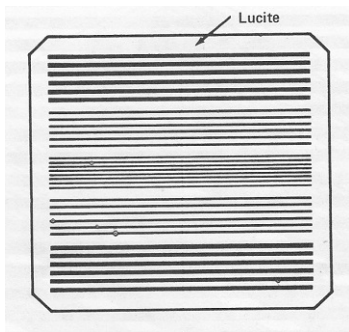


Fig. 4 Hine-Duley phantom

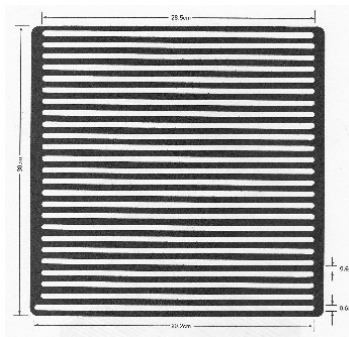


Fig. 5 PLES phantom

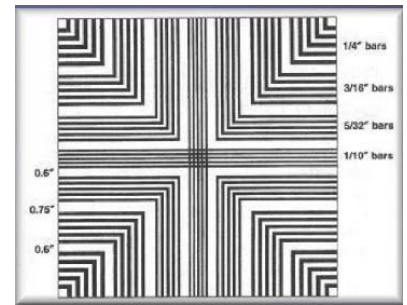


Fig. 6 UB (University of Buffalo)

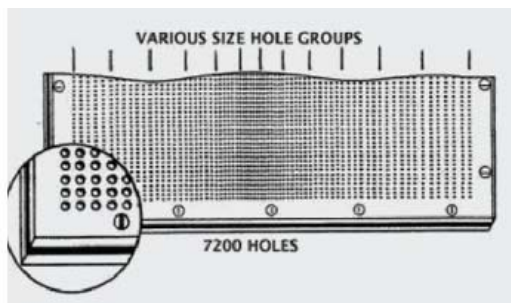


Fig. 7 BRH phantom

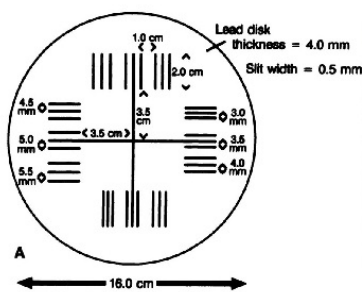


Fig. 8 LRP phantom

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The UB Gamma Camera Test Pattern provides all of the benefits of a four-quadrant bar phantom, with an important added benefit that allows to make direct simultaneous comparison and evaluation of resolution and linearity in each of the 4 quadrants in one image. This makes it particularly effective means of performing routine quality control check of gamma camera. To get closer to the test requirements of modern GC a better choice would be sets of bars 2, 2.5, 3, 3.5 mm.

The BRH Test Pattern (9,14) (Fig. 7) consists of an orthogonal array of 2.5 mm diameter holes in a 3.2 mm thick lead plate (1981). The minimal lead spacing separating adjacent holes is a constant 2,5 mm in the Y direction, but varies along the X axis, in 12 groups of six holes, The spacing separating the holes is constant within each group but differs from one group to another, from 1.5 - 7 mm in steps of 0.5 mm. The group of holes with the closest spacing that appears still resolved on the transmission image of the BRH Test Pattern is a measure of the camera's intrinsic resolution.

As a whole BRH Test Pattern is further growth of the Hine-Duley phantom. Remarkable novelty in the development of BRH Test Pattern is the idea to produce areas of well-resolved, barely resolved, and unresolved groups of holes within a single image.

As in the case of lead-bar transmission images, a fixed relation exists for the minimal lead spacing between the holes that can be resolved and the spatial resolution, expressed as FWHM. On our opinion this relation should be determined experimentally because it depends on the experience of the user and his/her perception of "well-resolved, barely resolved, and unresolved" groups of holes. For a complete analysis of local variations of the intrinsic resolution within the UFOV, several transmission images of the BRH test pattern at various orientations are essential.

An original approach for visual resolution assessment other than that of BAR phantoms was used in Line Resolution Phantom (LRP) phantom (10) (Fig. 8). Its construction is based on the definition that the resolution is the smallest distance at which two small objects become indistinguishable. The object used is a 0.5 mm wide slit. The phantom contains 6 groups of slits with different distances between them 3, 3.5, 4, 4.5, 5 and 5.5 mm. The resolution assessment is the group that is unresolvable.

This phantom clearly cannot be assigned to either bar phantoms or PLES phantoms, but it is a successful combination between them, allowing for both a visual assessment with a step of 0.5 mm and an FWHM assessment. Among phantoms with visual inspection and interpretation of resolution, this phantom is best approached to the quantitative assessment of resolution.

The LPR phantom has four great advantages over BAR phantoms- 1) the resolution is evaluated directly without the need for a correction factor; (2) include in the centre two slits wide 0,5 mm on which FWHM can be assesst in X and Y direction; 3) better accuracy of the assessment due to a smaller step between adjacent sets - 0.5 mm and 4, while in bar phantoms the step is $0.5 \times 1.75 = 0.875$ mm and 4) offers a larger range of choices of the type "well-resolved, barely resolved, and unresolved".

DISCUSSION

Overall, the view is that the advantage of subjective methods for assessment of camera resolution is that they cover the entire field, and the downside is that they are not particularly accurate. In our opinion, a great contribution to inaccuracy is the fact that the process of forming the final assessment involves a series of conditionalities that allow for a broader interpretation and application. We believe that if these conditionalities are refined, the accuracy and repeatability of the assessment can be substantially improved.

An essential component of the subjective method of evaluating resolution is the choice of the set of unresolvable bars. It's a little intimidating when the chosen set of bars or holes turns out to be the endmost in a series of sets. In this case, there is always the suspicion that perhaps the missing next.

This feeling is further reinforced by the vague and varied definition of choice: barely resolved bars (9), just resolved bars (6,11), minimum perceptible bar spacing (12), the smallest resolvable bar (1987), just barely resolvable bar (1988), minimum resolvable line separation (10), the smallest bars visible (13). In the context of the current topic, this concept is uncertain because it depends on a personal perception.

The only definition that points to a more objective choice of a particular set is that "at least one half of the length of the bars will be observed in a portion of a quadrant for that quadrant to be considered visible." (13). An additional condition that would contribute to a more accurate choice of a particular set is to introduce the series "well-resolved, barely resolved, and unresolved" in a single image (9) to facilitate visual evaluation and exclude a moment of hesitation.

An essential element that determines the suitability of phantoms for acceptance and routine testing is the step of change between adjacent bars or holes. A disadvantage of modern bar phantoms is that the step is too large and does not allow for intermediate results.

Table 1 4-quad pattern – step 0,5 mm

Bar width [mm]	FWHM [mm]	3.8 mm referent
2	3.5	-8%
2.5	4.375	15%
3	5.25	38%
3.5	6.125	61%

Table 2 4-quad pattern – step 0,3 mm

Bar width [mm]	FWHM [mm]	3.8 mm referent
2	3.5	-8%
2.3	4.025	6%
2.6	4.55	20%
3.1	5.425	43%

Table 3 4-quad pattern – step 0,25 mm

Bar width [mm]	FWHM [mm]	3.8 mm referent
2	3.50	-8%
2.25	3.94	3.9%
2.5	4.38	15%
2.75	4.81	27%

This statement is illustrated for a 4-quadrant phantom in Tab. 1. In the first column of Table 1, width of bars in all four sets are listed, while in the second column the corresponding FWHM values are calculated. The third column shows what is the deviation of the reported resolution relative to referent resolution - 3.8 mm - when the corresponding quadrant is barely resolvable.

Virtually only the first quadrant of a 4-quadrant phantom is used as barely resolvable one in present day cameras with a resolution of 3.8 mm. (Tab. 1). When the second quadrant becomes barely resolvable - the deviation is 15% and service intervention must be planned. When the third quadrant becomes barely resolvable - the camera has to stop. Therefore the 4th quadrant remains unusable (obsolete). This opens up the prospect of improving the accuracy of the 4-quadrant phantom assessment by changing the step between adjacent quadrants. Tables 2 and 3 provide examples of the results of such a change. The reduced step will make it possible to define more definitively and more objectively the resolution explored in the series, "well-resolved, barely resolved, and unresolved" in a single image. The reasoning outlined so far gives reason to argue that in its current form 4-quadrant phantom was suitable for GC with a resolution of 4.5 – 5 mm, but not for modern GC with resolution of 3.8 mm.

To quantify the result of the visual inspection, the width of the barely resolved bars has to be multiplied by a coefficient. The most popular value of this coefficient is 1,75 (6, 9, 11, 15), while other authors indicate a value of 1,6 (13). Our view is that the value of this coefficient should not be accepted as mandatory but can be determined locally in order to adapt to the perceptibility of the local staff. This can be done this way: suppose the barely resolved bars are in the upper left quadrant of the field. Determine the FWHM in the same location. Calculate the coefficient:

$$\text{Coefficient} = \text{FWHM} / \text{bar width}$$

Among the phantoms with a visual score, the best approximation to the actual resolution value is the phantom suggested by O'Connor (10). The main disadvantage of this phantom is that it covers a small area of the field. This flaw can be easily overcome by replicating the phantom in the 4 quadrants of entire UFOV with a central cross of two slits of

0.5 mm width (Fig. 9). Thus, a universal phantom is formed for visual and FWHM assessment of the resolution of modern GC with a rectangular field. The 6 groups of slits with distances from 3 to 5.5 mm and step 0.5 mm create comfortable conditions for working on the criterion "resolvable, barely resolvable, unresolvable".

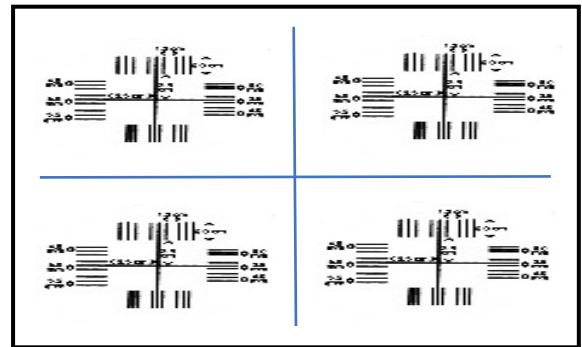


Fig. 9 Proposal for a new quadrant phantom

CONCLUSIONS

Bar phantoms, in particular the quadrant bar phantom, has been used widely as a simple, quick method for judging the spatial resolution of a GC. Phantoms for visual evaluation offer a convenient and quick way to test GC performance but in its current form they are not suitable for acceptance or routine testing.

It should not be overlooked that the assessment of resolution with these phantoms is too approximate, as it is generally the view that the variability of resolution is much greater and does not run out of estimates in the four quadrants of the field.

The accuracy of the phantom bar assessment can be improved by reducing the step between adjacent quadrants. Only then they can be used for routine QC.

Taking into account the requirement for visual resolution assessment on both X and Y, the UB phantom is preferable

to 4-quadrant bar phantom - only one transmission image to assess resolution and linearity on X and Y directions.

A new phantom based on the LRP test pattern of O'Connor has been proposed, which will give a direct visual assessment of resolution in 4 quadrants and in addition will allow for additional FWHM evaluation in both each quadrant and on UFOV's central X and Y axes.

Most of the phantoms for visual inspection has been developed almost 30 years ago for the assessment of GC performance of that time. Today's GC has significantly improved features that can't be accurately evaluated with old time phantoms. They need to be updated.

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Impact of Covid-19 outbreak on radiotherapy of cancer patients: Institutional experiences

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Abstract—

Introduction: The novel corona virus pandemic caused a dilemma into healthcare to facilitate the best possible management with safe practices. Radiotherapy treatment may include the radical and palliative intent(s) which should be given as early as possible to provide relief to patients. Cancer patients are already at increased risk of infection due to lack of immunity power. Different centres have developed institutional policy to combat the COVID-19 without breaking the radiotherapy treatment services.

Materials and Methods: The administrative department of the institutes released the protocols and strategies for effective management of patients undergoing radiotherapy treatment. Head of department summons online meeting for implementation of effective strategy to provide unhindered services to patients and safe practices amongst staff.

Results: Effective measures were taken to decrease the risk of contamination amongst staff and patients. Proper staffing rotation with reduced strength, use of personal protective kits, remote consultation, hypofractionation, radiotherapy treatment schedule management, online meetings, scheduled corona testing of the patients, attendants, sensitisation of units, use of mask and regular hand wash practices were key aspects of strategies during pandemic. Time to attend per patient for treatment was increased due to the inclusion of appropriate safety guidelines prescribed by management committee.

Conclusion: The remedial solutions assisted in maintaining the balance in work and effectively implementing the plans for radiotherapy treatments. The physical presence and contact duration was reduced for better outcomes. This practice ultimately helps in reducing the spread of infection amongst staff, patients and attendants.

Keywords— Radiotherapy department, COVID-19 Pandemic, Patient Management, Hypo fractionation.

I. INTRODUCTION

1.1 Novel Coronavirus Pandemic

The World health organization (WHO) had declared global pandemic due to the coronavirus contagious [1]. A person suffering from COVID-19 can infect at least two people as per its metric score of 2-2.5. First case of corona virus were declared in Wuhan city, China in December 2019 [2]. In March 2020, the Indian

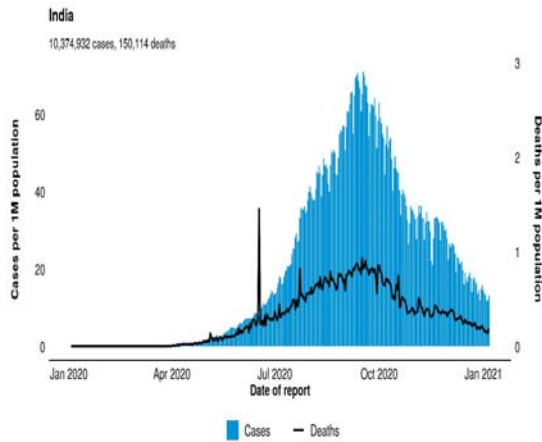
government had declared the Covid-19, a pandemic situation and initially complete lockdown was suggested to control the infection rate. In Mid November 2019 more than 1,300,000 deaths had been confirmed and 53,700,000 cases of infected people were identified worldwide [3]. The COVID-19 virus are enveloped, single stranded, positive strand RNA having characteristics of rapidly spreading, contagious and evolving in humans. Quarantine was the prime facia treatment practice for infected person at least for 14 days and, if required, necessary medicines for fever and multivitamins were recommended. The transmission of the virus was particularly suggested by contact with the infected person through droplets from cough, sneeze and verbal interactions. Regular hand wash, maintaining social distance of at least 1 meter and facemask was recommended by Indian Council of Medical Research (ICMR) to regulate infection rate. Person having symptoms of fever, headache, nausea, dizziness, running nose and eye are suspected case of COVID-19 and confirmation is subject to test results. COVID-19 was classified under acute respiratory syndrome by WHO [4].

1.2 Covid-19 infections in India

In India the first case of COVID-19 was reported in a student from Kerala who had returned from Wuhan China on the 30th of January, 2020. India reported its first death on 12th March 2020 of a 76 year old man who had returned from Saudi Arabia.

Subsequently, these numbers gained unimaginingly high access to the continent through travelers returning from hotspots in different parts of the globe. Since then, all the 54 countries in the region have reported confirmed cases [5]. The number of infections together with its pattern in India till 6th January 2021 could be summarized in figure no. 1.

Fig 1: Death and Infected Cases per 1 million Population in India



As per WHO data, 2021 has crossed 10,374,932, with 350,753 associated deaths. From the observations of initial cases, it was mainly confined to capital cities, however a significant number of cities in India have now reported confirmed cluster of cases as the mode of transmission in multiple provinces found[6,7].

Indian Council of Medical research (ICMR) & Ministry of Health and Family Welfare and the India Centers for Disease Control and Prevention (India CDC) graded Level 4 Very High Covid-19 in India for travelers which established the India Task Force for Novel Coronavirus to oversee preparedness and response to the global pandemic of Covid-19 [7]. The strategy to defeat this global disease in India was focused on rapid detection and rapid control of the disease through lock-down and isolation. The ICMR has worked with governments across India to scale up their capacities in critical response areas such as coordination, surveillance, testing, isolation, case management, infection prevention, contact tracing, and control, risk communication and community engagement, and laboratory capacity [8].

Among others, the establishment of a task force to deal with the situation, other measures include training to increase surveillance on countries' borders, mobilization of outbreak response teams, education and sensitization of the continent on Covid-19, and cooperation of various national International government agencies to accelerate tracing, testing and tracking and partnerships with many international agencies to reinforce the Indian response, as never before.

Agencies such as the Indian Council of Medical research (ICMR) & Ministry of Health and Family Welfare, have also assisted government agencies to fight the pandemic by

donating equipment such as real-time PCR, rapid test kits and personal protective equipment (PPEs). The IAEA, International Organization for Medical Physics (IOMP), American Association of Physicists in Medicine (AAPM), among other international and national agencies have recommended several Covid-19 safety measures to be implemented in radiotherapy facilities to guarantee safety of patients, care-givers and staff [9-11].

1.2 What is Radiotherapy

Radiation therapy is one of the effective methods for the treatment of cancer; in which ionizing radiation is delivered with the primary intention to kill the tumour cells and at the same time spare the normal cells as much as possible within the tumouricidal and tissue tolerance dose. With continuous technological improvement in cancer treatment, high energy x-ray and gamma photon beam of the order of MeV or MV is being used. Apart from its use for the treatment of cancer cells, radiotherapy is also useful for few non-malignant benign conditions. Sometimes it is used in combination with surgery, chemotherapy or hormone therapy. Broadly radiation therapy can be divided in two categories viz External Beam Radiotherapy (EBRT) and Brachytherapy (BT). BT uses sealed or unsealed sources placed in the vicinity of disease either temporarily or permanently whereas EBRT uses radiation beams originating from the sources located outside the patient. The most common radiation beam used in EBRT is of photons but it can be of electrons, heavy ions or some heavy particulate radiation. Radiotherapy is given either with curative intention or with the primary aim to relieve the pain and symptoms as well as to enhance the quality of life; commonly known as palliation.

