MEDICAL PHYSICS *International*

EDITORIALS
DRIVERS OF THE IOMP EFFECTIVENESS AND VISIBILITY DURING THE PERIOD JUNE 2015 – JUNE 2018
HISTORY OF THE BRITISH JOURNAL OF RADIOLOGY
THE VERTTM PHYSICS ENVIRONMENT FOR TEACHING RADIOTHERAPY PHYSICS CONCEPTS
DIGITAL ELEMENTS, IMAGE QUALITY, RADIATION EXPOSURE, AND PROCEDURE OPTIMIZATION
MEDICAL PHYSICS IN VIETNAM: THE CURRENT STATUS OF EQUIPMENT, WORKFORCE AND EDUCATION
2018 AAPM/IOMP – ISEP THERAPY COURSE CHALLENGES IN MODERN RADIATION THERAPY PHYSICS
IOMP-IUPAP WORKSHOP "MEDICAL PHYSICS PARTNERING WITH THE DEVELOPING WORLD" AT WC2018
STATUS OF MEDICAL PHYSICS AND ACTIVITIES IN THE SEAFOMP REGION
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SELECTING A CT SCANNER FOR CARDIAC IMAGING
IMPROVING ACCESS TO RADIATION THERAPY BY REIMAGINING TECHNOLOGY
AN UPDATE VIEW IN MEDICAL IMAGES ANALYSIS
A CASE STUDY OF CONTRAST INVERSION AND MODULATION TRANSFER
CLINICAL RADIOTHERAPY PHYSICS WITH MATLAB:
A BRIEF HISTORY OF THE AAPM

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The Journal of the International Organization for Medical Physics

Aims and Coverage:

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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EDITORIAL

This journal, Medical Physics International (MPI), continues to make major contributions to the medical physics profession and especially individual medical physicists and students. It is because of a combination of several unique factors not found with any other journal. Working in collaboration with other major medical physics journals around the world contributes to this success. Most journals focus on peer-reviewed research reports where MPI gives extensive coverage to publications to enhance the development of the medical physics profession especially in applied clinical physics and education. It provides an opportunity for medical physicists and organizations in all countries to share their experiences and progress in the continuing development of the profession. It contributes to a more unified global medical physics community with the inclusion of regions with limited resources.

As the only medical physics journal with extensive contributions to medical physics education the global impact is significant. A specific effort is to publish materials that can be used by educators to enhance the effectiveness of their programs, especially with the increasing availability of new and advanced technologies both for diagnostic imaging and therapy.

With the MPI being provided as an open resource and free to all its global impact is extensive. Every medical physicist, regardless of location and availability of resources now has access to the many valuable publications to enhance their careers.

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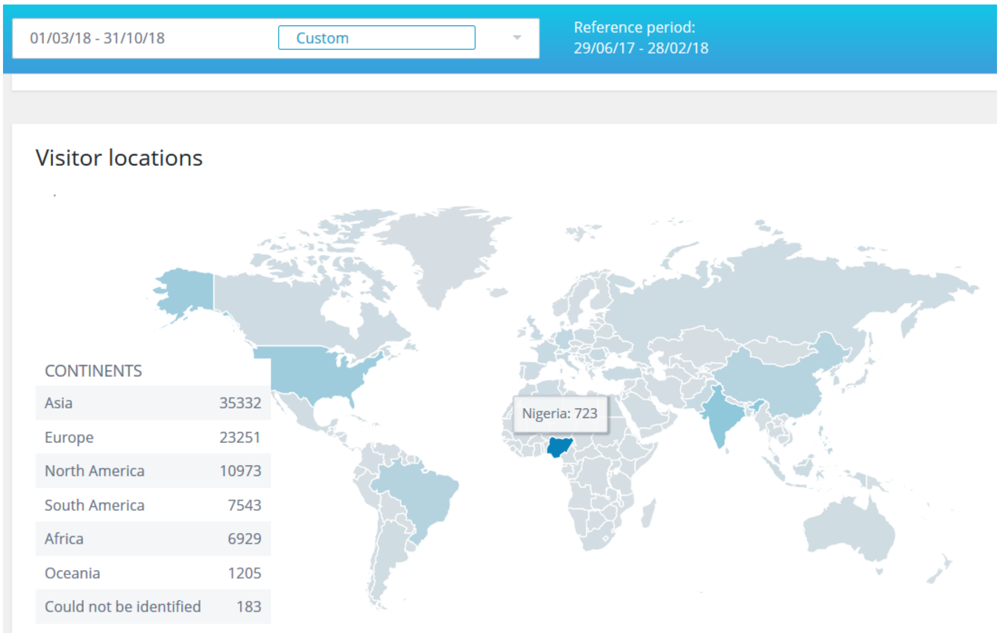
Perry Sprawls, Co-Editor-in-Chief

The Journal *Medical Physics International* completed another successful year. For the first 10 months of 2018 the MPI web site had 105,537 visits. The visits in the period 1/3/2018 - 31/10/2018, identified by country (on the figure below), show that 60% of the visits are from Low and Middle Income countries (LMIC). This is exactly according to the objectives of the Journal – to provide free resources to our colleagues in LMIC, where the professional development needs a strong boost. Naturally, among the most downloaded MPI papers are tutorials and educational materials. We would like to encourage all colleagues to send such materials, which are of great help for the development of the profession in LMIC.

MPI Journal is part of the long strategy of IOMP, addressing the challenge in front of the profession – the need of almost tripling the number of medical physicists globally by 2035. We produced and published several important papers on this subject – in MPI and in other Journals (the latest one is: Tsapaki V, Tabakov S, Rehani M, Medical physics workforce: A global perspective, Physica Medica 55, 2018, p.33-39). In this MPI issue I have included a condensed report about the related to this challenge many activities and initiatives of IOMP during the past term of office (June 2015 - June 2018). As per the tradition of IOMP, these activities will further develop in the new IOMP ExCom term and MPI will continue to strongly support these.

Slavik Tabakov, Co-Editor-in-Chief



DRIVERS OF THE IOMP EFFECTIVENESS AND VISIBILITY DURING THE PERIOD JUNE 2015 – JUNE 2018 : CONTINUATION OF PREVIOUS ACTIVITIES AND INTRODUCTION OF NEW INITIATIVES

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Abstract— **The paper describes the main activities of IOMP during the period June 2015 - June 2018, driven by the need of significant increase the medical physicists as part of the global healthcare workforce. These activities are separated in three main areas: Further expanding of professional growth through education; Quick translation of research into education and practice; Recognition and visibility of medical physics and engineering; Other ongoing activities. The paper underlines the role of IOMP for the global development of medical physics, especially in Low and Middle Income countries.**

Keywords— **IOMP, Medical physics professional development; Healthcare Workforce.**

I. INTRODUCTION AND MAIN AREAS OF ACTIVITES (JUNE 2015 – JUNE 2018)

The International Organization for Medical Physics (IOMP) was established in 1963, 55 years ago. During this time the Organization has been pivotal for the global development of the profession, and supporting healthcare delivery in various parts of the world. The impact of IOMP has been felt most strongly in the Low and Middle Income (LMI) countries by supporting their professional growth. The IOMP has stimulated links within and among LMI countries with the development of National Societies and International Institutions, who have provided educational courses and other support.

The history of the Organization [1,2] shows constant growth of membership, parallel with the growth of the profession [3,4]. However the ever increasing application of medical technology in contemporary healthcare demanded more and more specialists dealing with it. During the past decades we have seen shortage of medical physicists in many places. This was documented by the Report of the Global Task Force on Radiotherapy for Cancer Control [5], predicting the need of almost tripling the medical physics global workforce by 2035. The global need of more medical physicists shaped significantly the activities of the IOMP in the term of office June 2015 – June 2018, and will certainly influence the IOMP activities ahead.

Based on these documented needs, I as IOMP President in the period June 2015 – June 2018, prepared a plan creating a framework of activities. These activities were discussed, supported and executed by us - all colleagues in ExCom, and created the background for future development. The IOMP Executive Committee (ExCom) in this period included: S Tabakov (President), V Tsapaki (Secretary General); M Rehani (Vice-President); A Krisanachinda (Treasurer); KY Cheung (Past-President); G Ibbott (SC Chair); J Damilakis (ETC Chair); Y Pipman (PRC Chair); T Suk Suh (PC Chair); S Renha (AHC Chair); M Stoeva (MPWB Chair). Together with the ExCom there were about 100 colleagues from 43 countries who took part in the various IOMP Committees and actions during this period.

Fig. 1 IOMP ExCom (June 2015 – June 2018) and Regional Coordination Board, meeting at ICMP2016, Bangkok, Thailand

An outline of the activities of this plan was presented in the President's Report [6] at the end of the term and at the Plenary talk at the World Congress 2018 in Prague [7]. The plan had three main areas (hosting the activities to be described) :

1. Further expanding of professional growth through education
2. Quick translation of research into education and practice
3. Recognition and visibility of medical physics and engineering

This paper presents the above activities in more detail, both as record and as presentation of the vector of movement of the Organization during the period. I cordially acknowledge the feedback and gratitude from many colleagues at the end of this IOMP term, emphasizing the fact that the ExCom worked very well as a team to meet the challenges ahead.

Before describing the main areas of the plan and its activities, I would like to mention one new activity, which supported all others – the creation of the Regional Coordination Board (RCB). It was obvious that the support for various international initiatives required strengthening the cohesion between IOMP and its Regional Organizations (the Continental/Regional Federations). For this reason I proposed the creation of a new IOMP structure – the RCB [8]. The structure was approved both by the previous ExCom (June 2012-June 2015) and the IOMP Council at its meeting at our World Congress 2015 in Toronto.

Activity: Regional Coordination Board

This new IOMP Board, headed by the IOMP President, and including all Presidents of Regional Organizations (RO) had its first meeting immediately after the Council meeting in Toronto at WC2015 [9]. Its main aim is to increase the cohesion and coordination between all IOMP Regional Organizations (Federations). During the term of Office the Board had 4 meetings and agreed and supported all strategic activities of the IOMP, including the themes of the International Day of Medical Physics, the History project, the IOMP legal representation and other activities (to be listed below). The Presidents of AAPM, CAMP and IPEM (hosting IOMP) were also part of the RCB meetings. The Board was active in the provision of inter-continental coordination and support of various professional activities and quickly established itself as an important vehicle of the IOMP activities and a think-tank of the Organization [10] (Fig. 1). RCB continues its activities and a number of its members take part in other IOMP initiatives.

Here below the many activities during the term will be described, as part of the three main areas in the plan.

II. Further expanding of professional growth through education

It is obvious that the rapid expansion of the profession ahead will be based on creating more medical physics educational courses and associated training. The established societies could do this with their current resources, but special support is necessary for the LMI countries.

One very important element in this area was further stimulation of e-learning inclusion in the education. Our profession is one of the pioneers in this activity and one of the goals of the MPI Journal is to provide a platform for exchange of resources and experience in this field. This overarching activity was supported by including e-learning related sessions in all Conferences and Congresses during the period and publishing in the MPI Journal a number of examples of e-Learning use in practice.

Another very important element in this area was to support the establishment of international educational and training courses in medical physics. An outstanding example is the International MSc in Advanced Medical Physics (Directors R Padovani and R Longo) formed between ICTP, Trieste and the University of Trieste, with the strong support of the Italian Association of Medical Physics and IAEA [11]. The course produced its first graduates in 2015 and it was only natural for the first IOMP international accreditation to be associated with this MSc.

Activity: IOMP International Accreditation of Educational Courses

The need of an accreditation process was seen early on and initial steps were made back in 2006 [12]. The first implementation was during the term of office 2015-2018. The accreditations visits were performed by S Tabakov and J Damilakis in 2015 and 2016 with the support of the MSc team in Trieste and the IAEA. What followed was the preparation of the Accreditation Manual, a task headed by J Damilakis with the full support of all ETC and ExCom [13]. These activities continue in the current ETC, headed by A Chougule.

The accreditation was in close contact with the activities of the International Medical Physics Certification Board (IMPCB), headed by C Orton and R Wu. IMPCB was formed as an independent body (with IOMP support) during the IOMP term June 2012- June 2015. At the end of this term a Memorandum of Understanding was signed between IOMP and IMPCB at the Council meeting in Toronto, WC2015 [14], where the IOMP has the role of Principal Supporting Organization with three representatives on the IMPCB Board of Directors (the current such Directors being: KY Cheung, J Damilakis and P Russo). Other IOMP ExCom members (T Kron and T Suk Suh) also took part in the IMPCB activities. The first IMPCB certification of National Boards were in Hong Kong and South Korea and currently they also provide certification for the colleagues from the International MSc in Trieste. This collaboration between IOMP and IMPCB also continues and strengthens.

Activity: IOMP collaboration with IAEA, WHO and other International Organizations

This activity is ongoing for all previous IOMP offices and continued with the same strength over the past term of office. As an example almost all IAEA publications related to medical physics have been developed in cooperation with and endorced by the IOMP. These publications, as well as various courses, have educational purposes. It will be impossible to list all publications where all ExCom IOMP members contributed (in this and in the previous terms) [15]. However I shall mention the large International Conference on Radiation Protection in Medicine (Vienna, December 2017) [16], headed by the IOMP ExCom members G. Ibbott and M Rehani, who also supported effectively the links of IOMP with IRPA.

The highly effective work during the past term with the WHO resulted in the confirmation of our NGO status with the WHO in 2018 (what was a continuation of the activity from the last term, led by KY Cheung, S Tabakov and M Rehani) - this will be described further down. A relatively new activity was also initiated – the collaboration with the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), where G Ibbott and V Tsapaki are involved in the important new Report of UNSCEAR.

The links with our sister Organization – IFMBE were also strengthened through KY Cheung, who from June 2015 became the President of IUPESM - the Union of IOMP and IFMBE. For the first time we conducted a joint leadership meeting between medical physicists and engineers under the umbrella of IUPESM at the MEDICON2016 Conference in Cyprus. These meetings continue and plans are made for the joint celebrations in 2020 of the IUPESM 40th anniversary.

Activity: IOMP School

This was a new activity, which I proposed in 2015 primarily as a vehicle to help our young colleagues in LMI countries and to increase the IOMP visibility. The idea was supported by ExCom and introduced at the ICMP 2016 in Thailand as a Satellite event. The First IOMP School in Bangkok included 42 educational mini-Symposia [17,18]. It was mostly repeated at AOCMP 2017, Jaipur and a new IOMP School was also conducted at WC2018 in Prague. These Schools were mainly organized by J Damilakis, S Tabakov, M Stoeva, A Krisanachinda and A Chougule. The initiative expanded and now continues in the new ExCom, headed by a topical Work Group. The intention for the future is also to make the IOMP School as an established resource-generating activity, however its most important element will continue to be supporting our young colleagues from LMI countries.

Activity: IOMP incorporation

The activities, described above, prepared a very good background for the expansion of the profession. However, a problem the Organization had for many years was related to the fact that IOMP was not a legal body. Hence it cannot bid for projects and external funding for our future professional activities. Arranging the legal status of the IOMP was a main task over the past term of office. A Work Group was formed to explore this, including S Tabakov (Chair), S Keevil and S Hawking, with the strong support of the UK Institute of Physics and Engineering in Medicine (IPEM), who is hosting IOMP. The very important question about IOMP incorporation was discussed at each ExCom meeting.

The Work Group had a number of meetings with Law and Finance Companies for the purpose of finding a suitable legal status for incorporation. The subject was very complex, as IOMP has 86 national member organizations. The solution, which was found, and supported both by the IOMP ExCom and the IOMP Regional Coordination Board, included forming a specific IOMP Company to represent legally the IOMP Organization. The Board of Directors of the IOMP Company consists of the five elected Officers of the IOMP Organization – i.e. President, Vice-President, Secretary-General, Treasurer and immediate Past-President. The Directors plus the elected Committee Chairs form the Company membership. The members of the Company represent the interests and fulfil the objectives of the IOMP Council. The Company objectives are the IOMP Organization objectives. The IOMP Statutes and Bylaws remain in place to govern the way the Organization operates.

The major step of IOMP incorporation was completed at the end of 2017 and the IOMP Company was registered in the UK Companies House on 21 Dec 2017 under Registration No. 11119605 (Fig.2). The Company began its activities on 1 January 2018 [19]. This was one of the most important steps in the IOMP History and continues with the full support of the current ExCom and Council and plans are made for the first projects to bid for.

Fig.2 Installation of the IOMP Company Registration Plaque, with IPEM staff: M Tooley IPEM President, R Cook, IPEM Chief Executive and S. Hawking, IPEM, York, UK, April, 2018

III. TRANSLATION OF RESEARCH INTO PRACTICE AND EDUCATION

Medical Physics is an extremely dynamic profession. The changes and improvements of various types of medical technology and methods and its clinical applications occur with such speed, making it difficult to follow with clinical introduction and current education systems. It was necessary to create an environment which encourages our researchers to think about the implementation of their results in both clinical practice and educational programs.

This translation of research into practice was another important area of the tasks ahead, which was supported by a number of activities.

Activity: IOMP Award for Invention and Introduction in practice

IOMP introduced in 2016 a special Award for colleagues who invented AND translated their results into practice: The John Mallard Award. This Award is planned for presentation at each ICMP (International Conference of Medical Physics, which is normally between the World Congresses) and honors a medical physicist who has developed an innovation of high scientific quality and who has successfully applied this innovation in clinical practice. John Mallard, one of the main scientists behind the development and introduction of MRI and PET, is also one of the Founders of IOMP (the first IOMP Secretary General and the first President of IUPESM). I was assisted in this activity by S Renha and P Smith and travelled to Aberdeen, where J Mallard still lives for an interview before the inauguration of the Award at the ICMP2016, Bangkok [20,21].

Prof. John Mallard is also the founder of the MSc in Medical Physics in Aberdeen, UK and this award links well innovation with its implementation in education. The next such Award will be presented at ICMP2019 in Chile.

Activity: IOMP cooperation with CRC Press

The publications of high quality textbooks has always been a priority of the IOMP, handled by the Publication Committee (headed by T Suk Suh) [22]. The period June 2015 – June 2018 was very active for the CRC Series in Medical Physics and Biomedical Engineering (Editors: J Webster, R Ritenour, S Tabakov, K Ng). After 2009 the Series work resulted in 37 textbooks commissioned and published by CRC Press, about 45% of these – during the period 2015-2018. Among these publications were books edited by M Stoeva and P Russo, both members of the current ExCom.

Alongside these Series activities a new CRC Focus series was launched aiming at quick publications related to the newest development of the profession. Very active in this initiative were T Suk Suh and M Stoeva, who became the first Editors of the CRC Focus Series.

Activity: Journal Medical Physics International (MPI) expanding audience

The professional development of medical physics in many countries and the implementation of various methods and equipment in clinical practice were the main reason for the creation of the MPI Journal during 2013. As promoters of the idea, S Tabakov and P Sprawls were appointed as Founding Co-Editors of MPI. The continuation of MPI during this period expanded the focus on practical applications and links with the industry. A number of new educational initiatives were also included, as well as co-Editorials with the other Journals in the profession. MPI quickly established itself as an imperative online publication, free for all, focused towards our colleagues from LMI countries. The MPI fulfills a very special need by publishing articles to support education and the ongoing development of the medical physics profession and its organizations. In collaboration with the other medical physics journals, the MPI is with internal reviewing and does not publish research reports. The MPI statistics from this period showed that the number of readers per month reached 10,000. On this high note MPI Journal completed its first term in 2017 and the Co-Editors were approved for continuing another term [23].

The technical editing of MPI, as well as the editing of the IOMP Newsletter Medical Physics World, were expertly performed by the ExCom member M Stoeva. Both publications continue strongly in the current term of office.

Activity: Project History of Medical Physics

The foundations of this project were laid down in 2007, as part of the project EMITEL. Based on this I prepared the idea in 2015 as an international IOMP-led project [17, 24]. The project was discussed and approved both by Publication Committee and the ExCom. Its purpose is to show the creation and evolution of different equipment and methods, as well as their clinical application; the overall development of the profession and the main contributors in the various topics in medical physics. The first chapters of the History project were prepared by 2018 and published in the first Special Issue of MPI [25]. This project will continue its development over many years ahead and will be left with open end in order to be constantly updated in future.

The History of Medical Physics project is also related to the visibility of medical physicists, as it will show the contribution of many colleagues to the overall development of contemporary healthcare.

IV. Recognition and visibility of medical physics and engineering

The visibility of our profession is directly related with the recognition which our colleagues all over the world receive in their Hospitals, Universities and Institutions. This underpins the ongoing expansion of the profession. IOMP, IFMBE and IUPESM did a lot in previous periods to include our professions into the International Classification of Standard Occupations (ISCO-08) [26]. This work further continued in the activities bellow.

Activity: International Day of Medical Physics (IDMP)

This activity was also a continuation of the excellent work of the previous two terms of offices. The idea was introduced by S Renha and F Nuesslin in 2012 (based on suggestion of J Pinuela). The initially discussed IDMP date (30 August, establishing of IOMP) was not convenient, hence J Damilakis proposed several other dates. During the EMPEC2012 in Sofia an ad-hoc meeting of J Damilakis, S Tabakov, M Rehani and V Tsapaki agreed on 7 November (the birthday of Maria Sklodowska-Curie) as the IDMP date, what was approved by the then ExCom, headed by KY Cheung, and J Damilakis was appointed Coordinator of this activity. Since the first IDMP in 2013 almost all colleagues in the profession took most active part in celebrating our professional day and promoting the contribution of medical physics in medicine [27]. Over all year the overall IDMP coordination was done very well by the ExCom member J Damilakis and his team. Topical conferences were made in many countries and a dedicated website was created for the IDMP. All these activities continue in the new term of office, led by a new Work Group.

The 150th birthday of Marie Curie was celebrated with an additional dimension – Women in Medical Physics. It was web-casted globally and most ExCom celebrated it with our colleagues from Asia, at the AOCMP in Jaipur, India (Fig.4) [28]. The activities, aimed at encouraging women to enter the profession.

The work of the IOMP Women Sub-Committee, led by the Secretary General V Tsapaki, was very successful and resulted in a proposal to IOMP to form a full committee on the subject – an activity to be continued in the next term of office [29, 30].

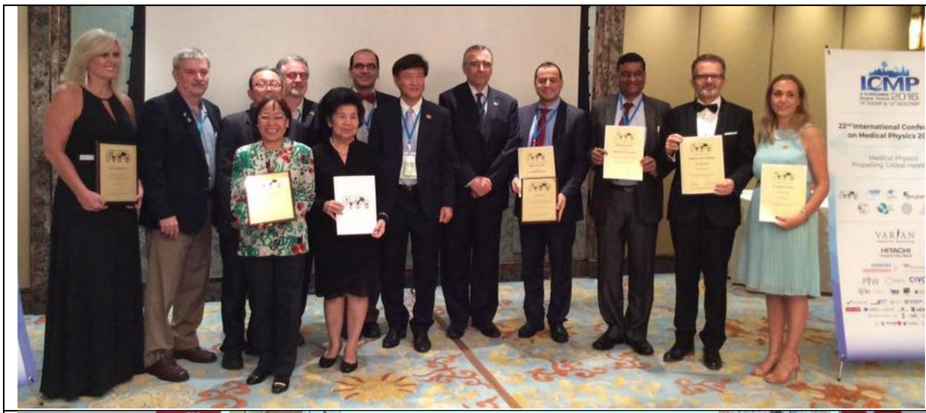

Fig. 3 First introduction of IDMP Awards and Honorable plaques, ICMP2016, Bangkok, Thailand

Fig. 4 Join celebrations of IDMP 2017 (Theme: Women in Medical Physics) at the Asia Oceania Congress of Medical Physics, Jaipur, India

Activity: Increasing the number of IOMP Awards

Acknowledging the contribution of various colleagues to our profession is another vehicle for its visibility. During the period 2015-2018 we continued and further expanded the acknowledgement of medical physicists with the IOMP Fellowship (FIOMP). This initiative was developed over the past years by S Tabakov, D Frey and T Kron and introduced during the celebrations of the IOMP 50th anniversary at ICMP2013, Brighton, UK [31,32]. During the past period we honored with the FIOMP leaders of our Regional Organizations (Federation) and other colleagues with significant contribution to the international development of the profession.

In this connection IOMP introduced also a new annual award – The IDMP Award. It recognizes excellence in Medical Physics with a particular view of promoting medical physics to a larger audience and highlighting the contributions medical physicists make for patient care. The first IDMP Awards were presented at the ICMP2016 in Bangkok and are now a regular IOMP activity (Fig.3).

As a whole the Awards and Honors Committee, headed by S Kodlulovich-Renha, had a very busy and productive period, which continue in the same way at present [33].

Additionally I ordered new Honorable Plaques, a new IOMP Gavel, and Folders with new design for the IOMP Diplomas and Awards.

Activity: Medical Physics World (MPW) Newsletter, IOMP Web site and other visibility

The new design of the MPW was made in the previous term (immediately after the World Congress in Beijing), this was the work of the MPW Editor at the time V Tsapaki and the Technical Editor M Stoeva [34], who became MPW Editor in 2015. Their very effective collaboration continued and MPW became an excellent e-publication, distributed globally [35]. During 2015-2018 MPW also pioneered special issues, specifically mentioning the one about Women in Medical Physics (in 2017) [36].

To further enhance IOMP visibility among the young colleagues, the MPW Board included activities related to expanded use of Social Media, what continues and expands at present. Also news were sent to all IOMP Member Societies by the Secretary General V Tsapaki, who worked relentlessly in handling very effective links with the IOMP Members worldwide.

The IOMP Web site Group was headed by the ExCom member M Stoeva. They handled very well the site and included in it new sub-sites for IDMP and for Women. An important activity during the period was the renovation of the IOMP Web site. The overall development and its funding were approved [30] and it was decided the activity to expand also in the coming period in order to collect better feedback from the new ExCom. The renewed IOMP web site (as before: www.iomp.org) will be announced soon.

Activity: Confirming the IOMP status as Non-Governmental Organization (NGO) to WHO

After the initial acceptance of IOMP as NGO by the World Health Organization (WHO) in 2015, we had regular meetings and projects with the respective officers of WHO. Due to space limitations I could not list all these, but would mention our input to the WHO List of Priority Medical Devices for Cancer Management, WHO Global Strategy for Health Workforce [37] and many joint activities related to Patient Safety. The confirmation of our NGO status with WHO required IOMP to be a legal body, thus as soon as we incorporated IOMP, we prepared our documents to WHO and our status was approved at the beginning of 2018 [38]. The Task Group of this activity included M Rehani, S Tabakov, V Tsapaki, KY Cheung. M Rehani was very active in these activities, and also in our links with IRPA, IAEA and other related International Organizations.

V. OTHER ONGOING ACTIVITIES

In parallel to the above three areas in the plan, which included mainly new activities, we continued with the well-established activities of IOMP, related to support for our National Member Societies in various countries:

Activity: Scientific, Professional, Educational and other activities

These activities are continuation of all previous years of IOMP existence and they were greatly handled by the Scientific Committee (headed by G Ibbott), Professional Relations Committee (headed by Y Pipman) and Education and Training Committee (headed by J Damilakis). These Committees approved many applications for endorsement or co-sponsoring, what helped the professional development and visibility of our colleagues in many LMI countries. These activities were included in the specific reports from the Committee Chairs [39, 40, 41]. Special mentioning requires our collaboration with the ISEP Programme of AAPM, supported by our colleagues from the USA, with whom we developed excellent collaboration over the past period (Fig. 5). Another mentioning is related to our collaboration with the IUPAP. S Tabakov and the Chair of AC4 (F Nuesslin), applied successfully for sponsorship of 3 Workshops related to Capacity Building in Developing Countries (the one from WC2015, Prague, features in this issue).

The work for the Scientific Congresses and Conferences was also very active. I shall mention some: The ICMP 2016 in Bangkok, Thailand (Organized by A Krisanachinda with support from T Suk Suh and S Tabakov), its Abstracts were published by MPI, co-edited additionally by G Ibbott, M Stoeva and V Tabakova [42]; The First European Congress on Medical Physics, 2016, Athens, Greece (Organized by J Damilakis and V Tsapaki), and the Latin American Congress on Medical Physics (organized by G Sanchez and S Renha, IOMP representative Y Pipman); at both of which IOMP started acknowledging the Presidents of Federations with special Plaques. Similar mentioning requires the Asia Oceania Congress of Medical Physics, 2017, Jaipur, India (Organized by A Chougule), from where IDMP 2017 was web-casted. The other Conferences and Congresses are in the respective reports in the Medical Physics World [43].

During this period the IOMP encouraged the development of several new societies. The PRC assessed positively their applications, among them specially mentioning the first Affiliated member.

The active work of these committees included also re-structuring of the Library program, initial steps for creating Emergency Response Sub-Committee and organizing a new Digital Library of educational resources. All these activities will continue in future.

Financially IOMP completed the term with a surplus, specially noting the work of the Treasurer A Krisanachinda, the Finance Sub-Com and specially H Hawking for their activities in arranging the taxation status of the Organization.

Activity: Support for the professional development in Africa and Latin America with Caribbean Region

This activity was a main focus of IOMP for the past three terms of offices. IOMP worked very closely with IAEA on the subject and supported their large Regional projects in these geographical regions, aiming at creating Regional educational and training activities. The Leadership of the respective Regional Organizations (FAMPO and ALFIM) were very active. As a result the coming ICMP2019 was selected to be in Chile. During this period ALFIM opened their Newsletter in Spanish

Fig. 5 Meeting of IOMP ExCom with the AAPM Officers, Denver, Colorado, USA, 2017

Fig. 6 Presenting the IUPAP Young Scientist Medal to Dr F Hasford in Vienna with colleagues from the IOMP RO in African (FAMPO) and colleagues from the IAEA, Vienna, Austria, 2016

"Revista Latino Americana de Física Médica".