Thus success of radiotherapy that can be quantified in terms of therapeutic gain (Eqn. 1) is the direct result of exposed dose.

$$\text{Therapeutic gain} = \frac{\text{Tumour Control Probability}}{\text{Normal Tissue Complication Probability}} \quad (1)$$

1.3 Radiotherapy treatment process

Typically radiotherapy treatment process consists of sophisticated steps starting from counselling and mould preparations, simulation, contouring, planning, quality assurance (QA) and finally treatment of patients. The mentioned steps may take two to three days or more, depending on other factors, to commence the radiation delivery of patient. Errors in any one of these steps may results into the large deviation in treatment outcome of patient. Figure 2 indicates the radiotherapy treatment

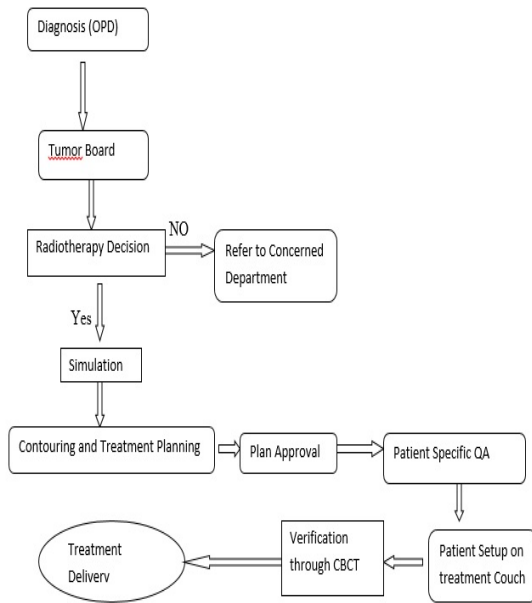


Figure 2.: Steps in Radiotherapy Treatment Process

chain process in the typical radiotherapy department from the beginning.

Team of Radiotherapy includes the Radiation Oncologist, Medical Physicist, Technologist, Nurses and other supporting auxiliary staff. Table 1 clearly indicates the key staff requirement and roles in department of radiotherapy. Patient first walks into the outpatient department (OPD) for necessary clinical workups relate do diagnosis and management. In addition, patients who are scheduled to undergo radiotherapy visit the campus of the radiotherapy department for later stages. Decision taken for check-ups and after inspecting all the reports the suitable patient selected for radiotherapy treatment course. Counselling to the patients and attendants for the various steps and procedures is appropriately given. CT Simulation is the next step in treatment procedure which starts with immobilization device mask preparation and subsequently computed tomography (CT) of patient taken and DICOM images send to the treatment planning system. Clinician will contour and delineate the target volume and normal structures and prescribe the dose to the tumour target. Medical Physicist makes the optimised arrangement of radiation delivery of the treatment considering all parameters of normal tissue structure and tumour volume and give best possible treatment plan with better coverage. The selected approved plan will be executed, with the

verification and quality assurance, by the technologist into therapy machine which finishes the whole course of radiation delivery.

Staff	Role
Radiation Oncologist	Patient Selection, Dose Prescription, Contouring, Plan Approval, CBCT matching, First day treatment, Follow-up
Medical Physicist	Quality assurance of linear accelerator, patient specific quality assurance, treatment planning, Verification, Treatment plan execution (first day or SOS), Modification in the plan for the maximum benefit of radiotherapy e.g.Phase-2
Technologist	Simulation, Treatment
Nurse	Primary care to patients undergoing radiotherapy, Simulation, Treatment
Hospital Attendant	Assist in patient preparation
Security Guard	Abide the rules furnished by management committee to allow persons

Table 1: Staffing in Radiotherapy Department

Despite the outbreak of pandemic worldwide, the mainstay radiotherapy treatment for cancer patients was not discontinued, in almost all radiotherapy centres, for patients undergoing daily fractionation and new cases. Cancer patients are mostly immuno compromised stage and there is a fair chance for all stages to become infected even with these adverse conditions treatment should not be discontinued. Therefore, it is a fairly ambiguous situation for cancer patients to provide health professional in this risk situation without putting employees at risk. The appropriate modus of operandi may help each RT centres for optimizing the activity of radiotherapy department to continue their services in such difficult conditions.

Since this kind of pandemic had never been experienced so far, we would share our planned strategy for smooth functioning of departmental work and patient treatment. To achieve the above objective,

we had focused on changing the work practice to perform the tasks better.

II. MATERIALS AND METHODS

The hospital administration organized meetings to combat the crisis by consensus which would serve as an execution recommendation plan in the department. The main objective was to prevent any source of transmission of infection to staff and patients. Committee had recommended to follow the guidelines furnished by Indian council of medical research (ICMR) time to time and apply in every department.

At OPD, patients are allowed with only one attendant after proper infra-red thermal scanning and temperature assessment. It was mandatory to maintain a distance of at least one meter and check the patient's health status and reports with the appropriate safety kits taken by physician etc. Patients selected for radiotherapy treatment after recommendation of tumor board committee sent to the department for simulation procedure where RTPCR negative report was mandatory to execute further procedures. At one time, only one patient was allowed in CT simulation area and rest patients was asked to wait for their turn and maintain proper social distancing with others. At one time, about five patients were allowed to sit in the waiting area with an alternate seat arrangement. Digital Imaging Communication in Medicine (DICOM) images from the simulation console were sent to the treatment planning system (TPS) for contouring and treatment planning. In TPS 3 contouring workstations and 2 planning systems were available and recommended not to over crowd the TPS room. At one time, a minimum number of oncologists and physicists were recommended to be in the TPS room for effective social distancing without compromising the quality of treatment and its workflow and may use related systems.

Remote planning was encouraged where the software like Team viewer and Any Desk was used for performing basic planning and calculation. Scheduling of patient on Mosaik system was performed onsite on the Saturday before performing patient specific Quality assurance check. During the daily QA process, only medical physicists and technologists were allowed in

the treatment room area with appropriate social distancing and personal protective wears. Five days in a week treatment protocol for patients were scheduled and Saturday was kept for patient specific QA check and scheduling.

Patients who were residing far places and due to administrative issues of transportation failure facility of "e hospital portal" was started where patients can upload their reports and obtain the consultants opinion. Patients were encouraged to talk on phone with respective duty senior resident/ junior resident in case of any problem faced by them. The duty of technologist staff was scheduled rotation wise to minimize any impact of the pandemic. At a time only one technologist will be available in treatment machine room to treat the patient. After every 2 weeks the duty rotation was kept on change. Three Senior residents and five junior residents were also scheduled on duty rotation wise to provide uninterrupted medical services to patients. After treating every patient treatment couch of linear accelerator was cleaned by hypochlorite solution to avoid any risk of transmission of infection through the droplets secreted by the patient.

III. RESULTS

Protocols developed and implemented are found to be effective in reducing the effects of pandemic disease that can be summarized in the following domains.

1. Reduction in transmission of infection

As per the directives of Ministry of health and family welfare and Indian council of medical research, the protocols were made by the administrative department were to be followed in all departments against COVID response. In radiotherapy department the directives were implemented after having electronic meeting on Zoom application for common consensus.

Minimum staffs were posted in the area prone to risk of contamination with proper PPE kits. Duties were scheduled in rotation to have backup staff in case of any covid infection amongst staff. Daily mopping of the radiotherapy facility with the sanitizer was performed by the staff before arrival of any patient into the department. Waiting area with proper sitting arrangements were made in

order to maintain the social distance of 1 meter amongst two patients. In one hour only four patients were scheduled and asked to enter into the waiting room premises. Only one attendant was made allowed into the department with every patient if needed. Patients and attendants were instructed clearly to have face mask, infra-red thermal scan and temperature assessment daily and noted into patient chart. Foot operated hand sanitizer was kept in entry and exit of department. It was mandated to produce a negative Covid-19 report by each patient on the first day of radiation treatment that was valid for the next fourteen days. And it was scheduled to do on every 12th day over the total duration of visit to department.

In case of any suspected symptoms, patients were sent to get PCR report before getting treatment. The days of CT simulation was also kept on Saturday to minimise the strength of patients in waiting area. The cardinal principle of radiation safety was applied in order to avoid any chance of infection and time, distance and shielding principle of radiation safety was used appropriately by staff. Minimum patient contact time, distance of 1 meter and use of proper personnel protection kit was the key practice in the radiotherapy department. Patients was instructed to strictly follow the social distancing, use face mask and regularly wash hands with sanitizer. Being immune compromised they were advised to avoid crowded place and maintain basic safety and hygiene standards.

In OPD consultants and residents were provided with proper PPE kit and patient chair was maintained at a proper (minimum) distance of 1 meter. All symptoms of patients were advised to confirmed before proceeding for physical examination in a shortest possible time. History of patients were taken through the short verbal communication and from the available old reports. Telemedicine consultation was encouraged to decrease physical presence and travelling of patients. Patients were counselled only for the symptoms raised due to radiotherapy treatment.

2. Treatment Priority

Patients prescribed radical intent of radiotherapy session having aggressive tumour classification was preferred to get the therapy on priority basis .

Delay in treatment of such patients may results into repopulation of tumours. Moderate preference was given to patients having history of less aggressive tumour but tried to start the treatment within a week to avoid any chance of growth. Patients having history of good surgical resection of disease with good margins and less aggressive tumour type were categorized into the low risk bracket and accordingly therapy was scheduled.

Hypofractionation treatment regimen were followed for patients were implemented as much as possible based on the guidelines available. For Breast cases with the nodal irradiation 40 Gy in 15 fraction was practiced instead of 50Gy in 25 fraction [12-15]. Since our facility was newly started, there was less patient load and so was practiced for the conventional fractionation regimen for other sites. Biological equivalence dose was balanced for every change in treatment. Time taken to complete the treatment of patients were increased compared to before covid situation and almost increment by 10 minutes per patient was scheduled. High end treatment methodology was preferred to have large outcome with best possible accuracy. Major patients were planned with VMAT and IMRT treatment techniques to avoid more time with patient and better results.

Due to sudden announcement of pandemic there was loss of public transportation and public fear about the risk and patients undergoing for treatment started breaking the session. There was a sudden break taken by patients scheduled for radiotherapy sessions. The figure 3 shows the trend in the patient load into the radiation oncology department. After announcement of pandemic in march 2020 by government of India there was up-down in the treatment break of 15 running patients and decreases later on as the situation was improved.

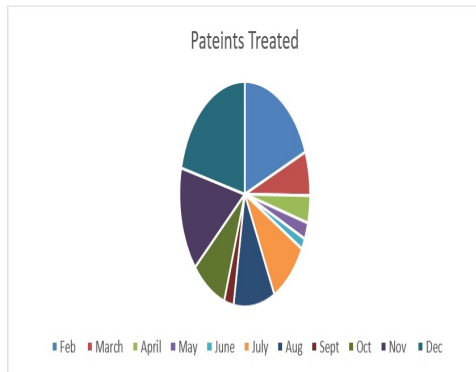


Figure 3: No of patients treated during pandemic

3. Teaching Schedules and Chart Round

A lot of webinars were scheduled based on a number of professional and super specialty health topics, which cater to the knowledge requirement of health professionals, students, to balance the damage caused by a sudden outbreak situation.

In our department regular classes of junior residents were taken by faculty, medical physicist through ZOOM application and all the course curriculum was effectively covered for the students. The online technology of hosting meetings were proved boon for the society as all the lectures, conferences, meetings and teachings were scheduled easily on it [16-17].

In radiotherapy department on every Saturday we had a provision of checking the charts of patients and cross checking if anything is missed during treatment by two to three members. Same practice was done using online web meeting system and one person from the treatment planning room gives the information of presence of particulars into the checklist and if anything is missed was pointed out and same was rectified in next working day.

IV. STATISTICAL ANALYSIS

The developed strategy was validated through a pilot study conducted with different institutions and based on the feedback from the participants. The Croanbach's alpha test for the adopted strategy was greater than 0.92

which reveals goodness of fit in methodology practiced [18].

V. DISCUSSION

The main objective of this research was the to assess the efficacy of implementing a protocol for the management of radiation oncology department at the time of COVID-19 pandemic and assessing the smooth functioning of department in terms of patient treatment outcome and covid positive cases in staff. The study clearly states to use the basic principles of time, distance and shielding (PPE kits) applied for consultant oncologist, medical physicist, nursing officer, technologist and even applies for patients to avoid any risk of infection from one personnel to another. Our no staff had any complaints of fever, headache, running nose, nausea etc till date although continues services to patients was given on priority. Rotation of duty was also very successful ways to handle the situation as any asymptomatic cases can have a break of 2 weeks and again can join the duty on his turn. Rotation was made after every 2 weeks with a mindset to allot the appropriate time for quarantine of staff who had provided unhindered services to patients. Use of teleconsultation through e hospital portal was also proved beneficial for patients who were staying in far away regions and due to administrative issues of failure in public transport could not manage to come for opinion and followups. Patients treated on couch were also advised to call on the mobile number of senior resident/junior resident if any adverse symptoms arises. Medical Physicist started doing planning using any desk and team viewer software. These practices ultimately reduce the physical presence of person and simultaneously all works were performed. Treatment strategy of initiating hypofractionation for breast patients were performed based on the evidences which results into shortening of treatment days with equivalent radiobiological outcome. Treatment modalities like Intensity modulated radiotherapy (IMRT) and volumetric modulated radiotherapy (VMAT) was encouraged to reduce the physical contact time with patient, more throughput and better treatment outcome of higher end technology. Patient specific quality assurance checks using PTW Octavius 4D was performed on Saturday before commencement of any

new patient. After the appropriate gamma pass results the scheduling was done to treat the patients on subsequent working days.

Teaching and chart rounds in department plays a pivotal role to cater the need of junior residents and quality checks of treatment respectively. The curriculum of M.D radiotherapy students was taught through online mode and no physical presence was required which may decrease the risk of transmission of contamination. The allocated time for teaching with the respective staff allows unhindered teaching services to the students. Seminars from residents side on the planned topics was also scheduled online using zoom to compensate for any loss in teaching classes. Students were benefitted by clearing all the doubts through online session in the form of audio and text messages mode. To check for any error in any step of prescription, planning, charts attachment, signature of personnel and running chemotherapy drugs were cross checked through online mode. One junior resident will be present with all the charts and one by one he may check the parameters as per the checklist and point out if any anomaly is found which may later be rectified for the respective patient. The chances of treatment error may be avoided using the above practice.

The protocols used in the department were helpful in reducing the physical presence of staff near to the risk area by 70% after implementing the remote access strategy and rotation of duty. As per the literatures this reduction in the physical presence and personnel encounter with the patients makes transmission of infection control very high in the department. The used methodology can be utilised as a reference for any management to counter the effect of outbreak and manage the patients treatment, follow-up and consultation smoothly. The crisis management policy adopted by our department helped in running the department with unhindered termination of services to patients along with keeping the safety of staff and public too.

Some studies have suggested to delay the treatment of patients and selecting only the emergency patients for treatment[17]. The disadvantage of such policies are the tumour repopulation, stress on patient and family, increased chances of metastasis and radiobiological challenges. Another studies had adopted the methodology of hypo fractionation schemes applied for all the patient treatment that reduces the physical presence of patients in the department. The major

disadvantages of this strategy are the radiobiological limitations, availability of linear accelerators and other auxiliary equipments needed to for the accuracy in hypofractionation regimen treatment[18].

Abide by the regulations and safety tips suggested by ICMR and MoHFW to use facemask, regular hand sanitization, PPE kits , gloves, goggles by the staff are key aspects of primary safety from infection shown in fig 4 . One disadvantage of these suggestions was unavailability of too much consumables in the department as supply from the government to all the sites was not much hence chances of propagation of transmission of increases due to repeated use of consumables.



Fig 4: Staff cleaning the couch after every patient treatment using hypo solution.

Moreover, the study developed protocol results into the important aspect for effective quality care of patients and staff with substantial effect on clinical implementation during pandemic of COVID-19.

VI. CONCLUSION

During pandemic situation world wide radiation oncology departments are required to step appropriate precautions to avoid any transmission of infection due to COVID-19. Patients undergoing into treatment sessions are more likely to be carrier because of lowered immunity level and necessary steps required to ensure smooth functioning of department. Proper social distancing, use of face mask, regular hand sanitization,

rotation wise duty scheduling, use of platforms like teleconsultation, teleplanning and reduction of physical presence may ultimately reduces the risk of contamination of staff and patients. These possible strategy adoptions may help the center to avoid any delay of patients treatment and regular running of department.

CONFLICTS OF INTEREST

There is no conflict of interest.

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BOOKS

Book Review

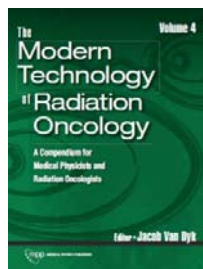
The Modern Technology of Radiation Oncology (Volume 4)

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Medical Physics Publishing



The book “The Modern Technology of Radiation Oncology” is the 4th volume in this series and has several new advances in Radiation Oncology included in it. The first volume had several technological advances in Radiation Oncology in precise detail, that I have used this volume extensively for teaching the advanced technology, probably the mostly used Medical Physics book by me after H E Johns and Cunningham’s book of “The Physics of Radiology”. This book, the volume 4, of this series again goes in to the details of the advanced and also newer technologies in Radiation Oncology, that would be useful not only for the students, but also for the teachers in Radiation Oncology Physics. This is mainly because the contributors to this volume are experts in the respective subjects discussed in this book.

Though this book is part of the series in The Modern Technology of Radiation Oncology, the more appropriate title would be “Emerging Technologies in Radiation Oncology” as several of the topics discussed in this volume are just getting into the Radiation Oncology space. This volume starts with an introduction to the technological evolution in Radiotherapy and to the new and evolving technologies discussed in this book. The chapter on Surface Guidance in Radiation Therapy comprehensively discusses all aspects such as historical evolution of the technology, technical details, its application, commissioning and quality assurance procedures. An interesting and useful addition is the chapter on PET/MRI as a tool in Radiation Oncology in which information on the common isotopes and tracers used in PET scanning for oncology, details on standardized uptake value and spatial resolution are provided. The chapter also provides details of MRI for oncology, on MRI contrast / maps useful for oncology. Other useful inclusions are the discussion on PET/MRI, its use in oncology, the considerations for housing a PET/MRI and the limitations of

MRI in providing electron density data of tissue for attenuation correction necessary for PET.