A Pan-African Conference was prepared to be in Nigeria, but was postponed. However, new FAMPO web site was developed and plans were initiated for opening a regular publication of FAMPO for medical physicists in Africa. In this line it was very good to see the IUPAP Young Scientist Medal being presented for the first time to a colleague from Africa, F Hasford, who was later elected Secretary General of FAMPO (Fig. 6).

VI. Conclusion

The activities described above created a good environment and background for further developments addressing the need for the rapid expansion of medical physics – by 2035 and beyond. The increased membership over the past 20 years confirms that this expansion, although challenging, is possible to achieve [3]. At the end of the term June 2015-June 2018 we created a Work Group to discuss the strategy of professional development in the next 6 years (S Tabakov, M Rehani, J Damilakis, KY Cheung), which drafted some long terms tasks [44], but left this to be completed in the new ExCom, having the input of the newly elected Chairs and Officers.

In the present paper I traced most of the activities, which IOMP continued from the previous successful period, as well as showed the new initiatives, which the tradition of our Organization will carry forward. More importantly, the paper presented an overview and a vision, which the IOMP ExCom followed during the term of office.

Over the many years of its existence IOMP achieved much for the profession and often these activities took very long time. For example more than 10 years work went into the inclusion of our profession in the ICSU/ICS (International Council for Sciences), and even longer time was spent to include medical physicists and biomedical engineers in the ISCO-08 of the ILO (International Labour Organization). However these activities were pivotal for opening new working places globally, for funding of new projects, for new research and clinical activities, for starting new educational classes, etc., etc. These achievements contributed to considering our profession among the main factors of contemporary healthcare. This work has been done by many of the past IOMP Executive Committees – i.e. continuity has been essential for the success.

The work of the IOMP ExCom and Committee members is made by colleagues who contribute voluntarily to the benefit of thousands medical physicists all over the world. On a personal level my activities in IOMP started in 1997 (when I was elected member of the Education and Training Committee), and for more than 20 years I was witness and contributor to various such initiatives. In 1997 there were about 14,000 medical physicists around the world (starting from 6,000 in 1963). Now we are more than 28,000 – doubling in just 20 years (very much underpinned by introducing e-learning). What is more important – we achieved increased visibility in all hospitals and universities. IOMP, its Regional Organizations (EFOMP, AFOMP, SEAFOMP, MEFOMP, ALFIM, FAMPO) and large societies with international activities as AAPM, IPEM, COMP and others, have worked very hard for this growth and success. It has to be underlined again that all this work was performed by colleagues alongside their clinical, academic, administrative or other duties. For me in particular the past 6 years were the period when my students in King's College London grew from 30 to 120, and this had to be handled with the same resources.

In the past period (June 2015-June 2018) IOMP had 14 meetings of ExCom and many other topical meetings (most - virtual). The atmosphere of these was one of collaboration and friendship, what was important for the effective progression and completion of the many tasks described here. I expressed in my official report cordial gratitude to the colleagues in the IOMP ExCom and Committee members [6], and sent Letters of Gratitude to each Committee member. Here I would like to again thank all colleagues who worked in IOMP in this period, also thanking my wife and colleague V Tabakova for her constant support. I would also like to wish all the best to our new IOMP ExCom toward the benefit of our profession: M Rehani (President), V Tsapaki (Secretary General); J Damilakis (Vice-President); I Duhaini (Treasurer); S Tabakov (Past-President); G Ibbott (SC Chair); A Chougule (ETC Chair); Y Pipman (PRC Chair); P Russo (PC Chair); S Renha (AHC Chair); M Stoeva (MPWB Chair).

Finally, I would like to complete this paper with the slogan, I used in the Plenary Speech at the WC2018 Prague to encourage all colleagues to work together for meeting the challenge ahead: ***"United We Are Strong"***.

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COLLABORATING JOURNALS

HISTORY OF THE *BRITISH JOURNAL OF RADIOLOGY*

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Abstract — **A short article tracing the history of British Journal of Radiology (BJR) through to the present day.**

Keywords— **British Institute of Radiology, Professional Journals, British Journal of Radiology.**

I. INTRODUCTION

British Journal of Radiology (*BJR*) is the journal of the British Institute of Radiology (BIR). The journal has roots dating back to 1896 and the launch of *Archives of Clinical Skiagraphy*, only a year after the discovery of X-rays, becoming the world's first journal dedicated to the then emerging field of radiology.

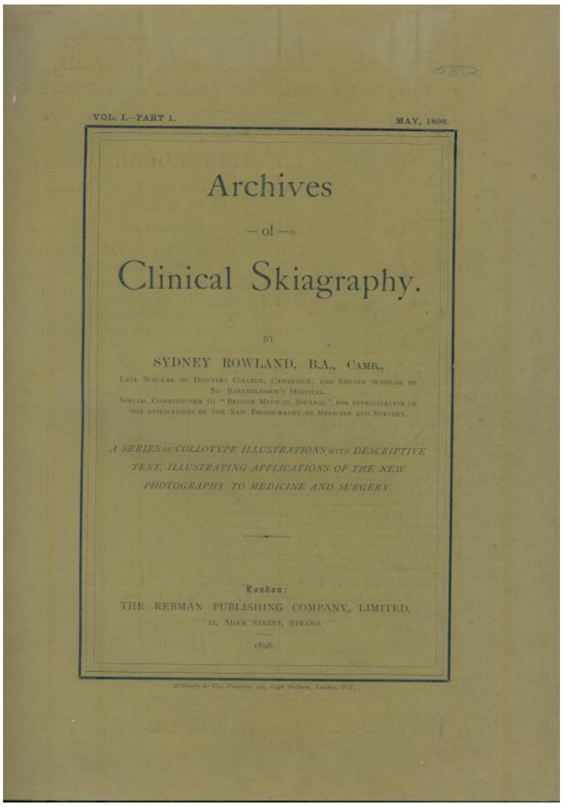
Medical journals may be compared to human life, having a conception, birth, growth, maturity, and possible decay and death. Journals may be conceived for a number of reasons. The journal may be purely scientific and perhaps with a specific purpose such as The Lancet which was conceived as a campaigning journal. The journal may be associated with a particular discipline, and this was the case with the journal that became the current *British Journal of Radiology* (*BJR*).

II. THE EARLY DAYS OF X-RAYS

Wilhelm Röntgen discovered the new X-rays on 9 November 1895, and there was an immediate international sensation in both popular and scientific circles [1]. The general public had to be reassured that this was a real discovery by a serious scientist. Röntgen presented his "preliminary communication" of the discovery on December 8 1895 and sent copies of his reprinted paper to scientific colleagues throughout the world.

The first radiograph printed in Great Britain was in the *British Medical Journal* (*BMJ*) of 25 January 1896, and was taken by Alan A Campbell Swinton of his own hand, who commented that, "these photographs are in the nature of shadows, though shadows produced by rays which are not luminous." [2].

This was rapidly followed by a long *BMJ* editorial on 1 February giving an account of what was known of the discovery [3]. Sidney Rowland was a medical student at St Bartholomew's Hospital in London and was working as a medical journalist at the *BMJ* under the editor Ernest Hart who was his uncle, in what we would now call an internship. Ernest Hart was one of the great medical editors and had been at the BMJ since 1866, leading many effective editorial campaigns and markedly increasing the prestige of the journal. Hart appointed his nephew Sidney "to investigate the application of Roentgen's discovery and to study practically its applications" and the first report appeared on 8 February 1896 [4]. Hart's choice of his nephew was inspired and the series of papers gave accurate and detailed accounts of the "New Photography" as it became known.


VOL. I.–PART 1. MAY, 1896.

Archives
– of –
Clinical Skiagraphy.

BY
SYDNEY ROWLAND, B.A., CAMB.,
LATE SCHOLAR OF DOWNING COLLEGE, CAMBRIDGE, AND SHUTER SCHOLAR OF ST. BARTHOLOMEW'S HOSPITAL.
SPECIAL COMMISSIONER TO "BRITISH MEDICAL JOURNAL" FOR INVESTIGATION OF THE APPLICATIONS OF THE NEW PHOTOGRAPHY TO MEDICINE AND SURGERY.

A SERIES OF COLLOTYPE ILLUSTRATIONS WITH DESCRIPTIVE TEXT, ILLUSTRATING APPLICATIONS OF THE NEW PHOTOGRAPHY TO MEDICINE AND SURGERY.

London:
THE REBMAN PUBLISHING COMPANY, LIMITED,
11, ADAM STREET, STRAND.
1896.

Fig. 1 Wrapper cover of the first issue of the Archives of Clinical Skiagraphy, May 1896.

Rowland obviously found medical journalism very much to his taste and started and edited a new journal, the *Archives of Clinical Skiagraphy* (Fig 1), which was the seed of the *British Journal of Radiology*. A skiagram refers to a radiographic photograph and is derived from the Greek σκια (skia) for shadow, since radiographs are of the nature of shadows. In his preface to the first issue Rowland wrote on 2 April 1896 that “the object of this publication is to put on record in permanent form some of the most striking applications of the New Photography to the needs of Medicine and Surgery.”[5]. Even at this early time Rowland comments on the obvious usefulness of the new discovery. The journal contained many full-page radiographic plates (Fig 2) and Rowland observed that “in the plates presented in the first number of a publication which will, I hope, take a permanent place in Medical literature, I have presented some examples of the more difficult and instructive achievements of Skiagraphy up to this date”. Rowland finished by thanking all those who had sent him radiographs for publication. Sidney Rowland was not to stay with radiology and joined the Lister Institute as an assistant bacteriologist in 1898. In the First World War Rowland took the first mobile pathology laboratory to France, and died in March 1917 investigating an outbreak of meningitis in Mesopotamia.

The Archives increased in size and changed its name to *Archives of Skiagraphy* in April 1897. It is now difficult to imagine the difficulties experienced by the pioneers, and this is shown in the words of Charles Thurstan Holland, the Liverpool general practitioner who became an early radiologist and ultimately the president of the First International Congress of Radiology held in London in 1925. Writing in 1936 towards the end of his life Holland said, “there were no X-ray departments in any of the hospitals. There were no experts. There was no literature. No one knew anything about radiographs of the normal, to say nothing of the abnormal.”[6]. The journal therefore became essential to disseminate information and experiences, and advice about practical radiography. There was a page devoted to answers to questions sent in by correspondents, and there were also book reviews and advertisements. The role of advertisements in journals has never been simply about generating income for the publishers. Advertisements give the readers of the journal information about resources that they need to develop their clinical practice, describing their photographic plates, X-ray tubes and apparatus.

III. THE INVOLVEMENT OF SOCIETIES

Many had seen Sidney Rowland’s articles both in the *BMJ* and in the popular press and wanted to meet to discuss this new field of radiology. Dr David Walsh therefore called a first meeting on 18 March 1897, and the first formal meeting of what was called the “X-ray Society" was held on 2 April 1897 [7]. The well-known physicist Silvanus Thompson was the first President by 3 June 1897 and on 7 June 1897 Wilhelm Röntgen was elected as the first honorary member, with the second honorary member being the British physicist Sir William Crookes. From the beginning it was decided that membership should “include all who are interested in the scientific study of the Röntgen Rays.” This decision was to prove crucial to the ethos of the organisation. The name of the new society was soon changed to “The Roentgen Society” in honour of the discoverer of the X-rays, and a temporary home was found in rooms at the Medical Society of London in Chandos Street. The name of the journal *Archives of Skiagraphy* was changed to the *Archives of the Roentgen Ray* for the July 1897 issue, and it was noted in the editorial that the journal will “record the proceedings of the recently formed Roentgen Society, and will consist of original communications, notes, and correspondence… (and) offers itself, not merely as a journal of the new photography, but to some extent as the exponent of an important discovery.”[8]. The journal was now quarterly and the complete title read *Archives of the Roentgen Ray* (Formerly *Archives of Skiagraphy*) *The Only Journal in which the Transactions of the Roentgen Society of London are officially reported* (Fig 3). Sidney Rowland initially shared the editor’s position with William S Hedley from the (Royal) London Hospital. The Archives went through a series of minor name changes until 1904 [9].

Fig. 2 Whole page image from the first issue of the Archives of Clinical Skiagraphy, May 1896. An enchondroma of the base of the fifth proximal phalanx is marked by an X.

In 1904 the new *Journal of the Röntgen Society* commenced as the Society’s journal and the link with the old Archives was broken [10]. This was related to tensions between the publishers of the journal and the council of the

Society. The new journal went through 19 volumes until 1924, when the name changed to *The British Journal of Radiology (Röntgen Society Section) The Journal of the Röntgen Society.*
The British Association of Radiology and Physiotherapy (BARP) was formed in April 1917 by a group of radiologists in London as a purely medical body unlike the multidisciplinary Röntgen Society. There was a concern that many who were in charge of radiology departments outside of the teaching hospitals were untrained in image interpretation although they were able to take good radiographs, and the aims of BARP were "to promote the advancement of Radiology and Physiotherapy on scientific lines under the direct control of the medical profession." Although BARP membership was only for clinicians it was possible for the council to elect scientists to both honorary and ordinary membership. The Archives became the journal of BARP and from June 1918 was called *Archives of Radiology and Electrotherapy. The Official Organ of the British Association of Radiology and Physiotherapy*. In 1924 the name changed to *The British Journal of Radiology (BIR Section) Archives of Radiology and Electrotherapy*. There had been a long-standing desire to have an institute for the study, and so the British Institute of Radiology (BIR) was formed. There were therefore two journals each called *The British Journal of Radiology*, which might be confusing.

The final change came in 1928 following the amalgamation of the BIR and the Röntgen Society, and the journal *The British Institute of Radiology, New Series* continues today.


Vol. VII.—No. 2.] JULY, 1902. [Price 2s. net.

ARCHIVES — OF — THE ROENTGEN RAY

(Formerly Archives of Skiagraphy).

THE ONLY JOURNAL IN WHICH THE TRANSACTIONS OF THE ROENTGEN SOCIETY OF LONDON ARE OFFICIALLY REPORTED.

EDITED BY

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Fig. 3 Archives of the Roentgen Ray from May 1902 with advertisement on the cover

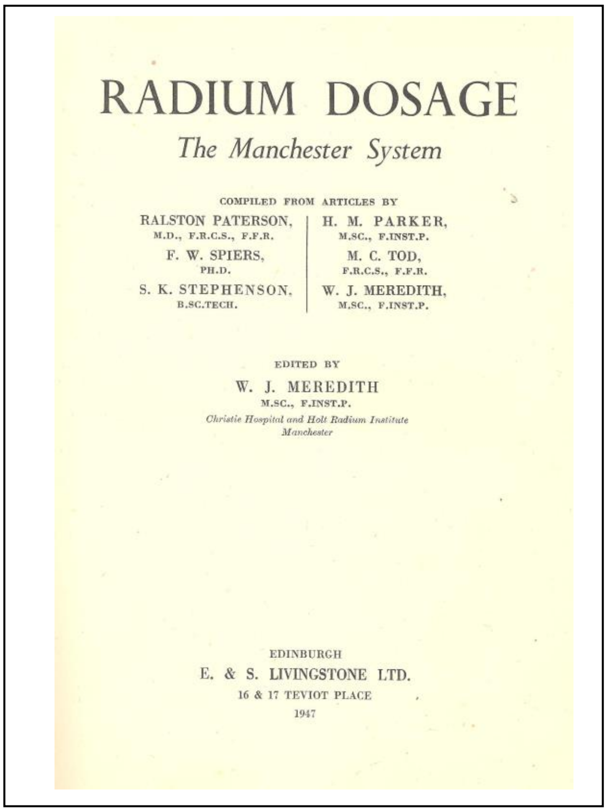
IV. The developing journal

It is interesting to observe changes in the journal that have occurred over the decades since 1896. These changes reflect both scientific, social and technical differences and developments.