It is very encouraging to see that one of the recent advances in Image Guided Radiotherapy (IGRT) systems, the Magnetic Resonance for real time image guidance in radiotherapy has been covered in a great detail in this volume. In addition to providing details of technological development by various researchers, this chapter also discusses important aspects such as the influence of the magnetic field on the dose distribution and also on the reference dosimetry which I am sure would be very useful for the students. Several radiotherapy centers are now practicing Stereotactic Body Radiotherapy (SBRT) either with conventional linear accelerator or with dedicated units such as the cyber knife. The MR linear accelerator which is one of the preferred units for SBRT and its essential details have been well brought out in this chapter on SBRT. The discussions on the GTV to CTV margin, CTV to PTV margin and the discussion on margin recipe for SBRT much needed topics for radiation oncologists and physicists.

The chapter on adaptive radiation therapy (ART) deals with several aspects of ART such as imaging, segmentation, plan adaptation, quality assurance and also deals both with offline and online ART. Automated planning, and knowledge based planning are now getting into clinical use and the need of the hour is to have a good quality assurance program for these and I am pleased to note that the failure mode and effect analysis of automated planning is discussed in detail in this book. Artificial intelligence, machine learning, Radiomics and Big Data are other emerging fields that are finding applications in radiotherapy and the discussions on the application of these in various stages of radiotherapy process is a welcome inclusion. For the sake of continuity, the chapters could have been arranged so that ART follows the one on SBRT and the chapter on machine learning follows the one on artificial intelligence.

This book covers not only the advanced technologies but also the emerging technologies in radiotherapy such as artificial intelligence and machine learning. To conclude, this volume is a welcome addition to the series on advanced technology of radiation Oncology and should be in the library of every radiotherapy department and would be an asset for both the teachers and the taught.

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Understanding and Optimizing Visibility in Medical Imaging Procedures

Image Characteristics and Controlling Factors

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Modern and Complex Technology

Sprawls

Comparing medical imaging procedures to flying modern aircraft. Both require highly educated and experienced professionals.

This comparison emphasizes the complexity of modern medical imaging methods and the requirement for highly educated and experienced radiologists to guide the procedures to obtain the necessary visualization to detect, diagnose, and guide the treatment of diseases and conditions in the human body.

Provided here is an introduction to the characteristics of medical images that affect clinical visibility and how they can be controlled by a radiologist to optimize imaging procedures.

Introduction and Overview

While radiologists might not always touch the equipment and adjust the controls radiologists do have the responsibility of selecting imaging modalities and methods and optimizing protocols for specific clinical procedures. Until a more detailed knowledge of equipment and the physics of image acquisition is acquired,

our initial approach is primarily functional, focusing on the factors selected and controlled by the radiologist. At this time an imaging system can be considered as a “black box” with controls as illustrated in Figure 2.

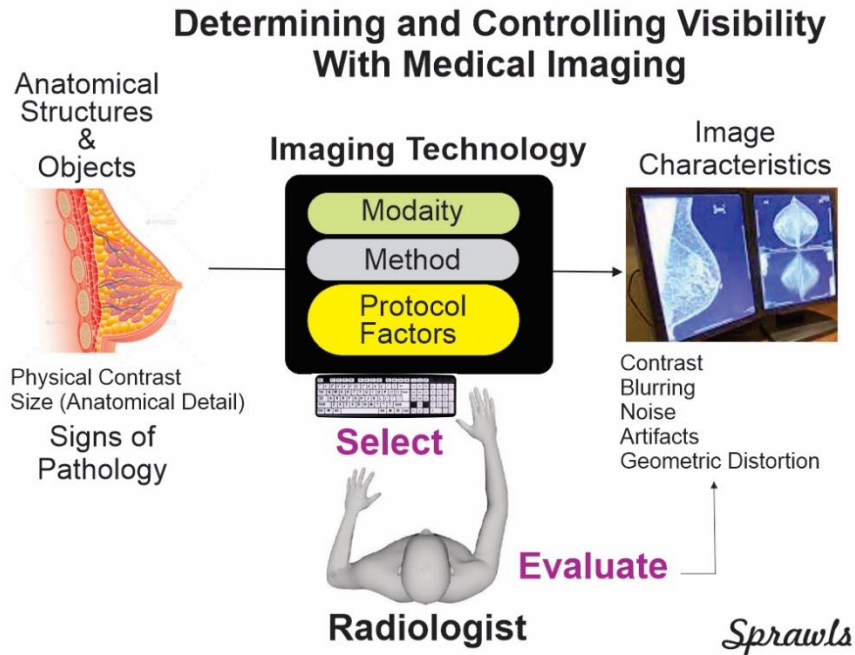


Figure 2. The factors that can be selected and controlled by a radiologist to obtain appropriate visibility in medical images.

This process requires knowledge of the *characteristics of images* that affect visibility in relationship to the characteristics of the structures, objects, and conditions within the body that are to be imaged along with the *imaging procedure factors* that determine or control the image.

Clinical Visibility

Medical imaging methods can be considered an extension and enhancement of a radiologist’s vision as illustrated in Figure 3.

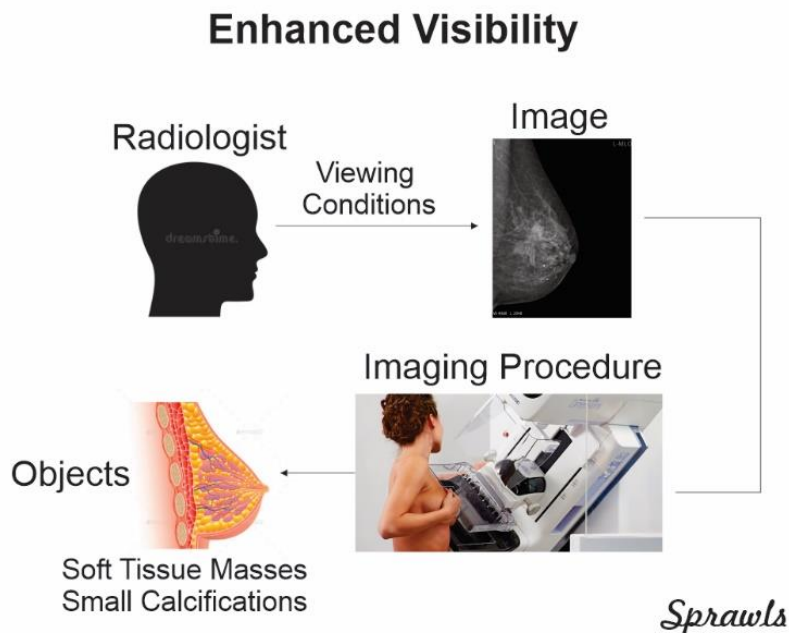


Figure 3. Medical imaging procedures enhance and extend human vision to see into a patient’s body and visualize pathological conditions--in principle comparable to a pathologist’s microscope.

Human vision has certain characteristics and limitations that are to be considered in relation to visibility. Two of these characteristics can be evaluated with the test charts/objects in Figure 4.

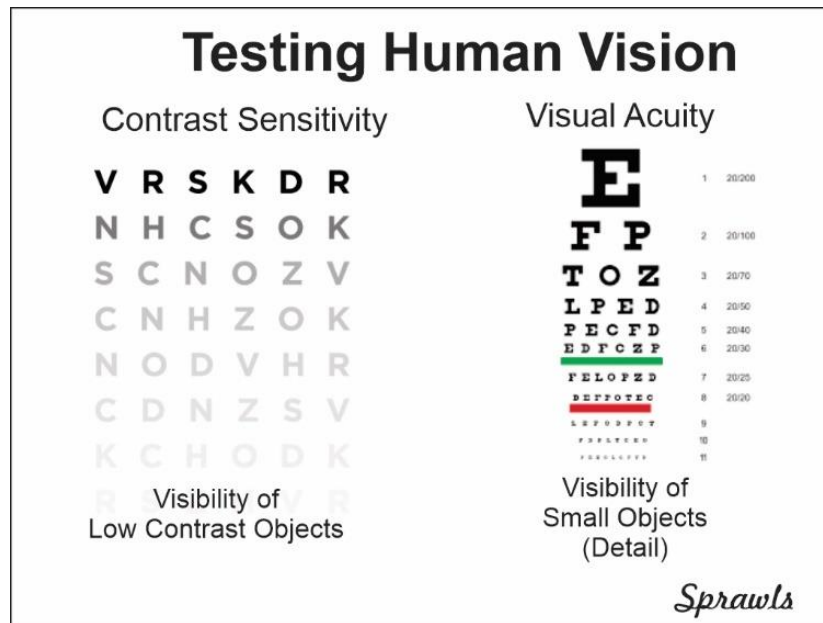


Figure 4. Two characteristics that limit visibility of objects in relation to their contrast and size.

Contrast sensitivity is the characteristic that relates visibility to the contrast of the objects being observed-- letters of the alphabet in the test chart. Visual acuity relates to ability to see small objects or detail. It is limited by blurring within the eye. These are two characteristics of human vision that extend to the medical imaging procedures.

Image Characteristics That Affect Visibility

There are five (5) specific image characteristics that have some effect on visibility. In addition to contrast sensitivity and blurring there are visual noise, artifacts, and geometric distortion. The three (contrast sensitivity, blurring, visual noise), referred to here as “the critical three”, are highly significant because they apply to all images. Artifacts and distortion are generally undesirable features but with less of a direct effect on visibility as the others.

A major issue is that the critical three often have opposing or conflicting effects on visibility and on other factors including radiation exposure to patients and image acquisition time, depending on the modality. Because of this interactivity the protocol for a specific clinical procedure should be optimized under the direction of a radiologist who can evaluate image quality and characteristics in relation to features in the body that are to be visualized and then adjust protocols as needed.

Radiologists need a knowledge and understanding of the characteristics of images in relation to the characteristics of the objects or conditions in the body that are to be visualized. This then enables the overall control of the imaging procedure to obtain the required visibility.

The necessary visibility is achieved by selecting an appropriate imaging *modality* and *method* and then selecting the combination of imaging *protocol factors*, also known as technique factors. For most clinical requirements

the modality and methods are established from experience and available in publications including the ACR Appropriate Criteria.

For an individual imaging procedure, it is the selectable and adjustable protocol or technique factors that must be considered to optimize visibility. These are the factors that establish the relationship between image characteristics and the physical characteristics of objects within the body as illustrated in Figure 5.

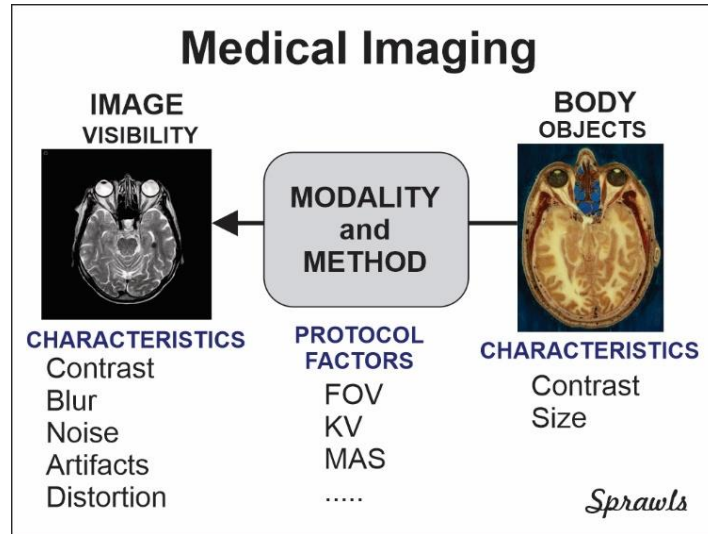


Figure 5. For a specific modality and method, for example CT and with spiral acquisition the protocol factors can be used to adjust the image characteristics for visualizing objects in the body in relation to their characteristics.

Object and Image Contrast and Procedure Contrast Sensitivity

The general meaning of the word *contrast* is the difference between or among things. It is the fundamental and major characteristic of images. Within an image, objects are visible because they have contrast and are different with respect to the surrounding area in either brightness or color. A certain level or amount of contrast is required for objects to be visible depending on viewing conditions (image brightness and room illumination), the visual acuity of the person, and the size of the object being viewed.

Objects in a body have *physical contrast* and objects in an image have *visible contrast*. The characteristic of an imaging procedure that relates contrast of objects to image contrast is *contrast sensitivity*.

Image Contrast

The *overall contrast* of an image is the range of brightness levels (or film densities) throughout the image as illustrated in Figure 6.

Image Contrast

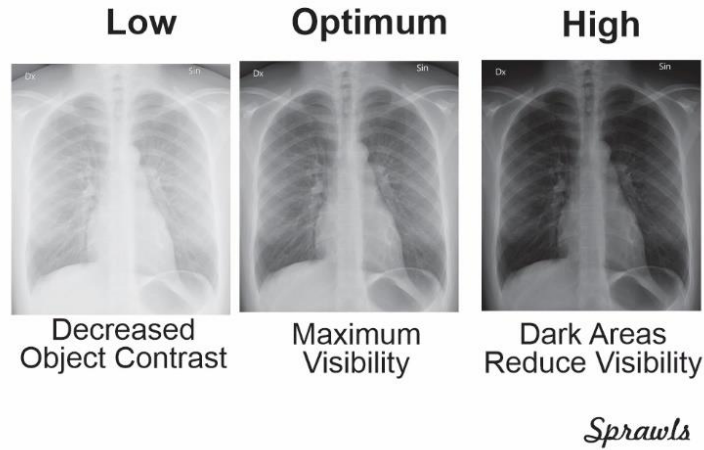


Figure 6. Different levels of image contrast and effects on visibility.

While contrast is a requirement for visibility of specific objects or structures, high overall image contrast is not always a desirable feature, as illustrated in Figure 6. In images with high overall contrast there can be areas that are either very light or dark in which the contrast and visibility of objects and structures is diminished.

Images with undesirable high contrast can result from imaging anatomical regions with a large range of either density, as in the chest, or thickness, as in the breast. The dark areas can reduce visualization by the observer. In the days of film, the contrast was reduced or completely absent in the dark areas.

This was an especially significant problem with images recorded on film. After an image is recorded on film the contrast cannot be changed or adjusted. A great advantage of images in a digital form is that the contrast of the displayed image can be adjusted by a radiologist. The window controls can be used to enhance visibility in the different anatomical regions as illustrated in Figure 7.

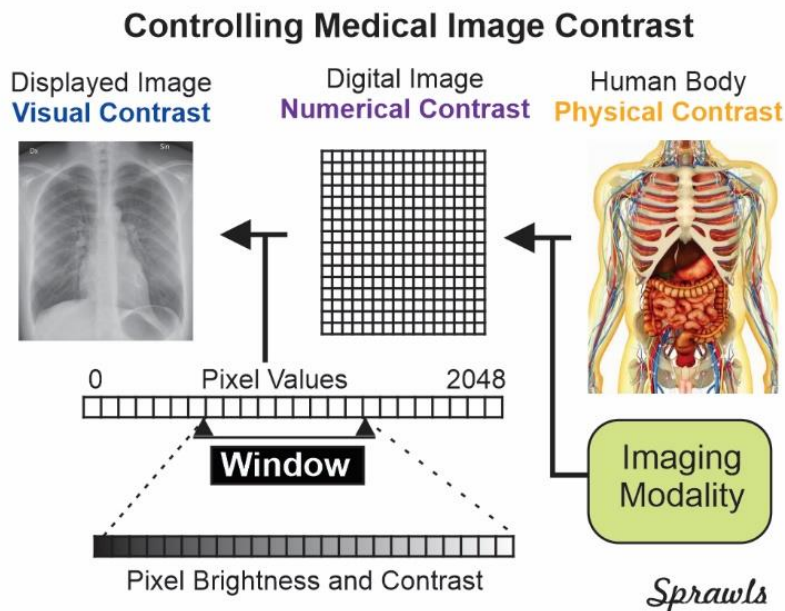


Figure 7. Controlling and optimizing contrast and visibility in a displayed image by setting the window center position and width on the pixel value scale.

A displayed image viewed by a radiologist is produced in two phases. The first being the production of a digital image by the imaging system. Each of the imaging modalities, CT, MRI, etc. produces a digital image from the physical contrast in the body. This is through a variety of physical interactions and mathematical computations that produces a numerical value for each pixel in the image that relates to physical characteristics of the corresponding tissue area in the body.

Physical Contrast Within the Body

The physical characteristics of tissue that determines pixel values and image contrast for several of the imaging modalities are identified in Figure 8.

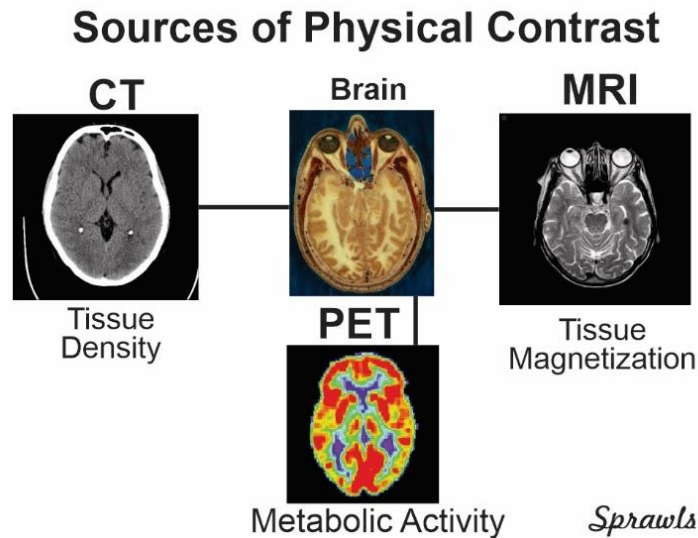


Figure 8. The types of physical contrast among tissues that form visible contrast in displayed images.

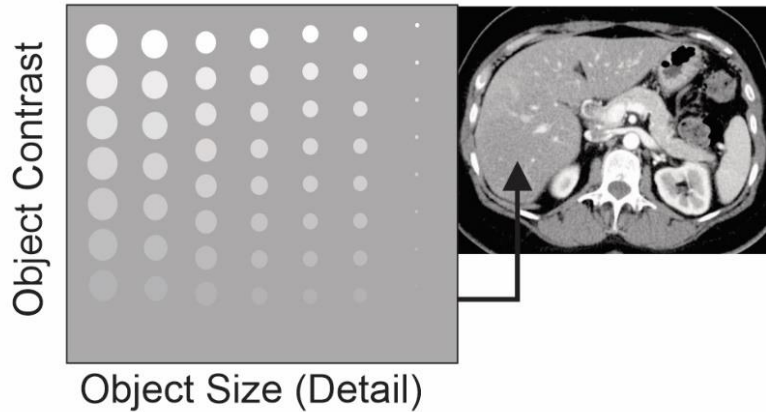
Medical imaging is a physical process. The unique feature of each of the imaging modalities is the physical characteristics of tissues that are transformed into visible images. It is when these physical characteristics are different for pathologic and normal tissues that makes the detection and diagnosis of many diseases possible.