The journal was traditionally published in regular hard copy issues and individuals and institutions would have them bound together for storage and reference. The author would purchase reprints of the publication from the publisher and would receive requests for reprints from colleagues often throughout the world. The author would then mail the reprint to the requesting individual. Today the journal is available online to members of the British Institute of Radiology and subscribing institutions, while reprints are available in PDF.

Many journals including *BJR* have undertaken a process of retrodigitisation of their historical archive. This has the significant advantage of making older material very much more accessible. The digitised *BJR* is a wonderful resource with papers by many of the great names of radiology having published in *BJR* or its precursors. The original writings of the major figures of the past such as Peter Kerley, Ralston Paterson, Douglas Lea, Louis Harold Gray, and James Brailsford are readily available. We can read the classic papers from the early days of radiotherapy, radiobiology, medical physics, nuclear medicine, ultrasound, CT scanning and magnetic resonance imaging (MRI). There is a tremendous wealth of material. As an example, the Manchester group made huge contributions to our understanding of cancer and to its treatment using radiotherapy. In 1947 the highly influential book "Radium Dosage, The Manchester System" (Fig 4) was published by E & S Livingstone and edited by the physicist WJ Meredith. The book was simply a collection of the papers that had been published in *The British Journal of Radiology* since 1934 by Ralston Paterson, Herbert Parker, FW Spiers, SK Stevenson, Margaret Tod and WJ Meredith.

The journal has however changed following changes in emphasis of the BIR. The early journals contained much more general X-ray publications, including more veterinarian, general science and industrial radiology. The journal continues to develop with the times and the needs of the community. *BJR* is now more devoted to radiological sciences as applied to human medical care.


RADIUM DOSAGE

The Manchester System

COMPILED FROM ARTICLES BY

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E. & S. LIVINGSTONE LTD.

16 & 17 TEVIOT PLACE

1947

Fig. 4 Radium Dosage, The Manchester System 1947

V. THE JOURNAL TODAY

Today *BJR* is a fully international journal with contributions from all over the world on topics covering all aspects of diagnostic radiology, radiography, radiotherapy, nuclear medicine, radiobiology and medical physics. Papers are published online via a continuous publication method; no longer do articles have page numbers, but each article stands alone with its own unique identifier assigned at the moment of acceptance [11]. As soon as a paper is recommended for acceptance by the editors, the author's version is made available online for all to read, while the final version of record is edited and prepared for final publication. The paper itself has evolved to include new types of media with functionality for video and audio content available as supplementary information along with multiple choice CPD questions included with some articles to allow the reader to get the most out of the research. *BJR* also publishes up to four themed special features per year; topical collections of articles on a noteworthy subject that are guest-edited by leading experts from around the world.

BJR is no longer a lone title but the head of a family: in 2015 *BJR|case reports* [12] was launched as a separate spin off to fill the gap left when Case Report articles ceased being accepted. Following its success, *BJR|Open* [13] was launched earlier this year. Both these new additions are open access meaning that everyone in the world has unlimited free access to the content.

Celebrating 125 years of publishing since its origins in *Archives of Clinical Skiagraphy*, 2020 will be a landmark year for *BJR*. A specially commissioned series of articles will be published throughout the year to celebrate the world's first radiology journal and look ahead to the future of this exciting and ever developing discipline.

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EDUCATIONAL RESOURCES

THE VERT™ PHYSICS ENVIRONMENT FOR TEACHING RADIOTHERAPY PHYSICS CONCEPTS – UPDATE OF FOUR YEARS' EXPERIENCE

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Abstract—**Radiotherapy Physics is a challenging subject – especially when teaching across disciplines. The primary role for therapy radiography students is entirely patient focused requiring clinical, empathetic, technical and other skills for successful treatment. Finding ways, therefore, of teaching fundamental Physics concepts, in a new and engaging manner, helps establish deep learning for enhancing excellent clinical practice and solid interprofessional working for advancing cancer treatments.**

Using a Virtual Environment for Radiotherapy (e.g. VERT™) as a specific form of eLearning is one way we've found that helps students engage better in learning and understanding key Radiotherapy Physics principles, in an interactive and dynamic manner, with all the benefits of the environment.

We have successfully used VERT™ Physics, a specialized module within VERT™, for over four years now at the University of Liverpool in both 2D and 3D immersive modes to teach fundamental concepts to undergraduate and postgraduate radiotherapy students. First formats used small group sessions blending lecture and practical use for teaching concepts like consequences of FSD set-up error; beam quality indices and the derivation of field size factors. For each subject area, workbooks were provided with subgroups performing, alternately, calculations and virtual measurements using VERT™ Physics. Evaluation and feedback were excellent, especially regarding the small group methods; the results of which have been described previously.

This paper details the rationale and results of the evolution of this format over four academic years – now bringing in interactive demonstrations of the measurement and characteristics of PDD Curves. Students predict photon curves and compare them with VERT™ Physics measurements, and consider electron and proton modalities too, with peer-to-peer and expert tuition. Evaluations have again been very positive, with students appreciating the small groups and focused tuition, and showing potential improvement in assessment results since PDD characteristics have been taught supplemented by our VERT™ Physics workshop sessions.

Keywords— **Simulation, radiotherapy physics, radiographers, eLearning, VR.**

I. INTRODUCTION

Teaching radiotherapy physics and technology to student therapeutic radiographers (radiation therapists) is challenging for the student – not necessarily because of the level of complexity required for their ultimate clinical task, but because of the range of skills which the radiographer needs to have for effective and safe clinical treatment delivery. The intention is an informed viewpoint and understanding of concepts to better aid clinical work and the patient experience through the radiotherapy pathway. Perhaps for this reason, blended learning and teaching methods bring real, positive results – by integrating more creative teaching and learning methods with the traditional, didactic ones in order to aid engagement and promote necessary deeper learning [1, 2].

These are continually our aims with both our undergraduate and postgraduate therapeutic radiography students at the University of Liverpool, for most of the modules on the radiotherapy programmes; complementing teaching methods by the use of real (clinical) world technologies which can simulate the full clinical world extremely well [3, 4]. The Virtual Environment for Radiotherapy Training (VERT™) (www.vertual.co.uk) is one such environment we've found which, as a virtual one, brings a creative edge to teaching, enabling students to learn in an extremely engaging and interactive manner, using a number of different eLearning components and styles, whilst at the same time providing extra resources to complement the highly pressured real clinical equipment; with safety and freedom of risk at the centre of its design [4-10]

VERT™ has been a key component for our institution and many others both nationally and internationally for many years [3, 11, 12]. Its origins and original design features are well covered in the literature [5-8]. Its use for student radiographer training has been well noted, with recent extensions reported for students of radiotherapy physics too [13-20]. Staff training and competency is part of its use [11, 12, 21-23], as is also as a method for helping patients themselves understand the treatment they are about to undergo [23-25]. Our own use for teaching radiotherapy physics concepts has been documented [16-18, 26, 27], but VERT™ Physics has been found to be highly adaptable and our methods have evolved over the last four academic years.

This paper examines that evolution – the changes in and the rationale behind their development; and the continuing results obtained in terms of feedback and response from our students and, most recently, in terms of assessment marks – as an indication of the students ability to demonstrate the depth of their learning and understanding in concepts which are extremely important for their clinical work. Here is described the nature of our use of VERT™ Physics, beyond its design for clinical simulation [15], to one which still simulates the radiotherapy physics environment; but always with a focus on learning to aid clinical work and patient benefit, in a highly interactive, engaging and kinesthetic manner. The work reported here has continued to be run with second year undergraduates and both first and second year postgraduate radiotherapy students for the last four academic years. The main subject matter extension for the latter two years has been aimed at improving knowledge and understanding of radiation beam characteristics – for different energies and parameters, and comparisons with different modalities of electrons and protons.

II. MATERIALS AND METHODS

A. *Methods*

A.1 First Iteration of Teaching Methods (2014). The first iteration of the rationale and teaching methods using VERT^{TM} Physics have been communicated previously [16-18]. For the purpose of illustrating the evolution of the methods and continuity, they are described briefly here. Year groups (approx. 20 – 30 in number) were divided into smaller groups of approx. 6 – 10 students for each session. This was done to make feasible a more interactive and kinesthetic approach for all of the students. Because of the timing of the teaching of theoretical concepts and this practical approach within the semester (the theoretical concepts having been taught and discussed some weeks before), a 2 hour slot was devised, with the first hour being dedicated to a formal, refresher lecture on the appropriate radiotherapy Physics concepts which would be used in the practical session with 'virtual' Linac experiments. The recap highlighted the concepts of (a) inverse square law, particularly with respect to its use in calculating dosimetric errors when the wrong FSD is used for treatment fields; (b) central axis percentage depth dose curves as a characteristic of beam energy (especially with regarding to quality control and the measurement of quality indices); (c) the measurement of field size factors, so showing the origins of the data which the students had used for manual MU calculations. It also included elements of dosimetry which had been taught in the semester, mainly the use of ion chambers for photon measurements, dosemeter calibration (cross-comparison against a secondary standard) and the practicalities of independent, definitive calibration [28]. The lecture was 1 hour, followed by 1 hour of practical experiments.

For the practical experiments, students were given detailed (verbal) instructions and shown how to use the VERT^{TM} Physics software to make virtual measurements using the Linac. These included choosing and setting up the ion chamber block, changing depth of the ion chamber, and making measurements with the dosimetry panel for photon energies of 6 and 15 MV. Students were encouraged to use the hand pendant for the virtual machine to adjust set-up parameters, as per a real patient, and were invited to work with a machine type they were unfamiliar with from their clinical placements – to further expand their experience [16-18].

The group was split up into two, so that one smaller group (of about 3 or 4) could perform the virtual experiments using VERT^{TM} Physics, whilst the other group worked together to perform the calculations associated with each experiment. Three practical experiments were devised and used; these were (a) an experiment using the ion chamber block to investigate the dosimetric effects on the patient of incorrect SSD set-up (whilst the calculation group used the inverse square law to predict the dosimetric error); (b) an experiment to simulate measuring quality indices for different photon beam energies using a fixed SSD and two depths in the ion chamber block (Whilst the calculation group considered how to calculate the quality index, compare it with a baseline value and determine whether it was within a 1% tolerance for routine quality control); (c) an experiment to measure the fieldsize factors, using a fixed FSD and depth for the ion chamber block and different fieldsizes - whilst the calculation group considered how the fieldsize factor data would be derived from each of the data points, normalized to a factor of unity for the reference field size of 10 x 10 cm. In every case, experiments and calculations were performed for each available photon energy (6 and 15 MV), with the two smaller groups swapping roles (calculation and experimental) between each energy [16-18, 26, 27].

A.2 Second iteration (2015 and 2016):

Most feedback from the first iteration of this work was extremely positive [18]. However, in response to some of the slightly less positive comments, a key change was made for the second iteration and the way the class was run for 2015 and 2016. A number commented that the revision lecture at the beginning made the session feel overly long, difficult to focus upon, and difficult to appreciate the practical aspects with VERT^{TM} Physics. These were possibly linked with those responses which also looked for more time for the calculations and for the session as a whole. In essence, the students wished to be engaged and interactive with VERT^{TM} Physics much quicker and to have more time working together in the small groups and with the tutor, which was their overwhelmingly most reported comment [18].

So for the second iteration, the refresher lecture at the beginning was omitted. The VERT^{TM} Physics session was scheduled closer to the subject matter pertinent to these Physics aspects and the clinical work which they were meant to help with understanding (i.e. the consequence of FSD set-up error), was timetabled, so only a small brief, introduction was used, together with the same tutoring and instructions for the use of VERT^{TM} Physics as before, prior to going straight into the three main practical experiments described in A.1 above.

As previously, the group was split into two smaller groups; one starting with calculations, the other with the virtual experiments. At the end of the experiment for a particular beam energy, the groups swapped over; again employing, as previously, a change of all set-up parameters – so the new group doing the practical experiments would perform the set-up ‘from scratch’, in a similar style to that used on a real Linac in a definitive calibration [18, 28] for independence of measurement and confirmation of Linac calibration – as taught in theoretical classes for dosimetry.

Identical peer-to-peer teaching was encouraged for the calculations and also in the practical groups, especially for those students unfamiliar with the hand pendants. Another identical feature, preserved because of the positive feedback, was the use of workbooks and the whiteboard space – so students discussed and performed calculations on the whiteboards, with the use of workbooks detailing the experimental work instructions needed, providing extra workspace and allowing notes to be made and kept for future learning and revision for assessments. Once again, the sessions were evaluated anonymously and these results have been reported previously [16-18].

A.3 Third iteration (2017 and 2018):

For the most recent two years, further changes were made to the sessions, partly in response to the continuing very positive comments (where students were asking for a greater use of VERT^{TM} within the semester for teaching), but also in a desire to see if VERT^{TM} Physics could supplement and improve upon teaching used for other aspects of Radiotherapy Physics necessary for clinical practice – most notably in improving understanding of radiation beam depth dose properties for different energies, different field sizes and in comparison with other modalities like electrons and protons in clinical treatments. Given the positive feedback in the use of VERT^{TM} Physics and small group work, an extension was added to the sessions for the third and most recent iteration.

A.3.1 Interactive Demonstration: The engaging practice of the large screen (4m wide by 2m high, back-projected) and immersive style of work was used to introduce an interactive demonstration at the start of each session. Once again, VERT^{TM} Physics was used to illustrate Radiotherapy Physics concepts and equipment – the extension to previous years now being the use of the plotting tank; firstly as a very brief demonstration of how depth dose data was collected in reality in clinic, for manual MU calculation data charts and MU programmes, and also for data to verify TPS models for photons (Figure 1).

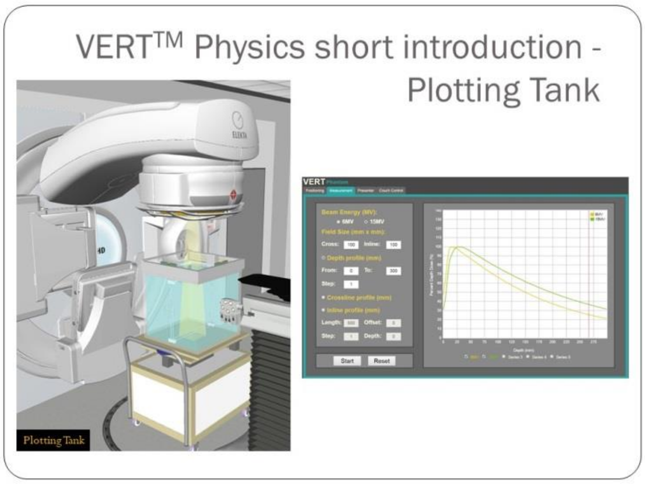

Fig. 1 Start of the interactive demo for teaching and learning about depth dose curves for different radiation beams – introduction to the plotting tank and the output (dosimetry panel) of the virtual measurements using VERT^{TM} Physics

The workbooks were also modified, with sections added in advance of the practical measurements, for students to predict percentage depth dose characteristics for photon beams (of different energies and different fieldsizes), electron and proton beams. Students discussed ideas in twos and threes during prediction, used the whiteboard to share their predictions and reasoning with the rest of the class and discussed the confirmation of results when measured with VERT^{TM} Physics on the large, immersive screen. Different modalities were also examined interactively, with students again making predictions of similarities and dissimilarities between modalities in their workbooks and on the whiteboards.

Concepts of changes because of phantom scatter and head scatter were examined for photons within the VERT^{TM} environment, using the large, wall-wide VERT^{TM} screen and immersive environment; with students encouraged to point out and discuss reasons for changes with energy and fieldsizes whilst gathered around the VERT^{TM} screen (Figure 2).

They were encouraged to make energy and fieldsize changes themselves, and dosimetric measurements using the virtual plotting tank in the VERT^{TM} Physics software. Similarly, students made predictions for electrons and protons, noting commonality of (e.g.) depth of maximum dose for electrons and photons. This was done again both in their workbooks after discussion with one another and on the whiteboards, before final expert, tutor-led versions were drawn on the whiteboard in summary of the main similarities and differences.

Fig. 2 Image of the full-size, 3D room screen set-up for the interactive demonstration and plotting tank measurements. Tutor and students would use mouse and machine specific hand pendant controls for set-up and measurements

A.3.2 Practical experiments: The second part of each session then proceeded with virtual Linac practical experiments in the same way as the previous two iterations. A very short introduction was given about the dosemeter block (see Figure 3) so students were aware of how actual measurements were conducted in the clinic, and also to continue their instruction in making virtual dose measurements themselves using the VERT^{TM} Physics software.

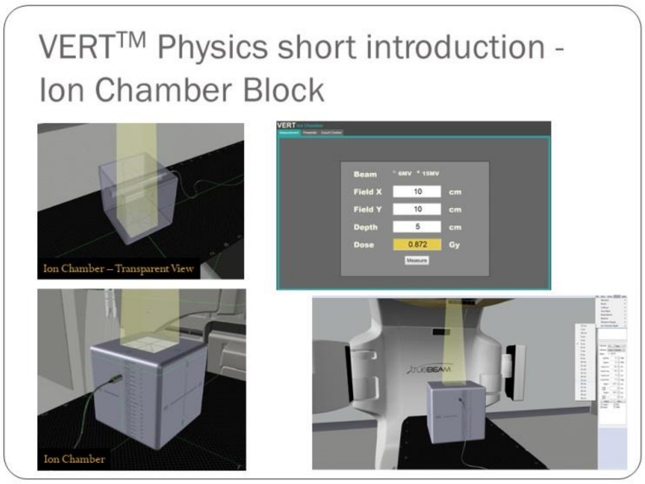

Fig. 3 Short introduction and instruction given in the use of VERT^{TM} Physics for the virtual practical experiments using the ion chamber block

The previous approaches of dividing the group into two to enable peer-to-peer and individualized expert tuition were maintained; as were the work instructions and workspace in the workbooks and on the whiteboards (see Figure 4); and the swap around between performing calculations and virtual experiments, and the concepts of independent set-up using the hand-pendants and software for each energy change.

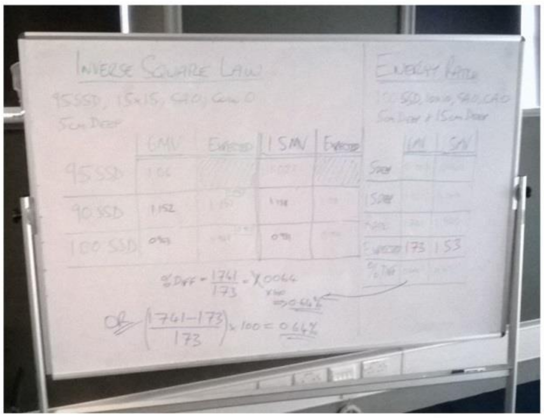

Fig. 4 The whiteboard workspace used by the 'calculation group' for the virtual experiments of using inverse square law to determine the dosimetric error involved with incorrect SSD in patient set-up (left hand side) and beam energy specification (quality index) (right hand side)

B. Evaluation and Analysis

B.1 Evaluations post session: For the first two iterations of the work, these have been reported previously [16-18] and were achieved using short, anonymized evaluation sheets given to each group member after the session. The same approach was maintained for the third iteration, inviting students to freely give feedback immediately after the full session (the interactive demo and the virtual practical experiments). The sheets used the same approach as previously, asking for open and honest opinions on the most positive aspects of the VERT^{TM} Physics session; the least positive aspects and any suggested changes for future sessions. All responses were qualitatively coded and organized into descriptive, common themes and responses.

B.2 Exam results analysis: Since part of the intention for making the changes for the third iteration was to see if VERT^{TM} Physics might potentially improve understanding in the assessment setting, the results of four consecutive years of unseen, written examinations were analyzed. These were for the 2nd year undergraduate students – for the postgraduates, this was not attempted, since their assessment was primarily by essay-style, written assignment, without the necessary sub-division of applied marks which could be analyzed. For the undergraduates, focus was maintained on the marks of parts of long answer questions which were posed to allow students to show their knowledge and understanding of the depth dose characteristics radiation beams of different energies, fieldsizes, FSDs and modalities.

III. RESULTS

The key responses from the first two iterations have been reported upon previously [16-18]; and key points following those publications and communications are shown in figure 5. The students enjoyed the ease of use of the software and were able to perform the virtual experiments extremely quickly. The blended learning approach made the sessions 'come alive' compared to the more didactic, but discussion led lectures. They enjoyed the safety of the virtual environment, but appreciated that the virtual experiments were conducted as if on a real Linac, with the same professional approach to independence of measurements and minimizing of risk for systematic errors (i.e. by way of independently setting up the virtual Linac). From both calculations and virtual experiments, they were able to appreciate the dosimetric consequences of a few cm of set-up error in FSD; and use their knowledge of legislation to determine whether such errors might be reportable to outside bodies under such directives.

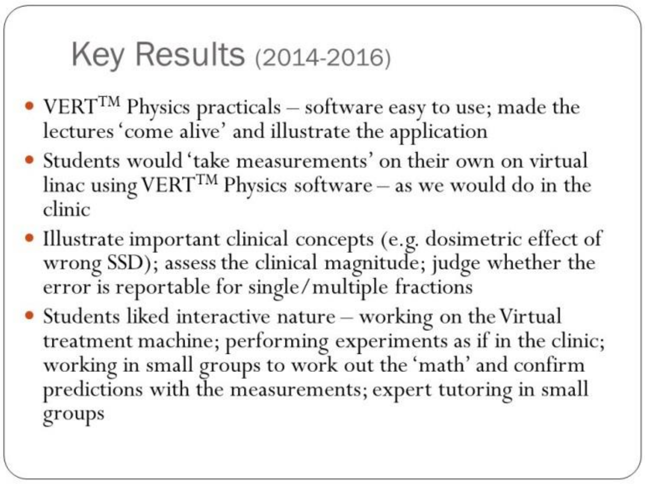

Fig. 5 Key results from the first and second iterations of the work with VERT™ Physics and therapeutic radiography students (UG and PG)

They commented highly and positively on the small group aspects, peer-to-peer teaching and individualized attention of the tutor for teaching and discussing concepts, particularly in relation to the calculations. So too the opportunity to perform calculations in predicting results which were then confirmed through the virtual practical measurements.

For the third iteration, the whiteboard final output is shown in figure 6, and the summarized and themed responses are shown in figures 7 and 8. Students engaged very well with the interactive nature of VERT™ Physics, and engaged very well with peer-to-peer discussion and prediction of depth dose characteristics in their workbooks. Some members of the group found the session a safe space to share their predictions with the class on the whiteboard for different energies and modalities. Students particularly liked the final, expert, tutor-led summary of characteristics drawn on the whiteboard, which they could use for their learning and revision for assessments (see figure 6).

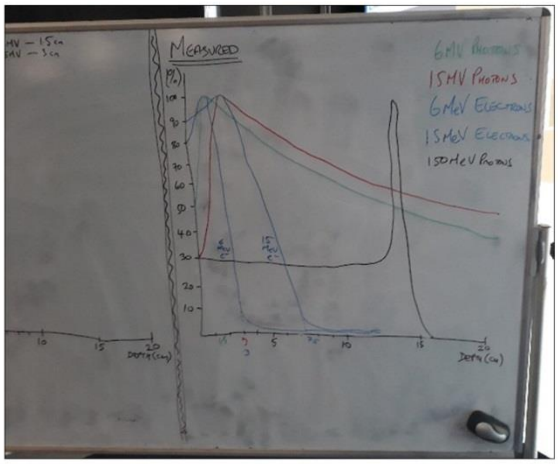

Fig. 6 The whiteboard workspace used for interactive work; predicting and comparing students' own knowledge and understanding with 'measurements' from the virtual VERT™ Physics environment. Final expert, tutor-led summary of characteristics is shown. Note, only photon measurements are possible through VERT™ Physics.

In terms of the anonymized evaluations and feedback from the students (figures 7 and 8), like the previous iterations, the responses are overall extremely positive. In terms of the good points listed, most felt that the sessions were well taught and explained and it made a difference in the use of VERT™ for this. The virtual environment was found to be very useful for explaining concepts and helping understanding. As with previous evaluations, the students appreciated the small groups, and working together within them, the interactive nature of the sessions, the workbooks for personalized working and the different way of learning enabled by the interaction, the whiteboards, the predictive nature of both the demonstration and the calculations, and the virtual environment. More sessions were called for like these ones.

In terms of points for improvement, they felt the session could have been longer, so that various elements (like the practical work) were not felt to be rushed, although some appreciated the time constraints within the timetable. As an illustration of different abilities, some felt that the session could have actually included more work, whilst some struggled a little with understanding the calculations within the available time. Some commented under this banner that there were no bad points, and they would like more opportunities like these.

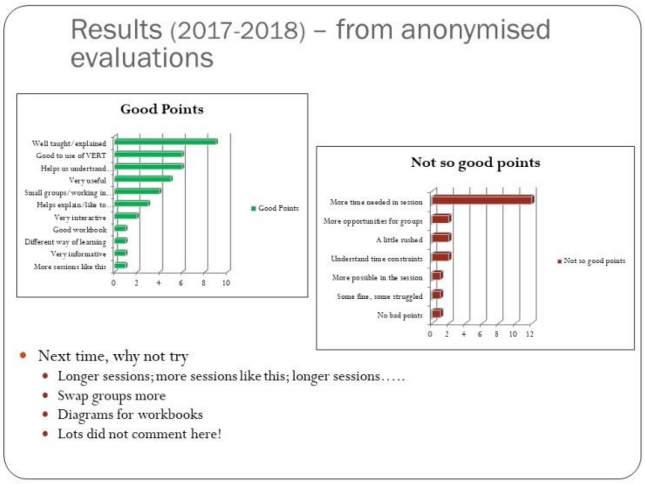

Fig. 7 Bar charts summarizing the key responses regarding 'good' and 'not so good points' for the third iteration of the work. The written responses for future suggestions are also shown.

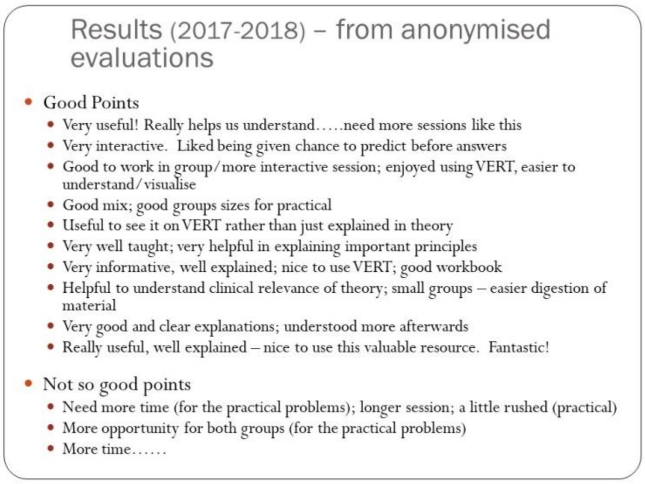

Fig. 8 Key responses from the third iteration of the work – where an interactive demo, followed by the virtual practical experiments, was used.

Regarding their suggestions for the future and things to try the next time, it was notable that many did not comment here – which may indicate an overall satisfaction with the session as it was. Those that did, re-iterated their desire to have longer and more sessions like this. By far the most popular response was for longer sessions, so that the smaller groups (calculation and practical) could swap around more. There was again appreciation for the workbooks, although some would prefer an enhancement here by providing more diagrams to explain the experiments and the clinical analogy being investigated for the simulation of FSD errors in set-up.

In terms of the analysis of examination results, the data is shown in figure 9. Exam scripts were analyzed for the maximum, mean and minimum marks, for the four years of assessments undertaken since VERT^{TM} was introduced into the department. Mean class size was 26, with a range of 22-30. Because of the timetabling of the sessions within the academic years, the data points for 2017 and 2018 shown in figure 9 correspond to results obtained after the introduction of the third iteration of the VERT^{TM} Physics sessions. We found that the range of maximum marks changed from between 71-80% to 86-89%; the range of mean marks from 46-47% to 58-61%....a full grade boundary (10%) change. Minimum marks are not really applicable, because they are weighted by the occasional student who did not answer the questions, and therefore scored zero for that question or part thereof.

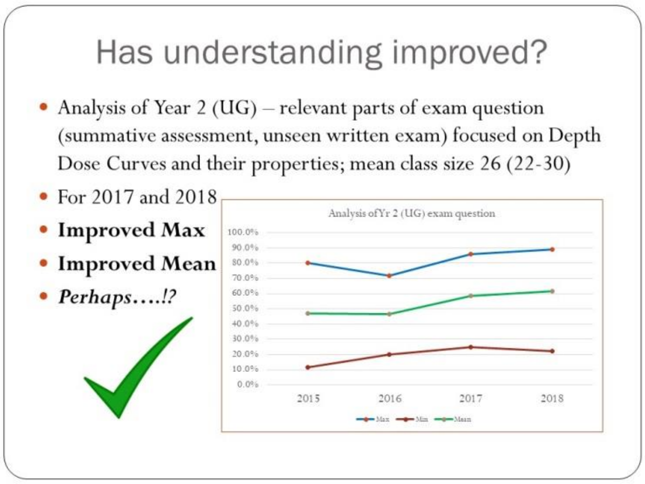

Fig. 9 Analysis of summative assessment components (exam results) which focus on depth dose curves for different energies and modalities. A modest improvement for both mean and maximum marks is noted for the third iteration (2017 and 2018)

IV. Discussion

The reasons for the evolution of this type of learning and teaching, in this very interactive and engaging way, have been explained earlier – but this was still quite a considerable risk; given the highly positive evaluations especially from the second iteration. However, as illustrated, changes were made for specific reasons (in response to the feedback) and only to parts of the sessions – thereby minimizing the risk to students own learning and to the engagement which the virtual environment engenders. The results have shown that the latest evaluations have been just as positive as the first two – with students finding the sessions useful and a great way to help understanding; for a number, they found the virtual environment and the interaction made it easier to understand the necessary concepts – better than just using theoretical, didactic classes on their own. They appreciated the clinical relevance of the concepts and the chance to use their knowledge and try to explain things first, before being confirmed by the software and the tutor.