Object Contrast

In general, it is not the overall contrast of an image that is the significant factor. It is the contrast of individual objects or anatomical structures within the image that determines diagnostic value. For an object within a body to be visible in an image it must have some form of physical contrast as described above with respect to the surrounding area.

The visibility of a specific object, micro-calcifications in a breast for example, depends on two characteristics: contrast and size.

Visibility of Objects



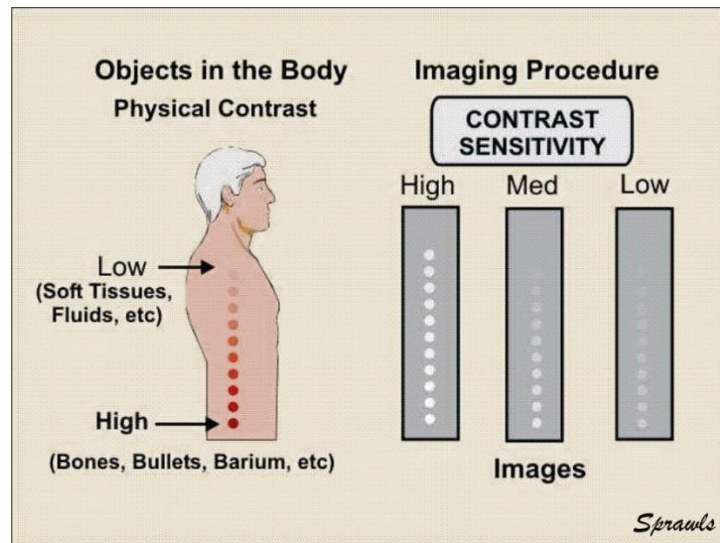
Sprawls

Figure 9. For a specific observer and viewing conditions the visibility of objects depends on their size and contrast. That is illustrated here with a Contrast – Detail Chart with objects arranged by contrast and size simulating objects within the human body.

As we can observe the large objects with high contrast are easy to see. Visibility decreases as the object contrast and size are decreased.

Procedure Contrast Sensitivity

Contrast Sensitivity is the characteristic of an *imaging process* that determines the lowest contrast objects that are visible. It is the ability of an imaging process to convert and transfer the *physical contrast* within the body to the *visible contrast* displayed in an image as illustrated in Figure 10.



Sprawls

Figure 10. The concept of Contrast Sensitivity.

Contrast Sensitivity is a predominant characteristic of each of the medical imaging modalities (Radiography, CT, MRI, etc.) that determines their clinical applications. In an imaging procedure there is no one factor that

determines and controls Contrast Sensitivity. It is determined by a series of factors beginning with how images are formed with the various modalities, selected protocol factors, image viewing conditions and adjustments, and the visual abilities of the radiologist.

A major objective in the development of new and improved imaging modalities and methods--mammography is an example--is increased Contrast Sensitivity so that more pathological conditions are visible.

Blurring and Visibility of Detail

Every imaging process, including human vision, is affected by some amount of blurring that limits the visibility of detail or small objects. For human vision this is most often described as visual acuity and is tested with charts as illustrated in Figure 4. This reduced visibility of small objects, such as letters of the alphabet, results from blurring within the eye, especially the reduced ability to focus the lens of the eye relating to ageing.

Some blurring occurs in all medical imaging procedures and is a factor that must be considered when selecting methods and adjusting protocol factors for specific clinical procedures.

It is the blurring that limits visibility of objects and structures because of their size, or visibility of detail as illustrated in Figure 11.

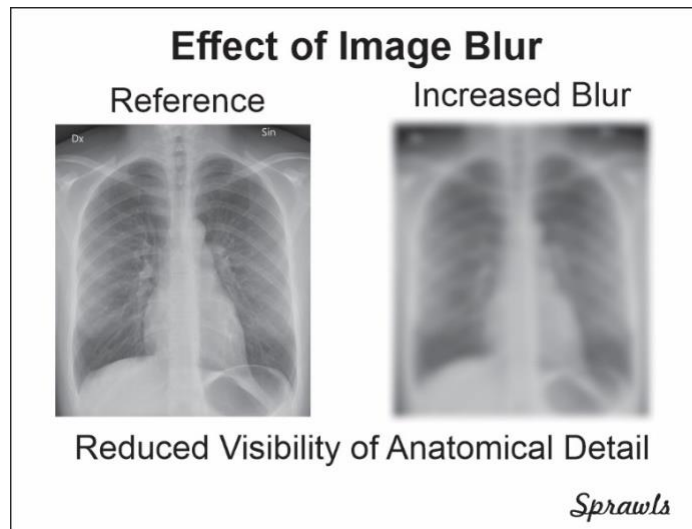


Figure 11. The effect of blurring on the visibility of detail within a clinical image.

The blur shown here is very large compared to what would be in an actual clinical image and is used to help illustrate the effect on visibility of small structures and objects.

The Blurring Process and Effect

Blurring occurs in all imaging procedures because of the physical characteristics of the various elements or components of the imaging system. Although the causes of blurring among the imaging modalities are very different, the basic process is illustrated in Figure 12.

Small Object Contrast Reduced by Blurring

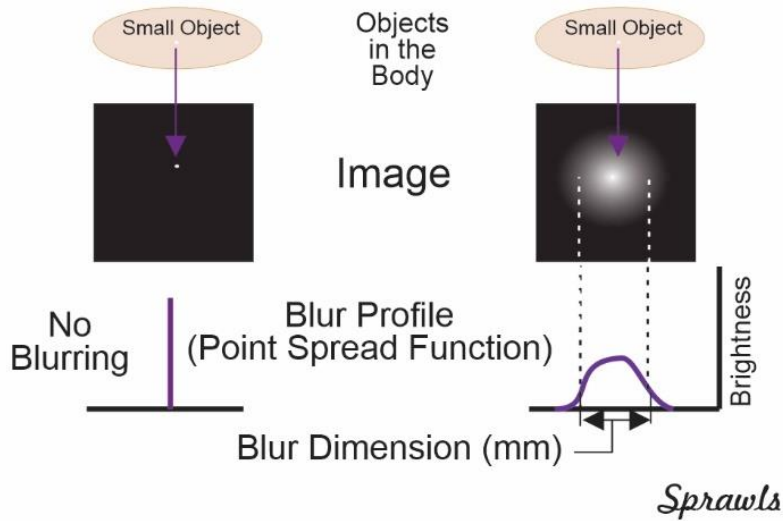


Figure 12. The effect of blurring on visibility of a small object.

If a small object in a body is imaged with no blurring (which is not possible) the image would be a small bright and highly visible point in the image as illustrated. The effect of blurring is to spread or smear the brightness over a larger area which reduces its contrast and visibility. As the blurring is increased the brightness and visibility continues to decrease and the object becomes invisible. The loss of visibility depends on the relationship between the size or dimension of the blur and the size of the object. For medical imaging methods blur values range from approximately 0.1mm for mammography to several mm for the radionuclide imaging methods.

Author's Observation: The smallest anatomical object that will be visible is often about the same size as the blur in the procedure.

That is not an established physical fact but provides some understanding of the significance of blurring in medical imaging.

Figure 12 compares an image blur with no blur with a profile of the brightness in an image. The profile has a scientific name--point spread function (PSF). The dimension of a blur in medical imaging is very small, especially in mammography and general radiography, making it difficult to measure directly. Therefore, other methods are used to evaluate are used to evaluate blurring in clinical practice.

Measuring and Evaluating Blur in Clinical Imaging

Blurring is a major and often limiting factor in medical imaging and needs to be determined and evaluated at several levels. These include the selection of imaging equipment, evaluation of equipment performance or quality control programs, and optimizing imaging procedure protocols for specific clinical examinations. The dimension of a blur in medical imaging is very small, especially in mammography and general radiography, making it difficult to measure directly. Therefore, other methods are used to evaluate. The two most often used methods are observing visibility of detail (objects of varying sizes) and limitations on a characteristic known as spatial resolution, described later. Each method is conducted by imaging test objects, often referred to as phantoms, and then evaluating the images.

Measuring Visibility of Detail

In the clinical setting test devices or phantoms with object sizes comparable to the anatomical or pathological objects of interest and the blur values for that modality are used. The test phantom used in mammography is illustrated in Figure 13.

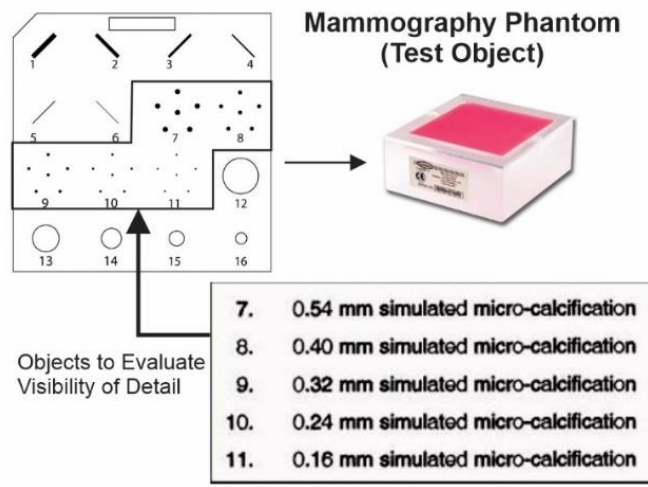


Figure 13. The phantom/test object used for the routine and often required evaluation of mammography image quality.

Small micro-calcifications are valuable signs of breast cancer, and their visibility is a critical feature in mammograms, the one with the least blurring *tolerance*.

Visibility is limited both by the contrast sensitivity and blurring of the imaging process. It is the effect of blurring and visibility of detail that is considered here. The phantom contains several groups of objects to test different characteristics of image quality. One group consists of small, simulated calcifications of varying sizes to evaluate visibility of detail as limited by the blurring. As shown, these range in size from 0.16 mm to 0.54 mm. The score is the number of groups in which the objects are visible. For some accreditation requirements, visibility of three groups, including the 0.32 mm calcifications, was required. This demonstrates that of all imaging modalities, mammography is the one with the least blurring and greatest visibility of detail.

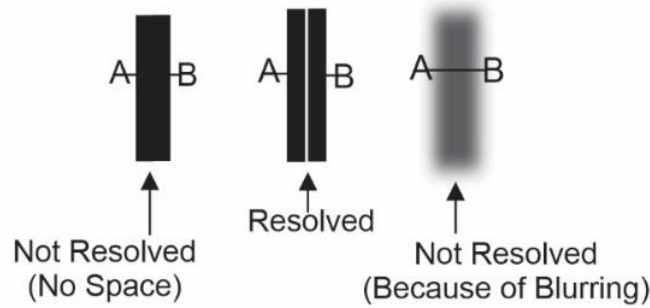
Phantoms for the other modalities contain objects with sizes comparable to the characteristic blurring for that modality.

Spatial Resolution

Spatial resolution is a characteristic of an imaging process and the resulting image that is affected by the blurring. It can be measured and is often used to evaluate the effect of blurring. While spatial resolution does not apply directly to clinical images, where visibility of detail is the significant and observable factor. It is often found in the literature, in descriptions of imaging systems, the selection of imaging equipment and is a common term used by radiologists. Spatial resolution is measured and used by physicists in evaluating imaging equipment as a quality control requirement.

One of the several meanings of “resolution” is the ability to see the difference or separation between objects as illustrated in Figure 14.

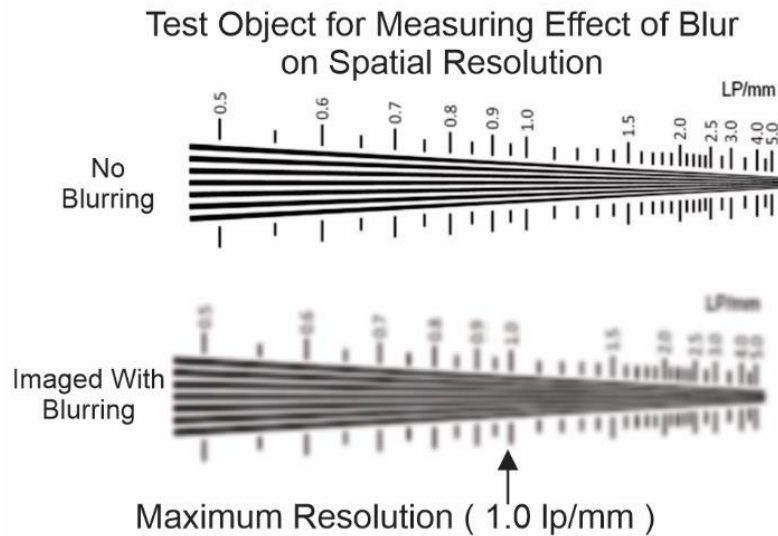
Effect of Blurring on the Visual Resolution Between Objects



Sprawls

Figure 14. The concept of spatial resolution and the effect of blurring.

Two objects (lines) are used to illustrate the effect of blurring on the visual resolution between objects in an image. Resolution is the ability to see a separation between objects. It can be limited by no space between objects or by blurring. When objects are *blurred together* in an image they cannot be seen as separate objects or resolved. This is an effect that can be easily seen in images of test devices or phantoms containing line objects with varying separation distances as illustrated in Figure 15.



Sprawls

Figure 15. A test object used to measure resolution as affected by blurring.

Test objects used to measure resolution capability and the imaging process consist of line objects separated by spaces. A line and the adjacent space form a line pair (LP) and the size is specified as the number of line pairs in a unit of length, LP/mm is shown in Figure 15. This is the quantity of *spatial frequency* that can be used to describe the performance of an imaging process with respect to blurring. Small objects are associated with high spatial frequencies, LP/mm. In the spatial frequency domain, blurring reduces visibility of the high frequencies (small objects). As blurring is increased the maximum frequency (LP/mm) that is visible is reduced. For the blurred image in Figure 11 this is 1.0 LP/mm.

The maximum frequency at which there is visibility (1.0 LP/mm) does not completely describe the effect of blurring. Blurring reduces the visible contrast of the lower frequency and larger objects progressively up to the point of invisibility as illustrated in Figure 16.

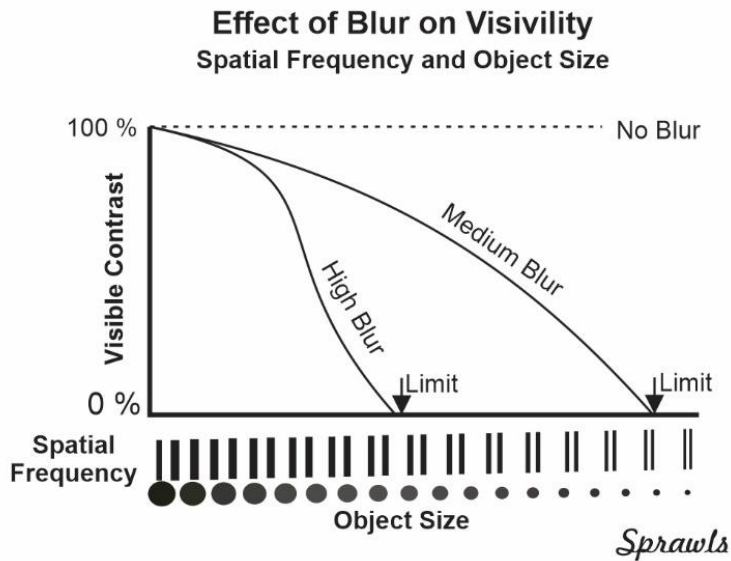


Figure 16. Measuring the effect of image blurring in the spatial frequency domain,

We don't have line pairs in the body but we do have small anatomical structures, like calcifications, that we need to see. So why are spatial frequency and line pairs used to measure the effects of blurring in medical images? The reason is ease of testing. With an appropriate test object, like that shown in Figure 15, an image can be created which shows which line pairs are resolved. This method is used with quality control procedures and evaluating equipment performance for accreditation and regulatory requirements which have required limits. The modulation transfer function (MTF) is another characteristic of medical imaging systems used to express the effect of blur in the spatial frequency domain in the units of cycles/mm. It is similar in principle to the graph shown in Figure 16. It is not used to evaluate blurring in quality control procedures in clinics but in research laboratories and sometimes to describe commercial products for medical imaging.

Blurring With the Imaging Modalities and Methods

Some blurring is inherent in *every imaging procedure* related to how the images are created. This is generally related to the design limitations of the technology which have advanced over the years for improved image quality.

The blurring and visibility of detail characteristic of each imaging method is a significant factor in determining the clinical procedures that the method can be used for. This is generally determined by the smallest objects or structures that must be visible in an image for diagnostic or therapeutic purposes. This can range from micro-calcifications in mammography to relatively large areas of radioactivity in the radionuclide imaging methods.

Figure 17. provides an overview of the modalities with respect to image blurring and visibility of detail.

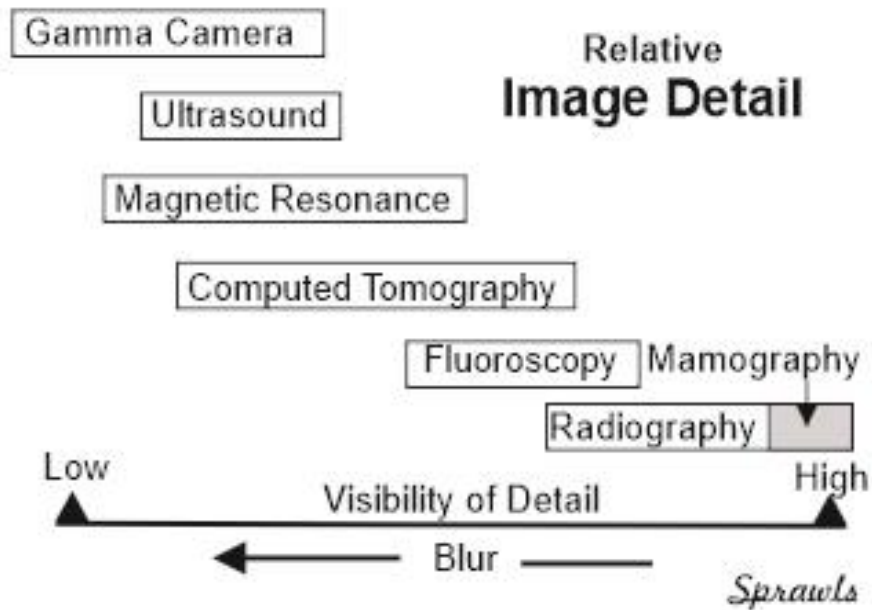


Figure 17. The relative blurring and visibility of detail for the imaging modalities.