The workbooks are very much appreciated too – similarly to the responses for workbooks used in other, more familiar clinical uses of VERT™ [14, 18, 19] and in other clinical modules within the programme (e.g. for studying anatomy and physiology). In an age of electronic, digital media being readily available (e.g. through tablets and phones), the students still value the tactile nature of the workbooks to perform calculations, share viewpoints and then to use for a revision resource.

The not so good responses all focused on 'more' – more sessions, more time, more opportunity to use this valuable resource and to have more sessions with this blend of interaction and engagement. This was particularly so for the virtual, practical experiments which followed the interactive demonstration. From a tutor's perspective, the time constraints on sessions were more difficult for the practical and calculation parts; for those students finding the calculations more challenging, this would naturally increase pressure and the feeling of being rushed. The increase in pressure was an aspect which was the antithesis of the desire of the sessions in the first place and is something to be addressed in the future – in order to hold a safe space for the students, with an environment to easily ask questions and gain from the individual tuition offered through the small groups.

Also from the tutor's perspective, the sessions in this format were extremely easy to devise and to run; an aspect which has been identified by other educational groups in the university [26, 29] when our experiences and results have been shared in general learning and teaching conferences and active workshops. The blended nature of the learning strategy, the work with small groups and the highly active and interactive nature of the work are common elements which can be applied across disciplines – and indeed is being shared across the University for innovation in educational methods and developing the university's curriculum across the board [29].

The analysis of the examination results shows some interesting trends and potential. Since the third iteration, both the maximum and mean marks have improved with changes of the order of a whole grade point (i.e. 10%). This could indicate the improved learning from these interactive and blended methods – but the exam questions used and considered are not always exactly the same format; so there are some potential difficulties in performing the comparisons. But the indicative direction is an improvement in results; which, for the best design of assessment, should mirror students being able to demonstrate an improved understanding in these subject areas.

As with previous reports in other sectors [30, 31], the virtual environment simulates the physical world extremely well – for us, it is in its use beyond its original design (i.e. mainly as a clinical tool), to one which VERT™ Physics was designed for (for simulating radiotherapy physics equipment and principles), to a further one which is simulating the real use of the Linac for performing dosimetric experiments and demonstrations for highlighting important physics concepts needed for clinical work, and confirming theoretical knowledge acquired, in a highly practical way.

V. CONCLUSIONS

In conclusion, the VERT™ Physics virtual environment has proven to be one which is useful and highly engaging for student learning. It is easily adaptable to different paradigms of learning and has continued, through different iterations, to work extremely well as a teaching tool – as evidenced by anonymized evaluations and feedback, and through the potential increase in assessment marks. Students continue to find it useful, helpful and interactive – enabling a more ready way for understanding these concepts. Students enjoy the sessions, especially the small group structure, with combined peer-to-peer and expert tuition; something which is transferable to other disciplines and subjects in education and learning. The results show they can undertake the virtual experiments very easily, and are more ready to try and discuss calculations in this style of environment – which they find safe and relaxed. However, longer sessions are necessary (and are being planned for in future semesters) in order to allow more and longer sessions, to maintain the relaxed and less-stressful environment originally designed. One might cautiously hope that the continued upward trend in assessment results continues, demonstrating a better and potentially deeper understanding of these important topics, for the good of the clinical service.

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DIGITAL ELEMENTS, IMAGE QUALITY, RADIATION EXPOSURE, AND PROCEDURE OPTIMIZATION

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Abstract — **The complex relation between digital image elements, blurring, noise and radiation exposure provides the opportunity for medical physicists to expand their professional activities from a focus on equipment function and safety to supporting the optimization of imaging procedures with a balance of image quality characteristics and radiation dose. This is being achieved with the enhancement of medical physics programs, for both physicists and other medical imaging professionals, to add emphasis to the effects of digitization on all aspects of image quality and the complex process of procedure optimization. The objective of this article is to contribute to the educational process for both medical physicists and other medical professionals with a focus on the characteristics of the digitizing process and its effects on image quality and related factors, with the goal of developing optimized clinical procedures.**

I. INTRODUCTION

The continuing development of medical imaging as a major clinical diagnostic method and the associated medical physics is defined by two major "landmark" events as illustrated in Figure 1.

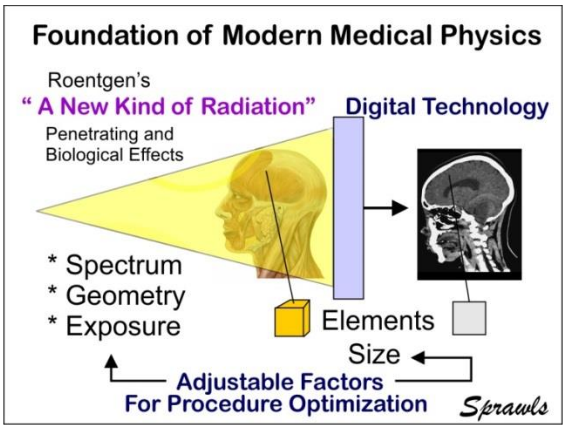

Figure 1. Two developments that form the foundation on which modern medical imaging methods are based.

The first was the discovery of "a new kind of radiation" and investigation of its properties by Roentgen in 1885. It was the radiation that could penetrate the human body, form images, and produce biological effects. This was soon followed by the discovery of radioactivity and radiations with similar properties. For almost a century both imaging and therapeutic applications developed and evolved based on the properties of these radiations. The practice of clinical medical physics and medical physics education was devoted to the characters of these radiations and the process of producing and controlling the radiation for both optimum imaging and therapeutic procedures.

The second was the development of digital technology with its major impact on society, including medical physics and clinical medicine. This was well underway in the 1970s and was a defining factor in the beginning of the second century of applied medical physics in the 1980s. Digital technology provided a foundation for image reconstruction from acquired data and made possible the development of the modern tomographic imaging methods--CT, MRI, SPECT, and PET--with the additional values of digital procedures for processing image to enhance quality, transmission, storage and retrieval and controlled display and viewing. Digital technology also contributes to radiation therapy, beginning with images and methods for treatment planning and controlling and optimizing procedures, such as IMRT, for effective treatment of cancer. However, in this article we confine consideration to the field of medical imaging, the author's area of experience.

Modern medical imaging and the associated medical physics is now the combination of two major realms, *radiation* and *digital technology*. Within each realm there are many controllable factors that must be considered to produce both diagnostic imaging and therapy procedures that are the most effective for each patient procedure.

A continuing challenge is that many of the adjustable factors have effects on several image quality characteristics and radiation exposure to patients, and these are often conflicting and opposing effects! An appropriate goal is to take the conflicting effects into account and for each patient procedure, diagnostic or therapy, develop a protocol or combination of adjustable factors that is *optimum* for that particular patient's clinical needs.

II. CLINICAL PROCEDURE OPTIMIZATION

Procedure optimization is an applied physics process. In *therapy* it is within the context of treatment planning and verification conducted directly by a physicist. In diagnostic imaging where a physicist is not directly involved with each individual patient procedure the role of a physicist is that of consultant to the clinical staff and as an educator. It is usually a radiologist who selects a protocol for a specific procedure, based on personal experience and professional references. However, there is a need for knowledge of physics and technology in order to understand the various protocols, their relation to image characteristics, and especially to the visualization of conditions within a patient body along with effects on factors including radiation dose to a patient.

The objective of this article is to contribute to the educational process for both medical physicists and other medical professionals with a focus on the characteristics of the digitizing process and its effects on image quality and related factors, with the goal of developing *optimized clinical procedures*.

III. THE DIGITIZING PROCESS AND ELEMENT SIZE

The major impact of applying digital technology in medical imaging and therapeutic procedures is that the patient body is divided into many individual small sample elements, voxels, and corresponding image pixels, with each represented by a numerical or digital value. It is the size of these elements that has a major effect on image quality and factors including radiation exposure and image acquisition time in many procedures. In principle, there is an optimum or "best" digital element size for each imaging procedure. This is determined by a combination of factors including the technical characteristics and design of the imaging systems, the physical characteristics of the anatomical structures, and signs of pathology within a patient's body. The adjustment of protocol factors including element size for each imaging procedure must take into account both the characteristics of the technology and the visualization requirements within the patient body as illustrated in Figure 2. As we will discuss later, it is the element size for a specific procedure that affects visibility within the body.

In projection imaging methods, especially digital radiography, mammography, and fluoroscopy, the design of the receptor generally determines element (pixel) size with some effect relating to the selected field of view (FOV). For the tomographic imaging methods (CT, MRI, SPECT, PET) element (voxel) is determined within the reconstruction process by a combination of adjustable protocol factors.

While some design characteristics of the imaging equipment (focal-spot size, collimation, receptor/detector thickness, etc.) do not directly determine element size they do establish ranges or limits on what would be an optimum element size for a specific imaging method.

It is the imaging elements, voxels and pixels that establish the major relationship between the design of the equipment and the optimization of clinical imaging procedures.

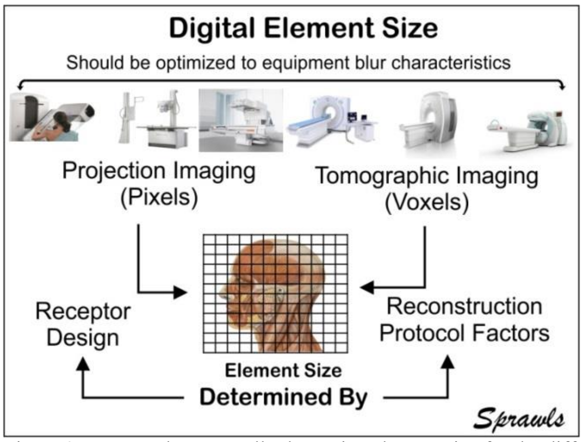

Figure 2. Factors that generally determine element size for the different imaging modalities.

Imaging element size varies over a considerable range covering the different modalities and relates to the design of the technology and the specific clinical applications. With each imaging modality or method, for example CT, the element size can be adjusted by the clinical imaging staff in the context of the imaging technique or protocol. It is these adjustments that can have a significant impact on image quality and other factors including radiation exposure to a patient. Voxel size is determined by the combination of three factors as illustrated in Figure 3.

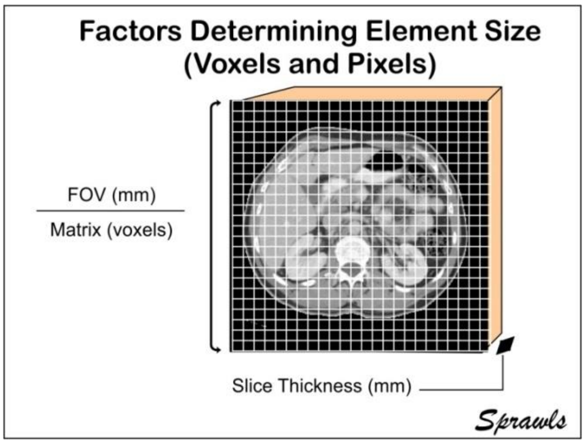

Figure 3. The three often adjustable factors that determine digital element size.

It is the ratio of the field-of-view (FOV) to the numerical size of the matrix that determines the "face" dimension of a voxel or pixel size in an image. For the tomographic imaging methods it is tissue voxel size, not displayed image pixel size, that determines image quality and visibility within the body. The significance is that the FOV within the patient's body is what affects mage quality. With many imaging methods the FOV is an adjustable technique or protocol factor. Using a smaller FOV reduces voxel or pixel size with the expectation of reducing digital blurring and improving visibility of detail as described later.

IV. IMAGE BLURRING

Blurring is the image quality characteristic that is directly affected by the digitizing process. All anatomical detail and structures within a voxel or pixel are "blurred together" and represented by one numerical value such as a CT number. The size and shape of the digital element defines the dimensions and characteristics of the blur. This digital blurring is in addition to the blurring from other design characteristics of the imaging technology such as focal-spot size, receptor thickness, and collimators in gamma cameras. This blurring is perhaps the most significant characteristic of digital imaging methods that relates and matches equipment design to optimized clinical procedures.

The fundamental question is this: what is the most appropriate element size for a specific clinical procedure? For this there is no simple answer because it depends on a combination of several complex relationships which we will now consider.

The general advantage and goal of reducing element size and the related blurring is to increase visibility of anatomical detail and signs of pathology. However, reducing element size and the associated blurring is limited by two factors. One is the design of the imaging equipment and the other is image noise considerations when adjusting imaging procedure protocols to be discussed later.

Imaging Equipment and Composite Blurring

All medical imaging methods produce blurred images. The range of blur values is an inherent characteristic of each modality, related to how images are formed and the design of the equipment. This ranges from very small blur values in mammography to significantly larger values with the several radionuclide imaging methods. This is sometimes designated as the "pre-sampled" blur (resolution) to distinguish it from the blurring produced by the digitizing (sampling) process.

For virtually all modern medical imaging methods the blur that is present in the image is a composite of blur values from several sources. The two major ones are the equipment and the digitizing process as illustrated for computed tomography in Figure 4.

For each imaging method and procedure there is a combination of factors that determine the amount of blurring in an image. The challenge is determining the *optimum combination* of design and protocol factor values. Computed tomography (CT) is an example. All imaging equipment is limited as to the lowest possible blurring because of several competing characteristics. With all x-ray methods focal-spot size is a major factor. Blurring is reduced by using smaller focal-spot sizes but this limits heat capacity and the ability to perform many types of procedures. The illustration in Figure 5 will now be used to develop both a conceptual understanding and the quantitative relationships determining composite blurring for an imaging procedure using digital radiography as an example.

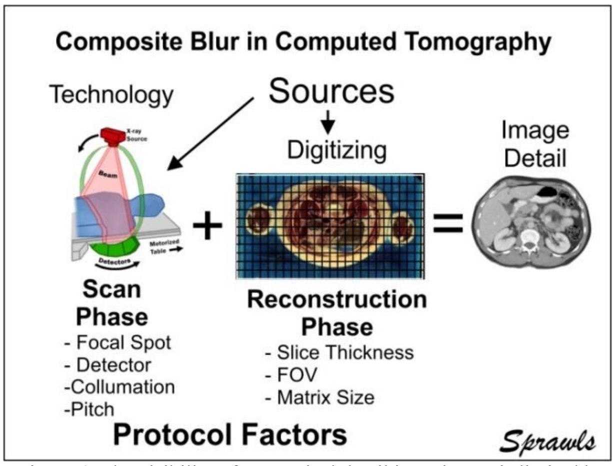

Figure 4. The visibility of anatomical detail in an image is limited by the composite blur from both the equipment design characteristics and the formation of the image in a digital format.

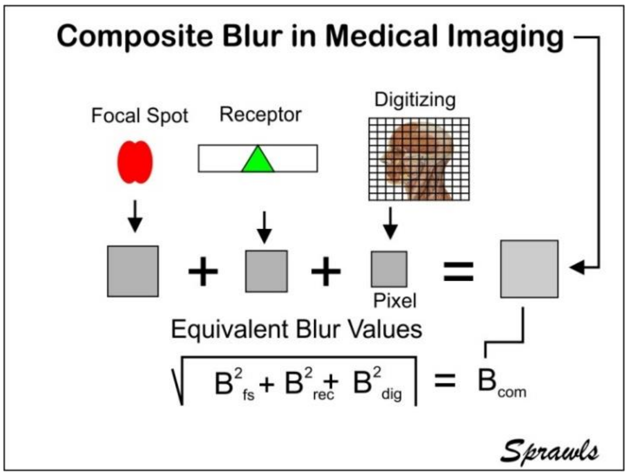

Figure 5. Sources of blur: focal spot (Bfs) , receptor (Brec) , and digitizing (Bdig) that combine to form the total or composite blur (Bcom) within an image.

In all medical imaging procedures the blur in the image is a composite, or combination, of the blur from several sources within the imaging process. The formation of an image in a digital format is one source with each voxel or pixel being a blur. Our specific interest is in deterring the appropriate or optimum size of the element for a specific imaging procedure. As described previously, this is determined by a combination of factors including the technical characteristics and design of the equipment and the image quality characteristics required for specific clinical procedures along with other issues including radiation exposure and imaging acquisition times.

Here we are considering the relation of element size to the technical characteristics of the equipment using radiography as an example as illustrated in Figure 5 where several sources of blurring are shown. With most imaging technology there are usually compromises and tradeoffs with other requirements.

Focal spot size is an example. Increased focal spot size increases x-ray tube heat capacity permitting the exposures required for many clinical procedures. This also increases blurring. For most radiographic procedures, including mammography, focal spot sizes for most procedures are established. These range from approximately 0.1 mm for magnification mammography to as large as 1.5 mm or more for thoracic and abdominal imaging.

For most radiographic receptors the thickness of the x-ray absorbing material is a source of blurring. Thicker absorbing materials require less exposure to produce an image but also result in increased blurring.

The blur produced by focal spots and receptors has specific shapes and spatial distributions. The blur produced by a focal spot is actually an image of the focal spot itself. The blur within a receptor is more of a Gaussian distribution. This becomes a factor when considering the contribution of each to the total or composite blur and including the blur produced by the digitizing of an image.

Effective Blur Values

The effective value of a blur in medical imaging is defined as the dimension of a square or rectangular blur with uniform distribution that has the same general effect on image quality and visibility as the actual blur from the various sources.

In digitized images the dimensions of the voxels and pixels are the effective blur values. The size of a focal spot measured with a star pattern is not the actual physical size but the effective size that can be used to determine the effective blur for a procedure. For receptors the effective blur can be calculated from the MTF.

Here we are not focusing on the precise blur values from the various sources but a more comprehensive model of how the blur from the different sources, including digitizing, can be combined to estimate the composite blur (Bcom) for a procedure. An approximation and generally used relationship is illustrated in Figure 5

There are several significant observations to be made. First, the blurs do not add numerically but it is a process of convolution with the blurs from the different sources somewhat superimposed or overlapping. Another factor is reducing the blur from one source does not have an equal effect on the composite or total image blur because it is combined and "weighted" by the blur from the other sources.

Now to the issue of what is the best digital element size for a particular imaging procedure as it relates to the equipment. A general "rule of thumb" is there is no significant advantage in having element sizes smaller than the blur from the other sources within the imaging process. It is the technical design of the equipment that establishes a limit on the advantage of reducing element size to reduce blurring and improve image detail.

V. IMAGE NOISE

Noise is related to element size. This makes noise a major factor in selecting or adjusting element size for specific clinical procedures.

Quantum Noise

There can be several sources of noise within the various medical imaging methods but quantum noise is in almost all cases the most predominant. This is appropriate because quantum noise relates to radiation dose to patients. In an optimized imaging procedure the objective is not to reduce noise to the lowest possible value but to a value that is acceptable for the specific clinical diagnostic requirements. Reducing the noise below this would generally result in unnecessary radiation dose to patients.

The actual source of the quantum noise is the natural random distribution of photons within an x-ray beam or from radioactive sources. However, the range of the photon distribution within an image area is also determined by the digitizing process, specifically the size of the digital elements.

The general concept of digital image noise is illustrated in Figure 6.

The random variation in the number of photons from pixel to pixel illustrated here is generally represented by a Gaussian distribution with a standard deviation (SD) value equal to the square root of the mean number of photons attenuated in each element. The SD, expressed as a %, is a useful parameter for expressing the noise level. Most digital imaging methods, especially CT, have the capability in the software to calculate and display the SD for a region of interest (ROI) selected by the operator. This can be used to obtain quantitative noise values for specific imaging protocols and used to optimize procedures.

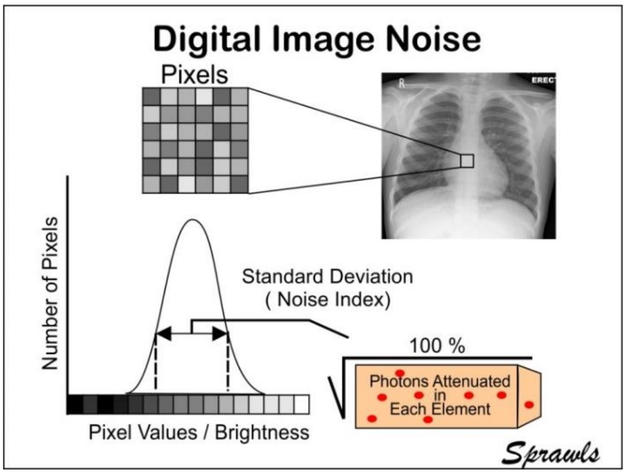

Figure 6. A magnified area within an image showing the random distribution of pixel values as the source of noise.

Element Size and Image Noise

As we have observed, the process of creating images in a digital format involves the segmenting of both the patient body and the image into a matrix of voxels and pixels. It is the size of these elements that has a major effect on two quality characteristics, blurring (detail, resolution) and image noise with an indirect effect on factors including radiation dose to patients and acquisition time for some procedures. Here we will now consider the effect of element size on noise using Figure 7.

Figure 7. The two factors--element size and radiation dose--that determine noise in digital images.

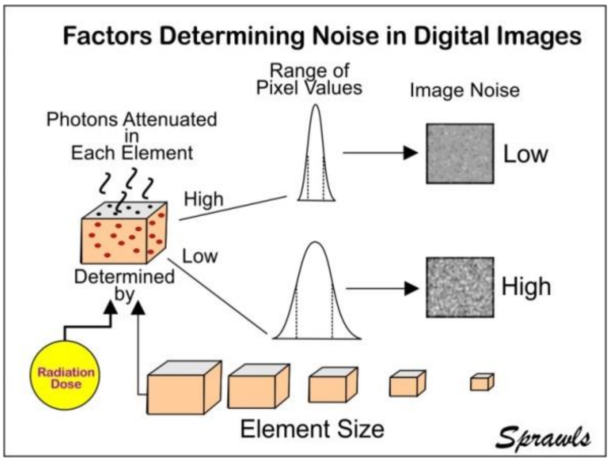

Figure 7. The two factors--element size and radiation dose--that determine noise in digital images.

In virtually all medical imaging methods the size of the digital element is a major factor in determining image noise. This includes methods using ionizing radiation (x-ray, gamma, etc.) and MRI but for different reasons.

The random variation in the number of photons from element to element, the source of the noise, depends on *the number of photons* attenuated in each element as we have seen. This is determined by the product of two factors, the concentration of photons (radiation dose) and the size of the element. It is the size of the elements that causes the conflict between the two image quality characteristics, blurring and noise. As we have seen, increasing element size increases blurring but has the desirable effect of decreasing noise. This is one of the major issues that must be considered in adjusting and optimizing imaging procedures for specific clinical objectives. Combined with this is the third factor, the radiation dose to the patient.

VI. NUCLEAR MEDICINE AND MAGNETIC RESONANCE

Up to this point we have focused on the x-ray imaging methods where a common factor is the radiation dose to patients that directly relates to image noise. This direct relationship does not exist for the other imaging methods but there are compromising factors determined by selected element size that must be considered when optimizing a specific imaging procedure.

In nuclear medicine imaging the photons per pixel acquired that affects image noise is determined by the concentration of radioactivity within the patient body and the time devoted to acquiring the image data. Both involve compromises. The concentration of radioactivity has a direct effect on radiation dose to the patient. While lower concentrations of radioactivity and dose can be compensated to some extent with increased acquisition and scan times this can limit some imaging capabilities. Selecting a digital element size for a procedure relates image quality to the both radiation dose and required acquisition time.

With magnetic resonance imaging (MRI) radiation dose is not an issue and the compromise determined by voxel size is the relation of image quality to image acquisition time. This is significant because MRI requires relative long acquisition times for many procedures and acquisition time is related to selected voxel size as illustrated in Figure 8.

Data for the reconstruction of MR images are acquired using two encoding methods, frequency and phase, for the radio frequency signals. The basic acquisition time is determined by the image matrix size in the phase encode direction. Although there are modifying factors (signal averaging, fast imaging methods, etc.) Each line of voxels in the phase encode direction requires one cycle or time interval (repetition time –TR) in the acquisition process. Acquisition time can be reduced by reducing the number of lines in the matrix which results in increased voxel size if the field of view is not changed. This reduction is a compromise between acquisition time and image blur.

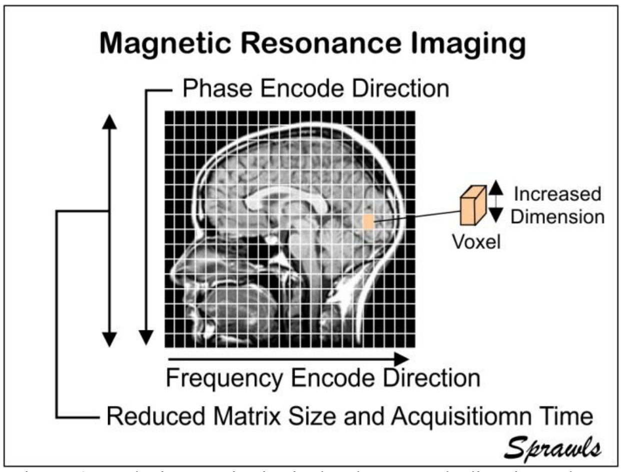

Figure 8. Reducing matrix size in the phase encode direction reduces acquisition time but results in a larger voxel dimension and reduced detail.

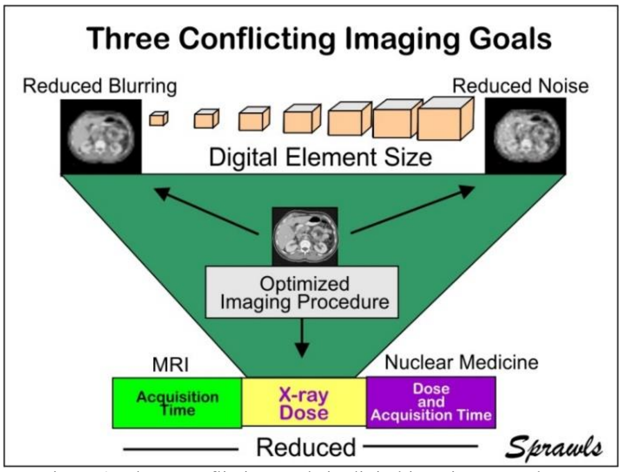

Figure 9. Three conflicting goals in digital imaging procedures: reducing image blurring and noise in relationship to radiation dose and required acquisition time.

VII. THE OPTIMIZED DIGITAL IMAGING PROCEDURE

A major goal of every medical imaging procedure is that it is *optimized* to have the necessary image quality to provide the required clinical information and without unnecessary radiation dose, image acquisition times, etc. A complicating factor, especially for images in a digital format, is the conflicting image quality characteristics illustrated in Figure 9.

With images in a digital format, now including most medical imaging modalities, the element (voxel and pixel) size covers a very large range and has a direct impact on two image quality characteristics along with an indirect impact on other significant factors. The three conflicting or opposing goals affected by element size are illustrated in Figure 9. We will now consider a general approach and process leading to an optimized imaging procedure with special attention on digital element size. This will be developed in three steps: factors determining image blurring, noise, and then radiation dose to a patient or acquisition time.

Image Blurring, Detail, and Resolution

It is appropriate to begin with blurring because the digitizing process adds blur to images. Reducing element size can be used to reduce this source of blur. However, as described and illustrated previously, there is a limit to the value of reducing element size because of the other sources of blur within the imaging equipment. Typical element sizes for each imaging modality are generally "matched" to the other sources of blur. A defining image quality characteristic of each imaging method or modality is the visibility of anatomical detail (spatial resolution) that can be achieved. This is a factor in determining the specific clinical procedures the modality is used for. Here are two examples. One of the clinical objectives with mammography is to visualize extremely small, or micro-, calcifications that can be signs of early breast cancer. This requires an imaging process with very low blurring and digital elements (pixels) as small as 0.05mm. The nuclear imaging methods, including SPECT and PET, are used to visualize larger regions of tissue and elements (voxels) with dimensions as large as 5mm used. For the digital elements in medical imaging this is a range of 100 to 1.

It is the clinical requirement for visualizing different levels of anatomical detail and small signs of pathology that is a factor in selecting a specific imaging modality and the associated digital element size.

Digital Image Noise

With a digital element size for a specific imaging procedure determined by the visibility of detail requirements and the design of the equipment a next step is to consider and control the noise in an image. As described previously, for a specific element size the noise is determined by the number of photons attenuated in the element. This generally relates to dose in tissue voxels in tomographic or exposure to receptors in projection imaging methods. With respect to radiation to a patient it is desirable to reduce these to "acceptable" values. And that raises a major related question: "What is an acceptable level of noise in a specific medical image?"

The impact of noise is that it reduces visibility of *low-contrast* objects and structures within the body. While this is different from the effect of blurring that reduces visibility of small objects and anatomical detail, many small objects also have low contrast and their visibility is also reduced by image noise.

As described before, the inherent sources of blur (focal spot, receptors, etc.) within imaging systems establish a limit to the improvement in image detail that can be achieved by reducing digital element size. The other factor that must be considered in reducing element size is that it increases image noise.

With the digital element size for a specific clinical procedure generally fixed by the physical characteristics of the equipment and requirements for image detail the controlling factor for noise becomes the quantity of radiation photons used to form the image.