For each imaging modality there is a range of blur values and visibility of detail as shown. Some of these are related to the design of the equipment and ongoing developments over the years. However, the highly significant factors that must be considered for specific clinical procedures are the adjustable protocol or technique factors that affect blur that must be selected.

With each of the medical imaging methods there are several sources of blurring as illustrated for one in Figure 18.

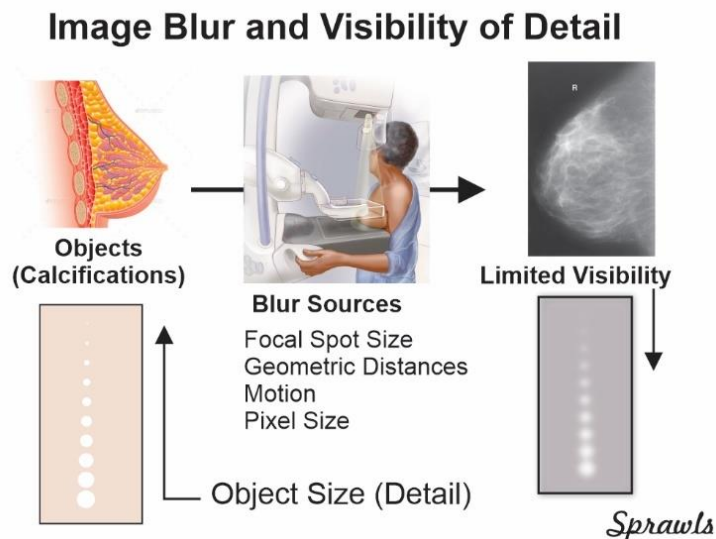


Figure 18. The visibility of small objects within the body limited by blurring that occurs during the imaging procedure.

Mammography is used as an example here, but the principle applies to all medical imaging procedures. With each modality there are several physical conditions in the image forming process that produce and control the

blur in the image. Some of these can be adjusted for a specific clinical procedure. For mammography these include focal spot size, geometric distances, and image formats as described later.

Why Not Minimum Blur and Maximum Visibility of Detail?

If the blurring is generally adjustable as described here, why not go for the best visibility of detail in all procedures? This is a major factor that must be considered in setting up the protocol or technique for each clinical procedure. The need for visibility of detail must be balanced or optimized with other requirements including controlling radiation dose and visual noise as described later.

Digital Image Structure and Blurring

The structure of the *digital image* used in the modalities is a major factor affecting three of the image characteristics--blur, visual noise, and contrast. Several of the factors relating to the structure of a digital image are variable, either by the design of the equipment or adjustable protocol factors and are illustrated in Figure 19.

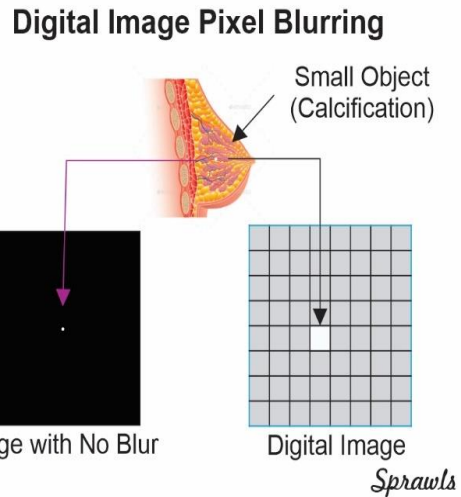
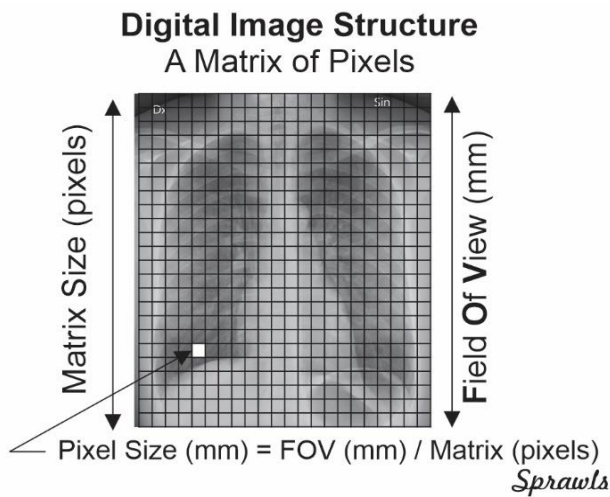


Figure 19. Image pixel size determined by the ratio of field of view (FOV) to matrix size.

Figure 20. Blurring produced by pixel size.

A digital image is a matrix of pixels (picture elements) in which the size of the pixel is a major factor in determining both *visibility of detail* and *visual noise*, to be discussed later. As shown, pixel size is the ratio of the FOV to the matrix size in each direction. In some modalities, especially radiography, matrix size is an equipment design characteristic and not changeable by the clinical staff. With other modalities including CT, and MRI there are design limits, but it is one of the adjustable protocol factors in setting up a procedure. Our interest currently is on the effects of pixel size on blurring and visibility of detail.

A Pixel is a Blur

In every imaging method that produces images in a digital format an additional source of blurring is added. The significance generally is the relationship of the digital pixel blurring to the blurring by other factors in the imaging process such as x-ray focal spot sizes, CT detectors, etc. The blurring effect of digitizing an image is illustrated in Figure 20.

The pixel is the smallest area than can be displayed in a digitized image. The image of a small object is spread out or blurred to the size of the pixel. Adjusting pixel size by selecting FOV and Matrix values for an imaging procedure is used to control the blurring and visibility of detail.

Tomographic Imaging and 3D Blurring

With the tomographic imaging modalities (CT, MRI, SPECT, etc.) there is an added blur dimension, the thickness of the slice. In the imaging process the slice of tissue is divided into voxels as illustrated in Figure 21.

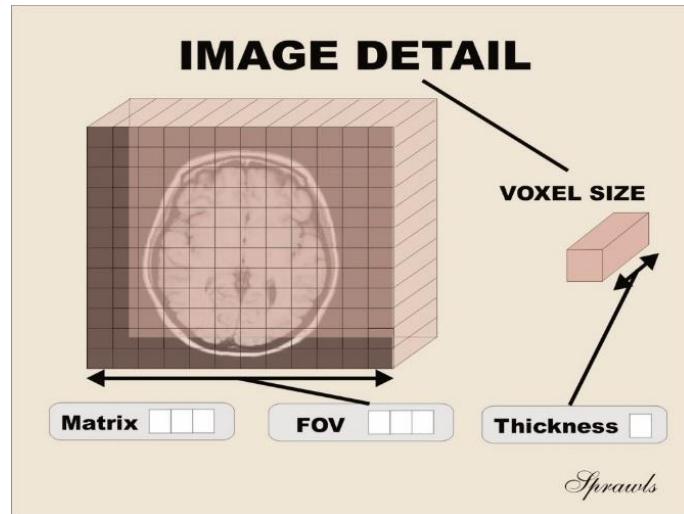


Figure 21. Voxel size is one of the sources of blurring and can be controlled with the combination of three protocol factors.

Composite Blur in Medical Imaging Procedures

In each of the imaging modalities there are multiple sources of blur relating to the process for producing images. These are generally related to the design of the equipment for a specific modality and that establishes the range and limits of blurring and visibility of detail as illustrated in Figure 17. The total blur in an image is a composite of the individual blur sources. It is not a direct mathematical addition but a more complex blending relationship that will not be covered here. Each source of blur contributes to the total image blur, but the larger sources generally predominate.

This is significant because each section of the human body is being viewed through a series of blurring processes. Many of the sources of blurring are adjustable when setting up the protocol for each imaging procedure as illustrated in Figure 22.

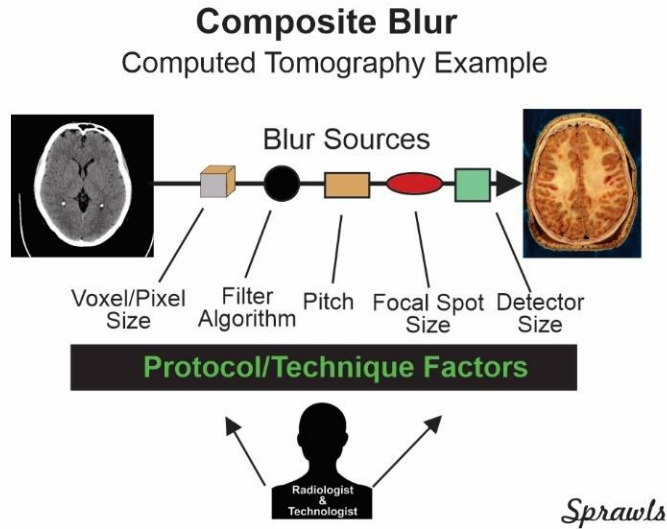


Figure 22. The composite of multiple sources of blur that can be adjusted by the imaging staff.

Summary and Overview of Image Blurring

Medical imaging facilities have established protocols for each type of procedure. These are generally specified by a radiologist and set up and adjusted on the equipment by a technologist for each patient examination. With knowledge of each of the blur sources the staff will have a better understanding of each protocol and how to adjust as needed.

While there might be a desire to change some of the factors to reduce blurring there are often tradeoffs to consider. Changing a factor to reduce blurring can have an undesirable effect of increasing some other characteristic such as image acquisition time, x-ray tube heating, and especially visual noise as will be discussed later. Especially when there are tradeoffs, there is limited value in reducing one of the factors much below the combined value of the others.

An optimized imaging protocol for a specific procedure is one in which the factors are balanced with respect to the tradeoffs and in relation to each other.

Figure 23 provides an overview of the factors contributing to the blurring and limits on visibility in medical Images.

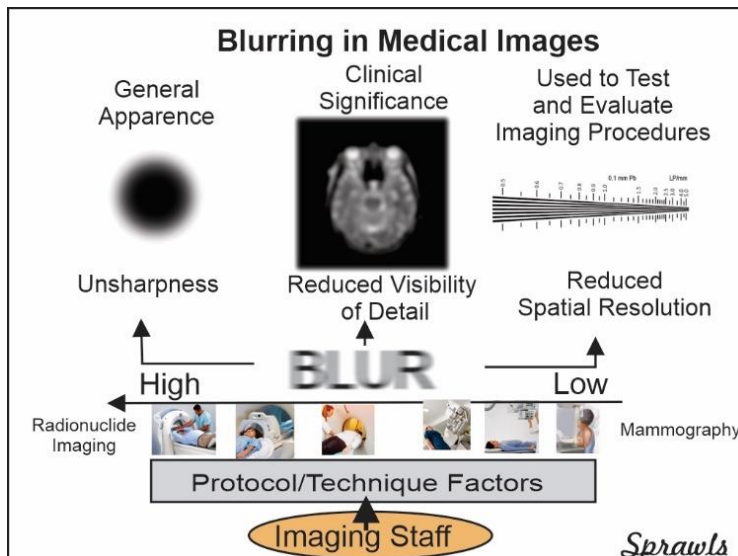


Figure 23. A summary and overview of blurring in medical images.

There is some blurring in all images that produces three observable effects. A common term is image unsharpness. It can be measured with test objects in terms of spatial resolution. The clinical significance is the effect on anatomical detail or small objects of medical interest in the body. Blurring is produced during the formation of images with each of the medical imaging modalities and depends on the physical dimensions of components (focal spots, detectors, collimators, pixels, etc.). Blurring is a major characteristic of each modality and determines the types of clinical procedures that can be performed, generally relating to the smallest anatomical structures or objects within a body that must be visible.

With each modality there are several sources of blur, and some can be adjusted for specific procedures. It is the values of these factors that form the protocol for a specific procedure.

Visual Noise

Visual noise, like audio noise is generally an undesirable characteristic that interferes with and distracts from the intended content of the image or sound. In images it is a random variation in brightness or color that is super-imposed on or added to the image as illustrated in Figure 24.

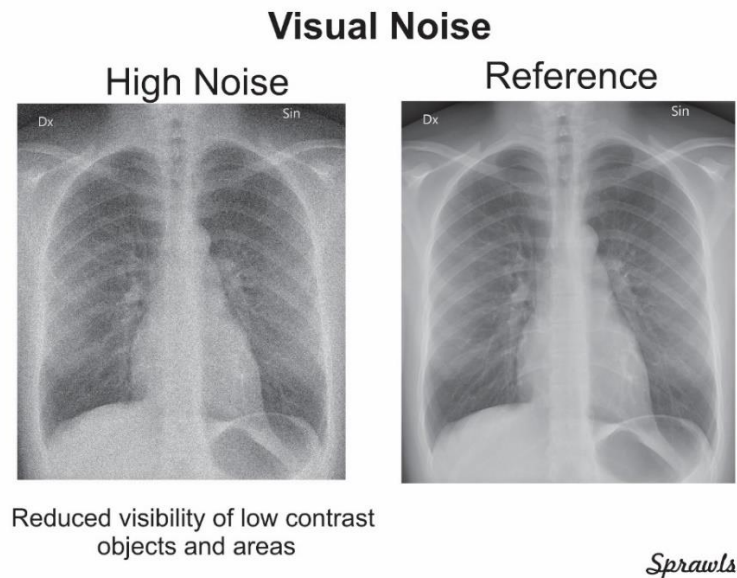


Figure 24. The general appearance of visual noise in a radiograph.

Some level or amount of noise is present in most images and especially medical images. It is a major characteristic that must be considered by radiologists in selecting imaging methods and protocols for specific procedures. It is usually adjustable and can be set for each procedure. This requires considerable knowledge of the source of noise, its relationship to visibility of anatomical structures and signs of pathology, and especially the compromises with other factors including radiation exposure to patients, image detail and time to acquire

The Effect of Noise on the Visibility of Objects

The effect of noise on the visibility of objects is illustrated in Figure 25.

Effect of Noise on Object Visibility

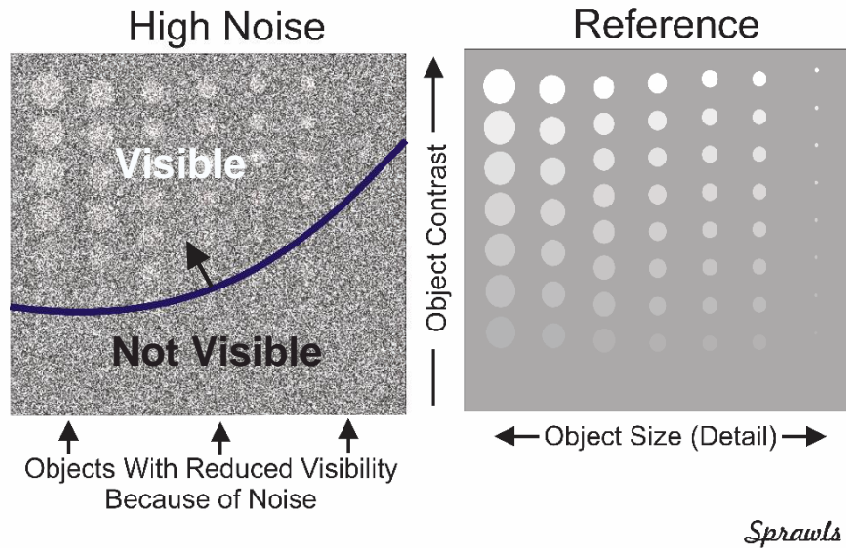


Figure 25. Visibility of objects reduced by noise relating to their characteristics. The amount of noise establishes a boundary between the visible and invisible.

As described previously, the two major characteristics of objects within the human body that affect their visibility are size (detail) and their contrast with respect to the surrounding area or background. These are the characteristics represented in a Contrast-Detail Diagram as shown in Figure 25.

A specific level of noise establishes a boundary between visible and invisible objects in relation to their contrast. This boundary moves with the level of noise. Noise reduces the visibility of objects in relation to contrast whereas blurring reduces visibility in relation to object size (detail). These are two very different effects that must be considered. In many cases, small objects such as micro-calcifications in the breast also have low contrast and their visibility is reduced by both noise and blurring.

The major source of noise depends on the imaging modality. For x-ray and radionuclide or nuclear medicine imaging it is the statistically random nature of radiation photon interactions. With MRI it is the random production of undesirable radio frequency (RF) radiation within the human body. Fortunately, these can be controlled and compensated for when setting up imaging procedures.

Visual Noise in Radiography and Mammography

In radiography and mammography, images are formed by projecting an x-ray beam through the body and producing shadows of the anatomical structures relating to their attenuation of the x-radiation. In this process two overlying images are formed. One is of the anatomy and the other is an image of the x-ray beam itself as illustrated in Figure 26.

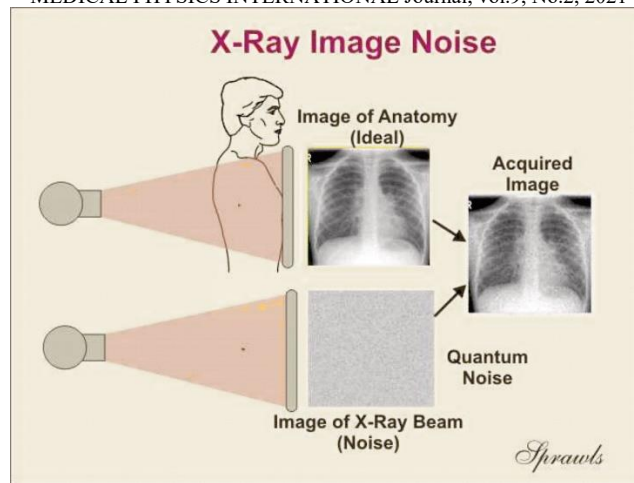


Figure 26. The image of the x-ray beam is the source of visual noise in radiographs.

An x-ray beam can be considered as a shower of many individual units of energy—photons—as illustrated in Figure 27.

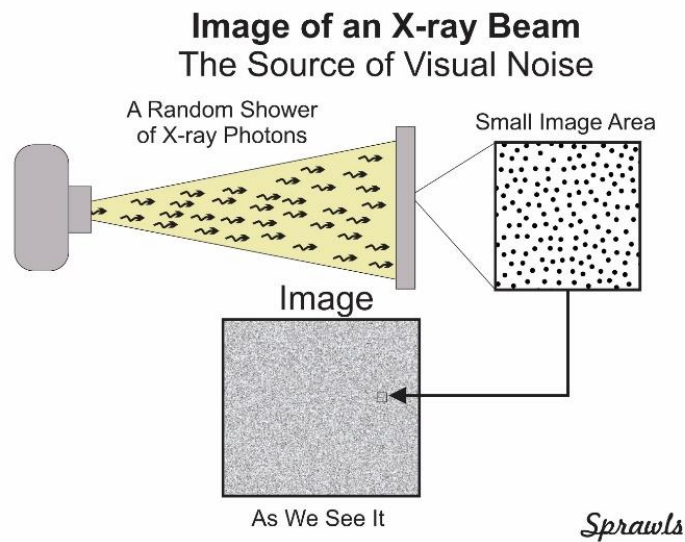


Figure 27. The random distribution of x-ray photons to the image receptor that appears in the image as visual noise.

X-radiation is a form of so-called electromagnetic radiation that is in the form of small units or quanta of energy, called photons. They have no mass, just energy, and move at the speed of light which is also in the electromagnetic spectrum. It is the energy in each individual photon that determines its type (x-ray, light, etc.) and how it interacts with matter like human tissue to form images.

The energy of photons is expressed in the units of electron-volts (eV). X-ray photons have energies of thousands of electron-volts (keV). An x-ray beam for general radiography generally contains photons with a spectrum of energies ranging from approximately 20 keV up to a maximum energy determined by the setting of the KV technique factor for each procedure. Mammography is performed with a spectrum with photons in the general range of 20 keV to 28 keV. The energy spectrum of the photons is a major factor in controlling image contrast in relationship to radiation exposure to patients.

In radiography, noise is the naturally occurring random variation in the number of x-ray photons among the pixels in an image. As illustrated in Figure 19 this follows an established statistical distribution. The so-called Standard Distribution (SD) is a characteristic of the distribution that can be used as a measure or quantification of the amount of noise. It is a factor that expresses the width or range of the distribution. Specifically, it is the range in which 68% of the pixel values fall. It is a measurement of the noise. The ability to control noise is through the relationship of the SD (the level of noise) to the number of x-ray photons per pixel captured in the image receptor.

It is the noise expressed as a percentage of the mean or average number of photons per pixel that is significant. Consider this example.

$$100 \text{ photons/pixel, } SD = \sqrt{100} = 10, \text{ 10\% Noise}$$

$$1000 \text{ photons/pixel, } SD = \sqrt{1000} = 33, \text{ 3.3\% Noise}$$

With noise being a major and limiting image characteristic with respect to visibility, it must be considered in all phases of the imaging process, from the design of equipment to the selection of methods and adjustments of protocols for specific clinical procedures.

The significance is this, The level of noise in an image can be controlled by radiologists, but it requires knowledge of the factors affecting the noise and the effects of these factors on other aspects of the imaging process especially radiation exposure to patients.

In radiography and mammography, it is the characteristics of the image receptor that determine the noise level as illustrated in Figure 30.

Effect of Image Receptor Characteristics on Noise and Patient Exposure

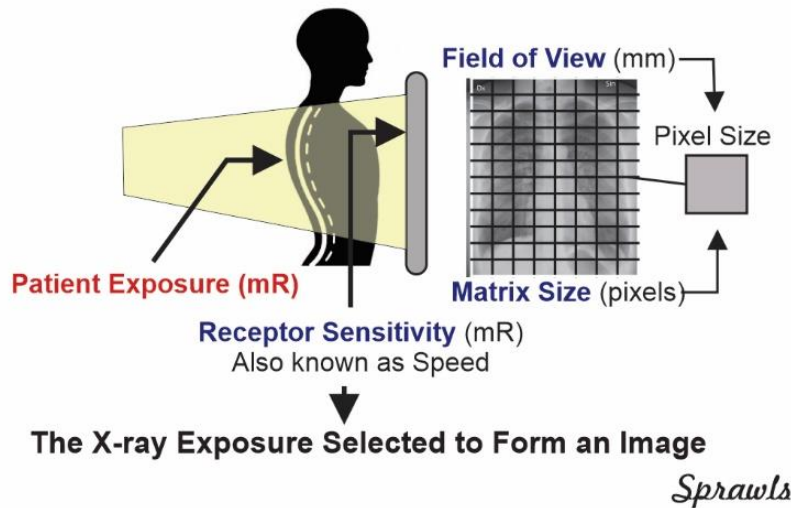


Figure 30. The role of the image receptor on determining visual noise.

The function of the image receptor is to intercept the invisible x-ray beam image from the patient’s body and convert it to a form that can result in a visible image. Throughout history there have been two major types-- film-screen and digital. The film-screen receptors, used for well over a century, recorded the image on film using fluorescent intensifying screens to give the receptor greater sensitivity or speed. The transition to digital

receptors and digital radiography provided many advantages, including more control on the imaging procedure and viewing by radiologists.

With the film-screen receptors virtually all image characteristics (contrast, detail, noise) and sensitivity or required exposure were established by the design of the receptor. In any imaging setting, there is a choice of film-screen receptor types for specific procedures, such as chest or mammography, but not the ability for other adjustments.

Digital radiography provides the radiologist with more control, including the visual noise and patient exposure considered here. *The critical and controllable factor is the average number of x-ray photons captured in each pixel by the receptor.* This is, in turn, determined by two factors: pixel size and the x-ray exposure to the receptor.

In radiography and mammography, pixel size is a design characteristic of the receptors and cannot be changed in the clinic. It is the ratio of the physical field of view (FOV) and the image matrix size (the number of pixels in each direction).

. It is the requirement for visibility of detail (pixel blurring) that is considered in the design of receptors as illustrated here.

	FOV (cm)	Matrix	Pixel Size
Chest	36 x 43	2140 x 1760	0.2 mm
Mammography	24 x 31	2394 x 3062	0.1 mm

The receptor FOV is determined by the anatomical area to be viewed and then a matrix size is selected to provide the necessary visibility of detail. Recalling from Figure 20, a pixel is a blur that combines with the other sources of blurring in a procedure that determines the visibility of detail. The pixel size in mammography is small to provide visualization of the small calcifications.

Here is the great compromise that applies to all imaging methods that produce digital images. Reducing pixel size to increase visibility of detail has the adverse effect of increasing image noise because the smaller pixels capture fewer photons.

The factor that can be selected by radiologists to set the level of image noise is the x-ray exposure used in each procedure. A characteristic of radiographic receptors is the exposure required to form an image. This is generally known as the exposure sensitivity or speed of the receptor. The term “speed” was used extensively for the film-screen receptors where it was picked up from the classification of general photography films. A “fast” film or receptor needed less exposure to form an image. Looking back in time, film-screen receptors were labeled or known by the speed numbers, 100, 200, 400, etc. The lower speed receptors provided higher quality, less blurring and noise, but required higher exposures to the patients. A radiologist could select an appropriate receptor for specific procedures that would provide the necessary image quality with the lowest possible exposure to the patient. The speed of the receptor determined the required exposure which had to be set very precisely. Variation from that specific exposure resulted in either under- or over-exposed films with low image quality and reduced visibility. This was a significant problem with film radiography often requiring repeated examinations to “get it correct.”

A major advantage of digital radiography compared to images on film is a large range of exposure to the receptor that will produce visible images. This characteristic is the *dynamic range* or *exposure latitude* of the

receptor. While this is a valuable feature that reduces exposure errors that result in loss of visible contrast, it introduces another image quality issue that must be considered by radiologists.

That is the variation in image noise and radiation exposure to the patient. These two factors must be considered and balanced for each procedure.

Digital radiographic systems are generally programmed to deliver specific exposures to the receptor, determined by the type of procedure or anatomical region being imaged. This is a form of automatic exposure control (AEC) so that *receptor exposure* is not an independent factor that must be set by the technologist for each procedure. However, the programmed exposure levels for specific procedures can be adjusted as needed.

Radiologists can monitor the exposure used for each image and use that as a guide for balancing image noise and radiation exposure to the patient. All digital radiographic systems calculate a quantity expressing the exposure to the receptor and it is available or displayed along with the image. This is the *exposure index* (EI) with a variety of names and methods for calculating it used by the various manufacturers. The example used here in Figure 31 is the receptor sensitivity or “S” number. Higher numbers represent a higher receptor sensitivity or speed and lower exposure. The deviation index (DI) is a related quantity indicating the relationship of the actual exposure for a procedure to what has been established as an appropriate or target value.

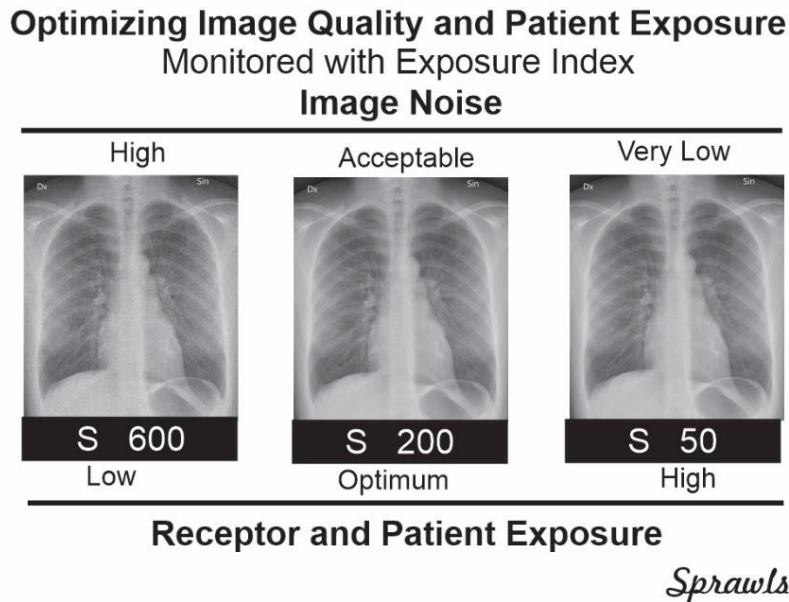


Figure 31. The Exposure Index (EI), in this example expressed as the “S” factor can be used by radiologists to monitor and optimize image quality and exposure to patients.

A first step is determining how the Exposure Index is expressed in the digital radiography systems in one’s clinic--then observing values, perhaps discussing with colleagues, and relating values to image quality.

Pixel and Voxel Size in Medical Imaging

The modern medical imaging procedures using digital technology divide the body into small volume elements (voxels) as illustrated in Figure 32.

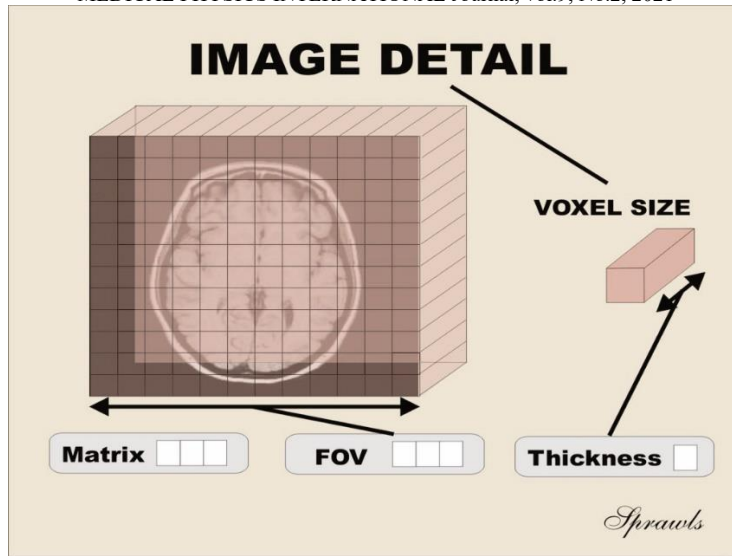


Figure 32. The dividing of the human body into voxels (samples) in the tomographic modalities, CT, MRI, PET, etc.

The imaging process creates numerical values for each voxel relating to the physical characteristics of the tissue: density in CT, magnetization in MRI, radioactivity in the radionuclide imaging procedures. These numerical values then translate into brightness or colors for the corresponding pixels in the image.

The sizes of the voxels and corresponding pixels are critical factors determining visibility, especially as affected by blurring and visual noise, and they have an indirect effect on other factors including radiation exposure to patients (radiography, mammography, and CT) and the time to acquire images (MRI and radionuclide imaging). Voxel and pixel sizes for specific procedures are determined by the combination of factors illustrated in Figure 32. These factors are design characteristics and might vary with each of the modalities (mammography, CT, MRI, etc.) but are often adjustable in setting up protocols for specific procedures.

Optimizing Imaging Protocols

For reference the illustration from Figure 2 is repeated here as Figure 34.

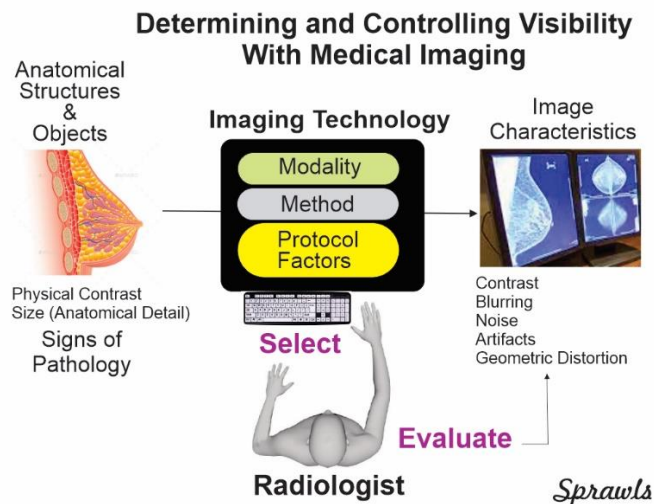


Figure 34. Actions by radiologists to control and optimize visibility for specific clinical requirements.

Optimizing is a critical requirement for an imaging procedure because of conflicts between and among several of the image characteristics and other procedure factors. These include factors associated with the formation of images (KV and MAS, for x-ray, TR, and TE for MRI, etc.) along with voxel/pixel size considered here and illustrated in Figure 35.

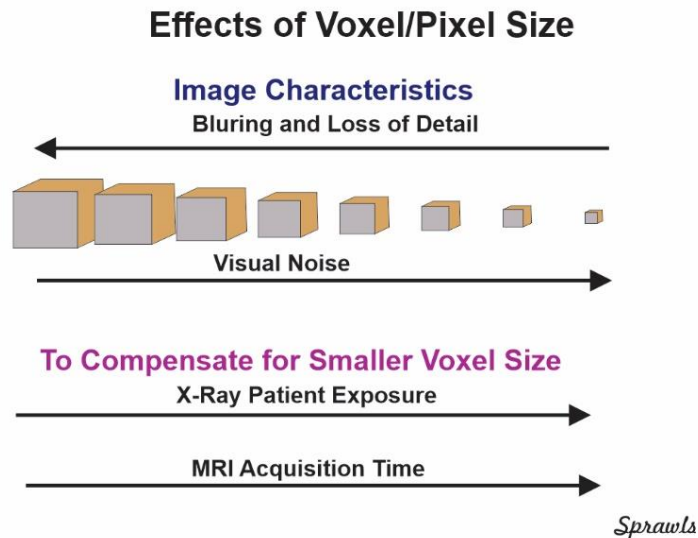


Figure 35. The multiple effects of selected voxel size on visibility and other procedure considerations.

For virtually all the imaging methods the selection of voxel and pixel size is perhaps the most critical factor to be considered in setting up an optimized procedure that provides the necessary clinical visibility in relation to other procedure considerations.

As described previously, a voxel is a blur. In the imaging process it is represented by one numerical value that generally is an average of the physical characteristics (density, radioactivity, etc.) within the voxel all “blurred” together. In all imaging procedures the voxels and pixels are two of the several sources of blurring as illustrated in Figure 22.

An obvious action in setting up an imaging procedure protocol would be to reduce voxel/pixel size to improve visibility of detail in an image. While that is desirable other factors must be considered. As voxel size is just one of the several sources of blurring, as illustrated in Figure 22, there is little to gain with voxel sizes smaller than the other sources of blurring in an imaging system that are related to the design of the equipment this varies among the imaging modalities as illustrated in Figure 8. This ranges from relatively large blurring with the radionuclide imaging methods to very low blurring in mammography.

In selecting an optimum voxel/pixel size there are other factors to consider as illustrated in Figure 35. Reducing voxel/pixel increases visual noise. In x-ray methods (radiography, mammography, and CT) the reduced number of photon interactions in each voxel increases the statistical variation among voxels and the resulting visual noise as described in Figure 19. For the radionuclide/nuclear medicine procedures it is the number of gamma protons produced in each voxel. In MRI the RF signal intensity that counteracts the noise is proportional to voxel size.

In selecting an optimum voxel/pixel size the balance between blurring (visibility of detail) and visual noise is a major consideration. Additional considerations are the increase in radiation exposure to control noise to an acceptable level and potential increase in image acquisition times with some methods, especially MRI.

Image Artifacts

In this context, artifacts are undesirable visual displays, sometimes referred to as “ghosts” that appear in images but are not representations of actual anatomical objects or functions. They are usually unique for each of the modalities and related to the characteristics of the equipment and the imaging process. In virtually all modalities patient motion during the imaging procedure, and foreign objects, especially metal ones, are significant sources of artifacts. With some modalities, especially MRI, there are functions within the imaging process that can be used to reduce artifacts.

Geometric Distortion

Geometric distortion is when an image is not an accurate geometric (size, shape, depth, and orientation) representation of an anatomical structure or region. Unless an artifact, like bright streaks or shadows, covers the image of anatomical objects of interest they do not reduce general visibility.

There is inherent distortion in all radiography and mammography procedures because of the varying geometric magnification as the x-ray beam is projected through the patient’s body. This needs to be recognized when evaluating object locations and sizes as displayed in an image.

Conclusion

Maximum visual clinical information that can be obtained using the complexity modern medical imaging methods requires guidance by radiologists with knowledge and experience in matching image characteristics for the required visibility of the structures, objects, and conditions in the human body. This capability will be developed over years of education and experience but can begin by applying the principles described here in ongoing clinical activities.

Radiologist & Residents



Airline Captain



Modern and Complex Technology

Sprawls

Curriculum Guide

Class and Conferences for Radiology Residents

On the Topic of

Understanding and Optimizing Visibility in Medical Imaging Procedures

Image Characteristics and Controlling Factors

Objective: Provide Radiology Residents with an opportunity to learn and develop knowledge of the physical characteristic of medical images and controlling factors associated with imaging procedures.

Method: Class and Conference presentations and discussions covering the topics below and augmented with clinical images illustrating characteristics that affect visibility. Review some typical protocols relating factors to image characteristics.

Image Characteristics

Identify and illustrate the five image characteristics.

Contrast

Blurring

Visual Noise

Artifacts

Geometric Distortion

Contrast

Sources of Physical Contrast in the Human Body

Image Contrast

Object Contrast Within Images

Procedure Contrast Sensitivity

Blurring and Visibility of Detail

Example Blurred Images

Effect of Blurring Related to Object Siz

Visibility of Detail

Measuring and Evaluating Blur

Blur Dimensions (Not Easy)

Test Objects/Phantoms (mammography example)

Spatial Resolution

Concept and Significance of Composite Blur

Digital Blurring (Voxels and Pixels)

Comparing the Modalities

Visual Noise

Demonstrate with Clinical Images
Effect of Noise on Visibility of Objects
Source of Noise in X-Ray Images
Measuring and Quantifying Noise (Standard Deviation)
Relation of Noise to Radiation Exposure
Effect of Voxel/Pixel Size on Noise

Optimizing Imaging Procedures

What is Optimization
Factors to Consider
Effects of Voxel Size

Image Artifacts

Show examples and Discuss Sources

Geometric Distortion

Show examples and Discuss Sources

Text: Sprawls P. Understanding and Optimizing Visibility in Medical Imaging Procedures.
Medical Physics International. December 2021.Addendum

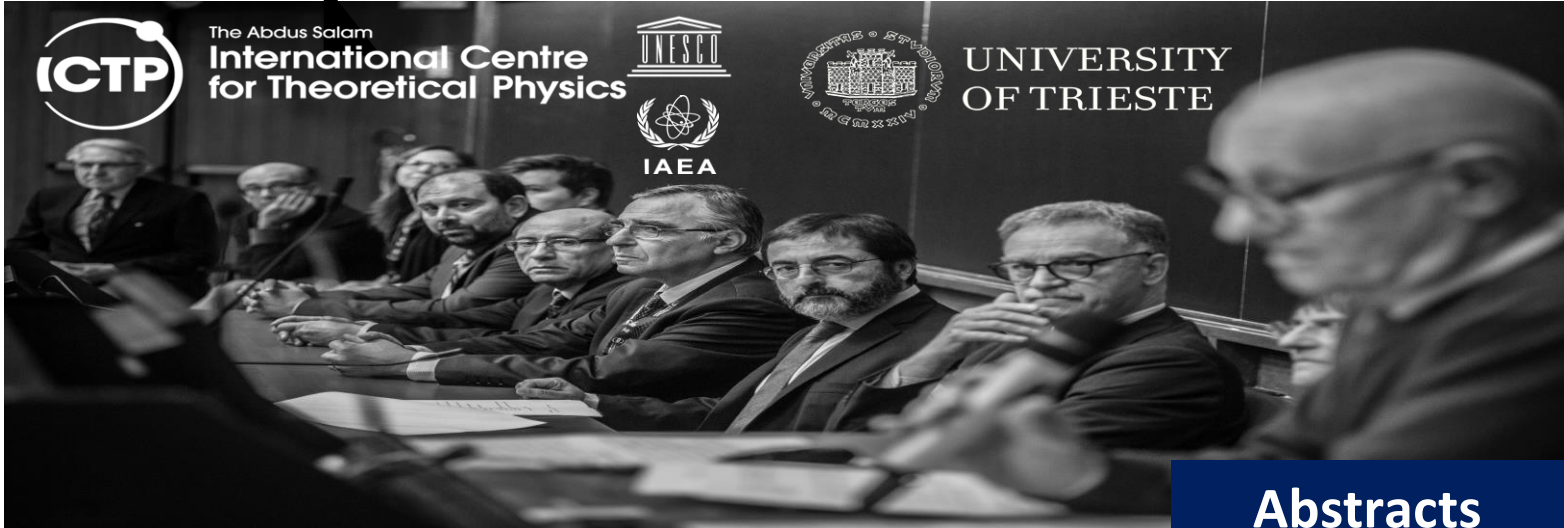
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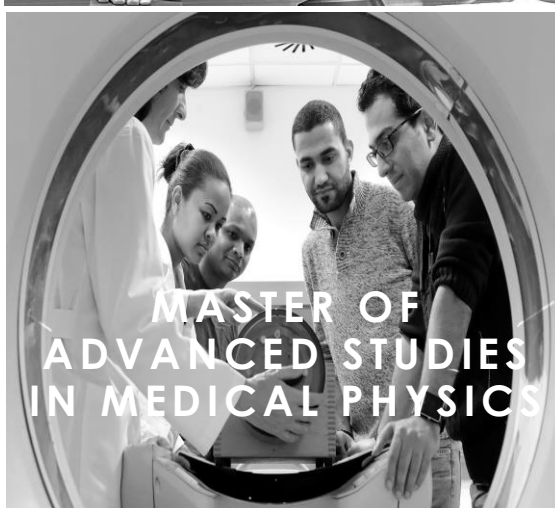
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Dosimetric Study of Fetal Dose during External Beam Radiotherapy using OSLD

Prospective/Objective: Fetal doses must be carefully evaluated if radiotherapy is used during pregnancy, as the fetus is extremely sensitive to radiation and fetal doses as low as 100 mGy can have serious effects. As fetal dose is outside the treatment field, special considerations must be considered. The objective of this study is to calibrate an OSL dosimetric system to measure out of field doses for brain and breast external beam radiotherapy plans, and compare the results to dose calculations from the Eclipse Acuros algorithm.

Materials and methods: A batch of Landauer nanoDots OSLD was calibrated in a 6 MV field on a Varian TrueBeam linac, both in in-field and out-of-field locations. The reader used was the Landauer microStar ii. OSLDs were irradiated in a phantom made of solid water slabs and Rando Alderson Phantom slabs, with a high enough number of MU to achieve sufficient signal even in out-of-field positions. A custom PMMA grid was built to precisely position the OSLDs and avoid air gaps. A Farmer chamber was used as the reference detector for calibration, due to its small energy dependence. A batch of Gafchromic EBT3 film was also calibrated in the 6 MV energy in-field. A 3DCRT breast plan and 3DCRT and VMAT brain plans were calculated on the Eclipse TPS with the Acuros algorithm, and compared to measurements. PMMA grids containing OSL detectors and EBT3 film were placed on the phantom and a total target dose of 60 Gy was irradiated for all plans

Results: Out-of-field doses were measured at different depths for a breast plan and a 3DCRT and VMAT brain plans. For the depth of 10 cm, the resulting dose was 2.5 cGy for the breast plan at a distance of 30 cm from the isocenter. For the brain astrocytoma plans, the doses were 0.8 cGy for the conformal plan and 1.1 for the VMAT plan, at a distance of 52 cm from the isocenter. These values are below the limits and comparable to other values reported in the literature. For the 3DCRT breast plan, the TPS significantly underestimated the dose in all cases. The dose differed by -40% at a depth of 5 cm, -48% at a depth of 10 cm and -67% at a depth of 15 cm, taking the OSLD measurement as the reference dose, and at a distance of 20 cm from the isocenter. For the brain plans, at a distance of 32 cm from the isocenter, no direct comparison was possible, as the TPS calculated zero dose at this point. The distance to agreement was 25 cm for the 3DCRT plan and 19 cm for the VMAT plan.

Conclusion: For fetal dose evaluation measurements before treatment should be done to avoid large errors. Landauer nanoDot dosimeters can be used with a phantom for these measurements by calibrating them in out-of-field conditions against a Farmer chamber. The Acuros calculation algorithm in Eclipse greatly underestimates the out of field dose and can be used only for a rough estimation in points not so far from the central axis of the beam (less than 20 cm).

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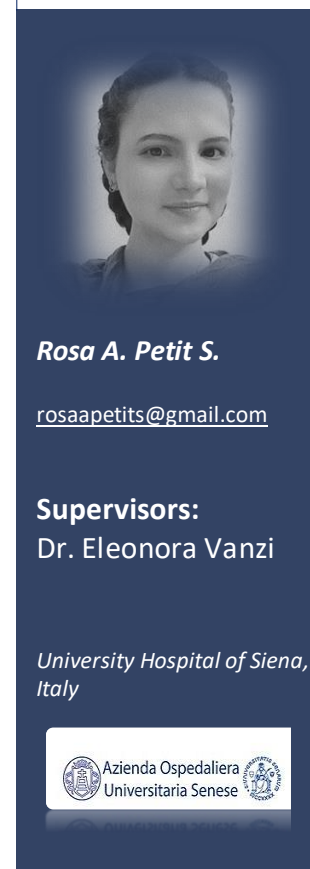
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Statistical Process Control in Tomotherapy pre-treatment QA: Fixing tolerance and action limits for the verification metrics

Prospective/Objective: We retrospectively applied the SPC methodology to gamma (γ) analysis and dose difference results in helical Tomotherapy™ (Accuray) pre-treatment verifications, using ArcCheck™ (Sun Nuclear) as QA tool, to establish tolerance limits (TLs) and action limits (ALs) for different anatomical sites (abdominal area, head & neck, breast plus supraclavicular nodes and prostate). The final purpose of this research is to evaluate the performances of SPC in the context of Tomotherapy pre-treatment QA in order to develop a methodology able both to promote detection of eventual delivery problems before the treatment and to monitor the system performances over time.

Materials and methods: The parameters selected to determine TLs and ALs in pre-treatment QA measurements were the γ -index passing rate obtained with two criteria: 3%3mm-local normalization (G33L) and 3%2mm-global normalization (G32G). The dose difference measured with an ionization chamber placed in the center of the phantom was also considered. The calculation of the patient plans on ArcCheck™ was done with Tomotherapy "Delivery Quality Assurance" method available in the planning station. TLs and ALs at the institution's local level were evaluated with the SPC method proposed in AAPM TG218, a safety standard report for measurements prior to treatment. AAPM proposal requires a minimum of 20 pre-treatment QA measurements. Here, absolute dose measurement and G33L analysis were evaluated on 727 cases (abdominal 166, breast + SVC 165, head & neck 115, and prostate 281); G32G analysis was performed on a subset of 343 measurements (abdominal 71, breast+SVC 79, head & neck 62, and prostate 131). SPC method was applied to evaluate TLs and ALs both starting from the whole dataset and from the first 20 measurements only.

Results: Different TLs and ALs were found for different anatomical locations. The highest Lower Control Limit (LCL) for the G33L criterion were for head & neck (90.69%) and prostate (88.27%), indicating that they are a very stable process in helical Tomotherapy. The lowest LCL were found for breast + SVC (74.59%) and abdomen (77.10%). The action limits determined for G33L also followed the same pattern described above, that is, head & neck (86.85%) and prostate (82.96%) as the highest values, while breast + SVC (59.35%) and abdomen (74.23%) as the lowest values. For the G32G criteria, the highest LCLs were observed for abdominal site (95.57%) and prostate (93.94%); the lowest LCLs were breast + SVC (84.49%) and head & neck (89.92%). The same happened with the action limits, with abdomen (92.67%) and prostate (90.46%) followed by breast + SVC (82.71%) and head & neck (87.42%). As far as the absolute dose difference is concerned, the smallest average difference and CL/AL values were: head & neck (average difference 0.62%), abdominal (0.81%) and prostate (0.81%). For breast + SVC (average difference 0.95%) a very high variability of results was found, producing high control levels. In summary, breast + SVC was found to be the most challenging kind of treatment: indeed, it involves large areas of very low doses and gradients where, especially local gamma analysis, gives not optimal results until you do not apply a high threshold (10% in our analysis). Moreover, these treatments generally involve large treatment volumes, and it may be difficult to position the ArcCheck in order to efficiently cover the entire dose distribution and sample it with the diodes while preserving suitable positioning of the central ionization chamber in a full dose, low gradient region. The high variability of dose difference values that was found reflects the fact that ArcCheck positioning in these cases often results in the ionization chamber placed in a low dose and/or high gradient region. In general, CL and AL calculated from 20 measurements only, gave more stringent tolerances since less variability of data is included.

Conclusion: TLs and ALs for different anatomical sites were successfully established both considering all the acquire statistics and starting from 20 measures only. Setting TLs and ALs locally helped to understand and validate the performance of treatment QA over time. In this way, negative results that may affect patients can be detected, avoided and prevented.

An interesting side result of this study is that results produced by the new AAPM suggested parameter (G32G) are definitively better with respect to the "historical" parameter G33L. This denotes how important it is to know the behavior of both parameters when changing from one focus to the other.



Commissioning of VERSA HD linear accelerator for FF and FFF beams: Evaluation of the performances of various detectors in relative small field dosimetry

Prospective/Objective: The main objective of this work is to evaluate the performances of different detectors in the small fields by using 6 MV FF, 6 MV FFF and 10 MV FF beam energies. The implementation of TRS-483 CoP for field output correction factors was used in this work, together with a comparison of correction factors adopted from literature, in particular for synthetic diamond and PinPoint detectors. To identify the detectors more suitable for dosimetry of small fields by evaluating perturbations and uncertainties associated with the determination of field output factors.

Materials and methods: In this study, the linear accelerator VERSA HD (Elekta, Stockholm, Sweden) of 6 MV FF, 6 MV FFF and 10 MV FF energies was used to obtain the Profiles (crossline and inline), Percentage Depth Doses (PDDs), Output Factors (OFs) with various detectors. The dose rate of 6 MV FF and 6 MVFFF can reach 600 MU/min and 1900 MU/min respectively. Beam Profiles and PDDs were obtained for field sizes from 0.6×0.6 cm² to 2×2 cm² with (PTW microDiamond 60019 (mD), PTW Diode 60018, PTW PinPoint 31014, Sun Nuclear EDGE detector 1118), by using all energies. The OF measurements were performed with all detectors including Exradin W1 plastic scintillator, for field sizes from 0.6×0.6 cm² to 3×3 cm² by using all energies. The correction factors from IAEA TRS 483 and from literature data (correction factors from (De Coste et al 2017 and Looe et al 2019) for mD for 6 MV FF and correction factors from (Francescon et al 2011) with Monte Carlo (MC) to PinPoint detector for 6 MV FF and FFF) were applied to measured OFs in order to make a useful comparison between detectors and to evaluate their accuracy. The differences between measured and corrected OFs were investigated in this work.

Results: Small differences in PDDs, FWHM and penumbra values were observed between flattened and FFF beams with the different detectors for smallest field size 0.6×0.6 cm². The standard deviation (SD) calculated on the measured OFs ranged from 0.2% to 3.7%. The application of the IAEA correction factors resulted in a reduced SD, ranging between 0.2% and 2.7% considering all field sizes and energies. Higher differences in OF values before and after the correction were observed in FFF beams than in FF beams as well as in the smallest field (0.6×0.6 cm²) for all detectors, as reported by other studies. The PinPoint detector under-responded for the smallest fields (especially for 0.6×0.6 cm² and 1×1 cm²) for all energies due to its higher active volume compared to those of the other detectors. For mD, the OFs calculated using the IAEA correction factors were found consistent with those obtained applying both De Coste and Looe correction factors, with differences within 0.7%. For PinPoint, the OFs calculated using the IAEA correction factors and those from Francescon et al., differ within 3% for both 6 MV and 6 MV FFF. The total uncertainties were found to be approximately 3% for 0.6×0.6 cm² field size.

Conclusion: The outcome of this study demonstrated that all the investigated detectors are suitable for small field dosimetry. The differences in dose response between the detectors used in this study were significantly reduced by implementing the correction factors reported in IAEA TRS 483 and in literature for all investigated small fields and energies. The EDGE, Diode 60018, plastic scintillator and mD detectors need smaller corrections for all field sizes and energies, they can be considered as a preferred choice, if available. The alignment and correction factors uncertainties can be considered as an important source of the OFs variation, especially for the smallest field size. It is worth underlining the importance of properly centering the detector on the central axis of the radiation beam, for small field



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measurements. However, further studies are needed to provide correction factors derived from an accurate modelling which may improve the treatment results with enhanced patient safety.



Measurements of planar and tomographic system spatial resolution in SPECT/CT with a home-made phantom

Prospective/Objective: The spatial resolution of a gamma camera is a critical parameter for the diagnosis, as it affects the ability of the device to detect small lesions and to assess them qualitatively. The aim of this thesis was to characterize the planar and tomographic system spatial resolution performance of a SPECT/CT equipment as the function of different parameters (related both to acquisition conditions and to image reconstruction algorithms) using simple home-made phantoms based on NEMA protocol.

Materials and methods: The equipment that was tested is a dual head Siemens Symbia SPECT/CT system installed in the Nuclear Medicine Department of Cattinara hospital in Trieste. For the planar system resolution, a home-made phantom was prepared with four plastic capillary tubes of internal diameter < 1 mm, filled with a solution of ^{99m}Tc and fixed on a polystyrene holder. Two collimators were tested, Low Energy High Resolution (LEHR) and Medium Energy Low Penetration (MELP), with and without a scattering medium (a flat-water plastic tank), positioning the phantom at two distances from the collimator (10 cm and 20 cm) and varying the matrix size (64 x 64, 256 x 256, 1024 x 1024) and the zoom factor ($Z = 1$, $Z = 3.2$). On the acquired images, the resolution in the x and y directions and the pixel size were evaluated. For the tomographic system resolution with scatter, a standard PMMA CT head phantom was used, inserting into holes three-line sources previously prepared with plastic capillary tubes of internal diameter < 1 mm, filled with a solution of ^{99m}Tc . A tomographic acquisition with matrix 256 x 256, radius 15 cm, 120 views per head was run; the transversal slices were reconstructed with a Filtered Back Projection (FBP) algorithm and an iterative algorithm (3D-OSEM). All the images were analyzed using the free software ImageJ, drawing rectangular ROIs to obtain the profile of the pixel counts perpendicularly to each line source (Line Spread Function) and applying a Gaussian interpolation; the resolution parameter was expressed as Full Width at Half Maximum (FWHM) of the resulting peaks. For the planar system resolution, the IAEA software NMQC Toolkit was also applied.

Results: The results showed that the system planar resolution increases as the source to collimator distance decreases, when no scattering material is interposed and as the matrix size increases, as expected. The tomographic resolution with scattering was found to be better in images reconstructed with the 3D-OSEM iterative algorithm than with the FBP algorithm.

Conclusion: It was found that the system spatial resolution values, both for planar and for tomographic acquisitions, were in agreement or better than the manufacturer specifications. Moreover, it was possible to prepare the phantoms required for the measurements using materials and tools easily available in hospitals, without acquiring commercial phantoms.

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Optimization of 18F- FDG oncological examinations on a TOF-PET/CT scanner

Prospective/Objective: The aim of this study was to Optimize the 18FDG Whole-Body oncological examinations on a TOF-PET/CT Scanner through assessment of image quality dependence on contrast and noise properties change as a function of emission scan duration (ESD) and Body mass index (BMI).

Materials and methods: 38 oncological patients (regardless their gender), 18 with BMI < 25 kg/m² and 20 with BMI > 25 kg/m² were selected for this study, which resulted a total of 74 lesions from head and neck, thorax, and abdomen district. The injected activity for all patients was about 3 MBq/kg of 18F-FDG and images were acquired with an Emission Scan Duration (ESD) of 2 min/bed position. Thanks to the list mode acquisition, the 2 min/bed acquisitions were reconstructed to 90, 75, 60, 45 and 30 seconds. Furthermore, the image quality dependency on contrast and noise properties was assessed through Contrast to Noise Ratio (CNR) and Coefficient of Variation (%CV) with respect to ESD and BMI. The Coefficient of Variation (%CV) was evaluated on the liver from any slice with uniform uptake by taking a ratio of standard deviation (SD) and mean activity concentration of 6000 mm³ circular volume of interest (VOI). Moreover, to evaluate Contrast to Noise Ratio (CNR) in each lesion, a volume of interest (VOI) was automatically delineated by using iso-contouring with 50% maximum threshold in the lesion and a U-shaped background ROI drowned around the lesion by using a closed contour, to obtain the mean activity concentrations and standard deviation.

Results: This study proved expected dependence of CNR and %CV on both ESD and BMI at constant 18FDG injected activity concentration of about (2.8±0.3) MBq/Kg.

Conclusion: It is reasonable to adjust the duration of the PET bed with the aim of improving CNR of the lesions while considering the patients' BMI, in the range of the explored values.



Dosimetric verification and comparative analysis of Collapsed Cone Convolution and Irregular Field algorithms for soft tissue, lung, and bone region treatment sites using an anthropomorphic phantom

Prospective/Objective: Treatment Planning Systems (TPSs) have proven to be an indispensable tool in radiation therapy treatment. The accuracy of any TPS to calculate dose is largely dependent on the mathematical algorithm used and can be well verified using a dedicated phantom. The aim of this study was the dosimetric verification and comparative analysis of three different TPSs (Precise PLAN R2.15, Pinnacle 3 and Monaco 5.11.03) using Collapsed Cone Convolution (CCC) and Irregular Field (IF) algorithms for soft tissue, lung and bone treatment sites using an anthropomorphic phantom, based on the methodology developed by IAEA-TECDOC-1583.

Materials and methods: The study was executed with a CIRS 002LFC IMRT Thorax phantom made of plastic water, lung and bone sections with holes to hold interchangeable rod inserts and an ion-chamber port. The phantom was simulated using a computed tomography (Philips brilliance Big Bore, multi slices) scanner and three TPSs (Precise PLAN R2.15, Pinnacle 3 and Monaco 5.11.03) for application of beam setup parameters. Treatment plans were generated for three megavoltage photons energies (X4, X6 and X10) using Elekta Precise Treatment System Clinical Linear Accelerator and a Pinpoint 3D ion-chamber (TW3101) was used to perform dosimetric verification. The ionization chamber was coupled to a PTW-UNIDOSE-E electrometer which measured the charge collected during irradiation. For each test case measurements were acquired and the deviations between measured and calculated TPSs dose values were analyzed using agreement criteria mentioned in IAEA-TECDOC-1583 report.

Results: A total of 8 clinical test cases for three nominal energies of photons 4, 6 and 10 MV were produced to evaluate the performance of CCC and IF algorithms to calculate the dose in media with homogeneities and heterogeneities. The dose deviations (error%) obtained for the three TPSs, in comparison with the experimental measurements are reliable in most cases with an error in the calculation of the absorbed dose of less than 2% in a homogeneous tissue equivalent medium, with the exception of the IF algorithm values corresponding to four field box (test no. 4), at 270° gantry angle (P5) for the nominal energies of 4 and 6MV which are slightly outside the confidence recommended limit. Good correspondence of the mean deviations of the calculated dose values with respect to the measured dose values were observed for all energies regardless of the algorithm considered. However, the deviations in the bony and lung regions insert regions are largely dependent on one algorithm to another. The results appear to be better for the CCC algorithm. The overall results in heterogeneous lung and bone inserts were 67% and 89% for PrecisePLAN, 100% and 95% for Pinnacle, and 100% and 100% for Monaco, respectively.

Conclusion: The dose prediction capacity of the Irregular Field algorithm appears to be comparable to the Collapsed Cone Convolution algorithm in soft tissue medium and was found to be 98 % within the agreement criteria. The most significant difference between the two algorithms were found in the bony and lung regions. This comparison shows a good performance on the part of the TPS Monaco and Pinnacle, with in particular a good taking into account of the lack of diffusing volume and a good modeling of the lateral electronic transport. This work could clinically help the user to appreciate the properties, qualities and operational characteristics of the 3 TPS and to better understand their limits.

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Internal Radiation Dosimetry Based on Dose Point Convolution Kernel (DPK) for ^{177}Lu -DOTATATE Therapy

Prospective/Objective: Organ Level Internal Dosimetry and Exponential Modelling (OLINDA/EXM) code is widely used in nuclear medicine internal radiation dose assessment for diagnostics and in targeted radionuclide therapy (TRT). Although OLINDA/EXM lacks adequate patient specific and comprehensive internal radiation dosimetry capacity, it is fast in evaluating mean absorbed doses. The purpose of this study was to implement in a MATLAB (MathWorks, Natick, MA) program, a more patient specific internal dose calculation algorithm based on voxelated dose point convolution kernel (DPK) for ^{177}Lu radionuclide. The DPK in the MATLAB program was used to generate three-dimensional dose distributions in SPECT/CT images for neuroendocrine tumor (NET) patients undergoing ^{177}Lu -DOTATATE therapy.

Materials and methods: Dose Point convolution Kernel (DPK) for ^{177}Lu were pre-calculated in EGSnrc user-code DOSXYZnrc Monte Carlo simulation. The kernel included all the beta energies and the two most prominent gamma energies of the radionuclide, 208 keV (10.4%) and 113 keV (6.2%). Two dose calculation algorithms, namely DPK and local dose deposition (LDP), were implemented in a MATLAB program. A graphical user interface (GUI) was built to load SPECT/CT images and RTstructure DICOM files. Activity evolutions for organs at risk (kidneys, liver and spleen) and lesions were quantified from SPECT/CT images. The SPECT/CT images were acquired at 4, 24, 72 and 168 hours post injection of ^{177}Lu -DOTATATE during first cycle and only one acquisition after 24 hours post injection for each of the three subsequent cycles. Bone marrow dose was estimated from 8 blood samples collected after 0.5, 1, 2.5, 4, 8, 24, 72 and 168 hours post injection. Analysis was based on comparison of mean absorbed doses calculated using OLINDA/EXM, DPK and LDP.

Results: The 50th percentiles at 95% CL for ratios of mean absorbed doses calculated with DPK and LDP algorithms to those calculated with OLINDA/EXM were 0.99 and 1.03 respectively in the first cycle. Bland-Altman statistics at 95% prediction level gave a mean dose bias of 0.77 Gy between DPK and OLINDA/EXM. DPK provided more comprehensive dosimetry information including full 3-dimensional dose distributions and dose volume histograms (DVH). Paired organs like kidneys were found to have variation in radio-pharmacokinetics and subsequently different mean absorbed doses by up to 17.53%. Based on full therapy cycles, the maximum estimated mean absorbed doses to organs at risk; bone marrow, right kidney and left kidney were 0.96 ± 2.00 Gy, 8.96 ± 2.00 Gy and 9.60 ± 2.00 Gy respectively. These mean doses are safely below the recommended limits to bone marrow and kidneys, 2.0 Gy and 23.0 Gy respectively based on external beam radiation therapy (EBRT) experience.

Conclusion: Voxel level internal dosimetry protocol for organs at risk and lesions for NET patients undergoing ^{177}Lu -DOTATATE therapy can be determined based on dose point convolution kernel (DPK). The implemented MATLAB program was easier to use, equally accurate compared to OLINDA/EXM, gave comprehensive 3-dimensional dose distributions and was fast enough for a clinical workflow.



Comparison of different treatment planning techniques for breast cancer

Prospective/Objective: The aim was to compare different treatment techniques for the breast cancer in order to evaluate if the use of inverse planning vs forward planning lead to improve dosimetry for targets and OARs.

Materials and methods: This study was conducted using CT simulation data sets of 11 right/left-sided breast cancer patients who had been previously treated at Radiotherapy Department of Sant'Anna Hospital - Ferrara. 3DCRT, IMRT, VMAT and VMAT obtained with an automatic planning system were compared retrospectively in terms of dose to target and to OARs. Planning target volume included both breast wall and supraclavicular lymph nodes. All the patients were prescribed a total dose of 50 Gy to the PTV in 25 fx and plans were performed using Pinnacle (Philips) TPS. For each treatment plan, DVH was analyzed to obtain PTV and OAR dosimetric data. For target coverage we compared, for the different techniques, Dmax, Dmean, D95%, V95% and calculated the Homogeneity and Conformity Index (HI and CI). We consider also OARs dose sparing: ipsilateral lung, heart (in case of left breast), contralateral lung and contralateral breast. Paired Student's T-test was finally used for statistical analysis.

Results: Results. For breast PTV D95% coverage was better for inverse planning techniques for all patients, with VMAT and Auto VMAT allowing similar dose coverage. For SVC lymph nodes PTV inverse planning techniques have almost similar D95% coverage. However, in this case D95% is satisfactory for all techniques for what concern V95%, in almost all cases IMRT, VMAT and Auto VMAT had similar coverage, better than 3DCRT one, both for breast and SVC lymph nodes PTVs. HI evaluation demonstrated, as expected, that for almost all plans the dose distribution from inverse planning techniques were more homogenous as compared to 3DCRT. Inverse planning techniques showed better results also for CI for all patient compared to 3DCRT. For what concern normal tissues dosimetry, all techniques allowed to comply with the requested constraints, except for high dose constraints in 3DCRT. Forward planning resulted in better sparing of heart, contralateral lung and contralateral breast in terms of mean dose. Statistical analysis gave significant results in comparing 3DCRT vs inverse planning techniques (IMRT and VMAT) for all dosimetric variables (D95, V95%, HI and CI). The comparison between IMRT and VMAT resulted in differences for CI in breast PTV and for all parameters in SVC lymph nodes target. VMAT and AutoVMAT are statistically different only for D95 and V95% in lymph node PTV.

Conclusion: The difference in dosimetric parameters between 3DCRT, VMAT and IMRT highlighted that the use of inverse planning techniques can significantly improve dose distribution for breast and lymph nodes targets. However, the choice of the better technique must be patient dependent. The use of breath holds systems, essential for VMAT treatments, requires compliant patients otherwise 3DCRT should be considered. In general, VMAT seems to provide the optimal balance between breast and regional node coverage, normal tissue sparing and treatment complexity. Moreover, VMAT techniques with auto planning modules could be a best option in order to reduce the variability of treatment quality standardizing the planning.

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6 MV and 6 MV FFF VMAT dosimetric validation based on AAPM TG 119 report using 3D phantoms, and an on board EPID in a Monte Carlo TPS.

Prospective/Objective: Evaluating the dosimetric accuracy of volumetric modulated arc therapy (VMAT) for a new Versa HD linear accelerator for 6 MV and 6 MV FFF (Flattening Filter Free) photon beams. All measurements were done accordingly the AAPM TG 119 report adapting it to the VMAT technique and two cylindrical phantoms: a Delta4 Wi-Fi and a Matrix phantom and an on board EPID. The cylindrical-shaped phantoms have the advantage that simulates the patient shape, and the EPID has the advantage to be fast and less time-consuming in pre-treatment dose verification procedures. Benchmarks were created in terms of confidence limits (CL) using the statistical methods suggested by the report.

Materials and Methods: VMAT plans were calculated and optimized following the AAPM TG 119 dose prescriptions and planning objectives, using a Monte Carlo based Treatment Planning System (TPS) Monaco 5.51.02 for 6 MV and 6 MV FFF photon beams. The TG 119 report suggests five test plans: Multitarget, Prostate, Head-and-Neck and C-Shape easy and C-Shape hard. Two different approaches measured the delivered dose: composite 3D or 2D dose distribution in the Delta4 and EPID respectively and single point absolute dose in the Matrix phantom. The measured dose was compared with the TPS calculations using gamma criteria of 3%/3 mm and 2%/2mm. Confidence Limits were generated and compared with the TG 119. Delta4 and EPID were also used to verify the dose distributions of the first 26 patients treated with this new linac.

Results: he overall passing rates for 6 MV with 3%/3mm for Delta4 and EPID were 99.57±0.26, 99.44±0.52 respectively and 99.78±0.49, 98.92±1.34 for 6 MV FFF; with CLs, 0.95 for Delta4 and 1.70 for EPID for 6 MV photon beam compared with 1.18, 3.71 for 6 MV FFF respectively. For, 2%/2 mm for Delta4 was 95.87±1.84 for 6 MV and 98.77±0.79 for 6 MV FFF, compared with EPID 95.92±1.32 for 6 MV and 94.28±3.94 for 6 MV FFF. The obtained passing rates with 3%/3 mm for the 6 MV plans were always better than that reported in TG 119 (97.06±1.81%). Gamma passing rates obtained with the Delta4 were usually higher than EPID pass rates due to the higher sensitivity of the EPID to the accumulated dose. Regarding Point Dose Measurements, local CL for VMAT plans evaluated with the Matrix phantom was 0.013 for 6 MV and 0.028 for 6 MV FFF respectively. Regarding the patient measurements, the Delta4 has a passing rate ≥ 97.5% while the EPID has a lower corresponding passing rate ≥ 91.6%.

Conclusion: Even if not specifically designed for VMAT treatments, TG 119 methodology has successfully been used to evaluate the commissioning accuracy of VMAT on a Versa HD linear accelerator, and a dosimetric validation was performed. All results were well inside the acceptable values suggested in the protocol. The methodology of the TG 119 was easily applied to all phantoms and devices proposed in this work. Local institutional CLs were established which can be used as benchmarks for future measurements and as a baseline for future patient-specific pre-treatment quality assurance.



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Impact of the detector type on the implementation of an Eclipse treatment planning system.

Prospective/Objective: The aim of this study was to study the impact of different detectors on an Eclipse treatment planning systems in terms of implementation and dose distribution in planning on clinical patients.

Materials and methods: Two different detectors, the PTW-31010 Semiflex 0.125cc ionization chamber and the PTW-60019 microDiamond, have been used to acquire beam data that we implemented two Eclipse treatment planning systems with. Detectors beam data have been compared first, then comparison between systems have been done at two levels: configuration data and treatment planning in clinical patients.

Results: It has been found that the detectors beam data are somehow different, with discrepancy lower than 1% in general, for measured PDDs, beam profiles and TPR_{20/10}. As expected, the penumbra showed differences going up to 43%; the semiflex chamber having the largest penumbra. The systems implementations have been found within good agreement, with average gamma errors lower than 1 for both systems. Plan comparison showed few differences that have been found not statistically significant, even if some important dose differences (up to 5%) have been found in some organs at risk. Overall, the differences found in dose distribution in structures, mainly in PTV, were not clinically relevant. The dose coverage was also similar between plans done on both TPSs.

Conclusion: Definitely, from our analysis we can conclude that whatever the kind of detector used for beam data acquisition, if it has been found suitable for measurement for the range of field sizes, it will be able to perform a good system implementation.




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Impact of the detector type on the implementation of an Eclipse treatment planning system.

Prospective/Objective: Purpose of this study is to analyze and to compare results regarding the profile (penumbra, flatness), percentage depth dose (PDD) and output factors (OF). Obtained using different detector size under beams, with various field size and different energy.

Materials and methods: Beam profile, PDD and OF measurement will be performed in standard water phantom (which are the primary tool used for absolute dosimetry and it consist of a transparent plastic tub (about 60cm in all dimensions) filled with distilled water) in Various square fields size for different photon beam energy which I used Elekta SL15 {(6 and 15MV x-ray energies) accelerator equipped with multi leaf collimator(MLC)}, by scanned different detectors such as Semiflex31010, Semiflex31013, Pinpoint31016, Farmer30013, Markus 34045, Diode P Type 60016, and Diode E Type 60017, Micro-L-ion Chamber 31018 .

Results: Our results, evaluated in terms of PDD, OF, profile (penumbra and flatness) will indicate which detectors are appropriate for measuring photon beam depending on the set field size.

Conclusion: Regarding profile, PDD and output factors determination, MicroLion31018 detector is stable for both filed, diode60016 detector and diode60017 detector are acceptable for small field, and Semiflex31010 detector are good for collecting data in large field Pinpoint31016 detector is a small detector, it was stable for some measurement, but not for much accuracy in both fields. Parallel plate ionization chambers (Markuse34045) are not appropriate for penumbra and buildup region measurements. In case of inconsistency and improper behavior of data collection from Semiflex31013 and Farmer30013 detectors. We stopped collecting data, after when we checked them in three fields.



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INFORMATION FOR AUTHORS



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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 Editors(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.

Font: 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: Four - 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 four size 12, regular and other letters are four 8 regular style. Indents - 20 point before and 10 point after each Chapter Heading.

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- 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
Author's info	9	Regular	After: 20
Abstract	9	Bold	
Keywords	9	Bold	
Chapters			
Heading - 1 st 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, 1 st letter	10	Regular	Before: 15
Caption - other letters	8	Regular	After: 5
Legend	8	Regular	
Column titles	8	Regular	
Data	8	Regular	
Figures			
Caption - 1 st letter	10	Regular	Before: 15
Caption - other letters	8	Regular	After: 5
Legend	8	Regular	

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

$$A + B = C$$

(1)

$$X = A \cdot e^{\alpha} + 2kIt$$

(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

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ACKNOWLEDGMENT

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