With the x-ray imaging methods it is the relationship of noise to radiation exposure that requires considerable effort in optimizing. The objective is not to reduce noise to the lowest possible level. It is to set the noise to an *acceptable level* for a specific clinical procedure. This can be done by collaboration between medical physicists and radiologists. With their knowledge of the clinical conditions and visualization requirements along with experience, radiologists are in a position to decide on acceptable levels of noise. The medical physicists can then analyze the factors affecting the noise with an emphasis on radiation exposure. Determining the radiation exposure or dose to patients and comparing to established references and guidelines gives some indication if a procedure is optimized with respect to noise and radiation.

A special opportunity for medical physicists through education and consultation is providing other medical imaging professionals with an understanding of the relationship of noise to radiation exposure. Radiologists like visually appealing images with low noise. However, when they have knowledge of the related factors, especially radiation exposure, they can contribute to the optimization process.

This takes us to the root of one of the major issues in applied clinical physics and the expanding role of medical physicists. That is the transition from *equipment performance* in the context of quality assurance and control activities to *procedure optimization* in clinical applications.

VIII. THE MEDICAL PHYSICIST AND CLINICAL PROCEDURE OPTIMIZATION

The formation of medical images in a digital format brings advantages and values but also adds complexity to the imaging process. This is because of the digital elements with sizes that vary over a large range (0.05mm – 5.0mm) which impact two generally opposing image quality characteristics (blur and noise) along with other conflicting factors including radiation dose to patients and image acquisition time in some procedures, including MRI and radionuclide imaging. It is this complexity and added physics issues associated with the digital process that requires knowledgeable and experienced medical physicists as active members of the clinical imaging team as illustrated in Figure 10.

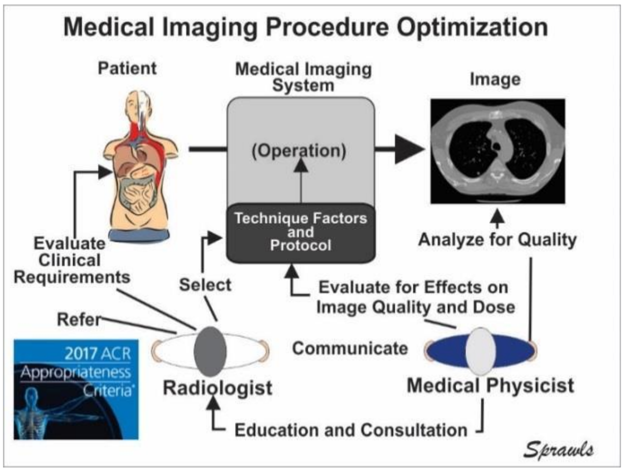

Figure 10. The role of the medical physicist in obtaining clinical images that is optimized with respect to quality and risk to patients.

A first step for the medical physics profession is to enhance educational programs, including degree granting, residency, and continuing education, to include comprehensive coverage of the digital process, its impact on image quality and related factors, along with knowledge of the imaging methods and procedures as they relate to the anatomy, physiology, and pathological conditions within the human body, as now required for medical physics certification by the American Board of Radiology (ABR). Providing some of the educational topics specific to the structure of digital images is one of the objectives of this article. It is this knowledge that enables the medical physicist to become an active member of the clinical medical imaging team with the ultimate effect of providing optimized medical imaging procedures with respect to image quality and risk management. As illustrated in Figure 9 this involves two major functions with respect to other members of the clinical team--education and consultation. As clinical medical physicists we are not the members of the staff who select and adjust the imaging methods and procedures for each individual patient. That is the responsibility of the radiologists and imaging technologists. However, especially because of the complexity of the physics relating to the digital imaging process it is the physicist who has the knowledge that is required for obtaining optimum imaging outcomes. The greatest impact medical physicists can have is by providing education for the other medical imaging professionals.

Educational resources that can be used for that purpose are available at:

http://www.sprawls.org/resources/DIGITAL/

IX. SUMMARY AND CONCLUSIONS

With images from all methods and modalities now in digital form there are factors in addition to characteristics of the radiation that must be considered in adjusting imaging procedures that are optimized for a specific clinical procedure. The digital element (voxel and pixel) size is a critical factor in this process. Because of the multiple and conflicting effects of element size on image quality and factors including radiation dose to patients, medical physics educational programs need to be enhanced to provide this knowledge for both medical physicists, working as educators and consultants, and radiologists who have responsibility for individual clinical procedures. This is the expanding opportunity for medical physicists.

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PROFESSIONAL ISSUES

MEDICAL PHYSICS IN VIETNAM: THE CURRENT STATUS OF EQUIPMENT, WORKFORCE AND EDUCATION

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Abstract — **Since 2010, Vietnam has been working actively to improve the medical system, especially for cancer treatment. Many hospitals have investments by the government or private companies to install new or upgrade their diagnostics and treat-ment facilities. Demand for well-trained medical physicists also increases quickly with the challenge of new technologies applied in medical equipment. This paper reports the updated status of medical physics in Vietnam - in equipment, workforce, and education.**

Keywords— **Medical Physics Professional Development, Medical Physics Education and Training, Medical Physics Equipment, Medical Physics Vietnam.**

I. Introduction

Located in South-Eastern Asia region, Vietnam is a lower middle-income country with the GDP per capita of 2067.9 USD in 2017. Vietnam has a population of 95.54 million and a surface area of 330,967 km^2 [1]. It is the fact that Vietnam has a high risk of deaths due to cancers. The age-standardised incidence and mortality rates are 140.4 and 108.7 (per 100,000) respectively [2]. The most frequent cancers are liver, lung, stomach, breast (female), and colorectum [3]. Therefore, the number of oncology centers has been growing rapidly nationwide since 2010.

Many public and private hospitals developed radiation oncology and nuclear medicine departments where physicists are essential members of the medical team. In hospitals, medical physics frequently assess the qualities and performance of the radiotherapy and nuclear imaging equipment. They also ensure clinical radiation protection to patients, staffs and the public. In radiotherapy, medical physicists work closely with oncologists to ensure accurately delivered doses to the patients [4]. The more sophisticated technologies are applied in medicine, especially in radiotherapy, the more professional knowledge and skills are required for medical physicists.

Vietnam Society of Medical Physics (VSMP) was found in 2008 to support medical physicists developing their professional career. In 2018, the Society has nearly 200 members with 149 members are clinical medical physicists.

To update information on medical physics status in Vietnam, a survey was done nationwide by Vietnam Society of Medical Physics. A questionnaire was sent to key persons who work actively as senior medical physicists at local hospitals. During March and May 2018, 37 public and private hospitals joined the survey. This number of hospitals covers 95% of hospitals in which there are oncology or nuclear medicine departments [5]. The questionnaire covers two main fields: equipment and workforce.

About the equipment - the numbers of radiotherapy and nuclear medicine equipment were collected. For diagnostic imaging machines, only those used for radiotherapy such as simulation CT, 4DCT and MRI were counted.

About the workforce - the data includes information of clinical medical physicists and the university where ones received the highest education degree. The data are analyzed based on regions. It is not surprising to see that the distribution of equipment and medical physicists are not the same between regions. Most of the large oncology centers are located in big cities. Many small provinces still don't have enough facility for cancer diagnostics and treatment. This causes trouble not only in providing early and effective treatment for patients but also in training the local medical team.

II. Radiotherapy equipment

The number of radiotherapy equipment in Vietnam inventoried in 2018 is shown in Table 1. Totally, there are 30 radiotherapy centers with 48 linear accelerators and 15 brachytherapy units. Though Ha Noi has a double number of radiotherapy centers in compare to Ho Chi Minh City, the total number of equipment are nearly the same for these two most populated cities. There are 5 hospitals with Gamma knife for radiosurgery. Table 2 shows the number of imaging equipment mainly used for diagnostics and treatment planning in radiotherapy. The survey only counts the number of simulation CT, 4DCT and MRI machines which belong to the radiotherapy centers and are under the care of medical physicists. Most of the hospitals are equipped with simulation CT and MRI. There are five centers which have 4DCT used for therapy. The ratio of radiotherapy equipment per million population is 0.73 - nearly the same as in other Southeast Asia countries [6].

Table 1. The number of radiotherapy equipment by region, inventoried in 2018

Region	Number of radiothera-py centers	Tele Co-balt-60 unit	Linear Accelerator	Branchy-therapy, HDR	Branchy-therapy, LDR	Gamma knife
Ha Noi	12	0	16	3	1	3
North	6	1	4	1	0	0
South	3	1	3	2	0	0
Middle and highland	4	0	6	2	1	0
Ho Chi Minh City	5	0	19	5	0	2
Total	**30**	**2**	**48**	**13**	**2**	**5**

Table 2. The number of diagnostics equipment used for radiotherapy by region, in 2018

Region	Number of radio-therapy centers	Simulation CT	4DCT for therapy	MRI
Ha Noi	12	12	2	14
North	6	9	0	6
South	3	2	0	4
Middle and highland	4	3	1	6
Ho Chi Minh City	5	11	2	11
Total	**30**	**37**	**5**	**41**

Table 3. Number of nuclear medicine equipment by region, in 2018

Region	Number of nuclear medicine centers	PET/CT	SPECT	SPECT/CT	Cyclotron
Ha Noi	9	8	11	3	2
North	4	0	4	0	0
South	3	1	3	1	1
Middle and highland	3	1	3	2	1
Ho Chi Minh City	5	3	4	2	1
Total	**24**	**13**	**25**	**8**	**5**

III. NUCLEAR MEDICINE EQUIPMENT AND THE PRODUCTION OF RADIONUCLIDES USED IN NUCLEAR MEDICINE

The number of nuclear medicine equipment is shown in Table 3. There are 24 nuclear medicine centers in Vietnam. Most of them have SPECT or SPECT/CT machines, and thirteen hospitals have PET/CT units. To produce fluorine-18 for medical use, four hospitals and the Institute of Nuclear Science and Technology have 05 cyclotrons with energies from 11 MeV to 30 MeV. Besides, the nuclear reactor in Nuclear Research Institute also produces Iodine-131 for thyroid cancer therapy. In total, Vietnam can produce approximately 650 Ci radionuclides per year, response 46% local demand [5].

IV. MEDICAL PHYSICISTS AND THE STATUS OF EDUCATION AND TRAINING

Vietnam Society of Medical Physics has 149 members working in hospitals as clinical medical physicists. Among them, 77% are male and 23% are female. There are 37% of medical physicists have the Master and Ph.D. degrees as shown in Table 4. Currently, only 06 members studied Master programs in medical physics in Thailand, Italia, Taiwan, France, and Australia. Table 5 shows the list of universities from which the clinical medical physicists got their highest education degrees. Most of the medical physicists graduated from the University of Science VNU-Ha Noi, Ha Noi University of Science and Technology, and the University of Science VNU-HCM in Ho Chi Minh city.

So far, Vietnam does not have internal certification of medical physicists. After finishing a four-year bachelor program at the university, students who are interested in

Table 4. Number of medical physicists by region, in 2018.

Region	Number of hospitals	Number of Medical Physicists	Male (%)	Female (%)	Master and PhD. (%)
Ha Noi	13	49	73%	27%	39%
North	6	14	71%	29%	50%
South	6	19	84%	16%	32%
Middle and highland	4	14	86%	14%	7%
Ho Chi Minh City	8	53	75%	25%	42%
Total	**37**	**149**	**77%**	**23%**	**37%**

Table 5. List of universities providing training programs for medical physicists in Vietnam

Region	University	Number of MPs	Bachelor	Master	PhD
Ha Noi	University of Science, VNU-Ha Noi	40	25	15	
	Ha Noi University of Science and Technology	18	11	7	
	Ha Noi Pedagogical University II	1	1		
	Institute of Physics	2		2	
	Posts & Telecoms Institute of Technology	1		1	
	Hanoi University of Industry	1	1		
	Military Technical Academy	3	2	1	
Middle and highland	Da Lat University	2	2		
	Da Nang University of Science and Technology	2	2		
	Hue University, College of Sciences	4	4		
	Hue Medicine University	1	1		
Ho Chi Minh City	University of Science, VNU-HCM	60	41	19	
	HCM City University of Science and Technology	3	1	2	
	HCM City University of Pedagogical	2	1	1	
Abroad	Chulalongkorn University, Thailand	2		2	
	Trieste University - ICTP, Italia	1		1	
	Grenoble University, France	1		1	
	Blaise Pascal University, France	1			1
	Belarus National University	1	1		
	Chang Gung University, Taiwan	1		1	
	Wollongong University, Australia	1	1		
	University of Bordeaux I	1		1	
	Total	**149**	**94**	**54**	**1**

medical physics look for jobs in hospitals or medical equipment trading companies. Then they go through on-site training by senior medical physicists or be sent to big oncology centers for training. Medical physicists frequently attend intensive training programs organized by Vietnam Society for Medical Physics or abroad. Besides, workshops or conferences are also good opportunities for medical physicists gathering and sharing knowledge and professional experience with each other.

However, the roles of medical physicists in hospitals are still not recognized appropriately. Officially, the medical physicists work 42 hours per week. In major oncology centers, medical physicists frequently work overtime due to heavy workload. In small hospitals, the medical physicists lack essential equipment and training resource. Medical physicists and the status of education and training

V. Conclusion

The expected cancer incidence in Vietnam will be roundly 98,100 cases [7]. To reduce the mortality rate due to cancer, the hospitals will have to upgrade their diagnostics and treatment equipment. The needs of medical physicists still high. However, it takes approximately 2-3 for training a new medical physicist both in theory and clinical. To meet this trend, beside developing good education programs from undergraduate to graduate levels, the university must collaborate with the hospitals in training and research. For certifying the medical physics, Vietnam Society for Medical Physics is organizing the National Certification Board with the help of IAEA.

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2018 AAPM/IOMP – ISEP THERAPY COURSE CHALLENGES IN MODERN RADIATION THERAPY PHYSICS

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I. COURSE OUTLINE

The purpose of this article is to report on the joint AAPM-ISEP/IOMP Therapy Course that took place in July 3-7, 2018 in Ljubljana, Slovenia. The course was given in collaboration with the Institute of Oncology in Ljubljana and Faculty of Mathematics and Physics at the University of Ljubljana. The Ljubljana Institute of Oncology and its associated hospital are modern, well equipped institutions. Faculty of Mathematics and Physics runs a dynamic educational and research program of medical physics and many future medical physicists thrive in its stimulating environment.

The title of the course,” Challenges in Modern Radiation Therapy Physics” well reflected the topics that included modern radiation dose calculation algorithms, treatment modalities including proton and heavy ion beams, imaging and dosimetry. The course directors were Joanna Cygler, Božidar Casar (local arrangements) and Robert Jeraj (scientific content).

Lectures were given by several faculty sponsored by AAPM: Thomas Bortfeld, Joanna Cygler, Saiful Huq, Rock Mackie and David Rogers. They were supplemented by three local speakers from Ljubljana Institute of Oncology: Božidar Casar, Robert Jeraj and Ignacio Mendez. Special guest lectures were delivered by Stine Korreman (IGRT), Bert van der Kogel (Radiobiology) and Slavik Tabakov (Medical Physics Global Workforce).

Ervin Podgoršak, currently a Professor Emeritus of McGill University in Montreal, Canada, attended the course as a special guest of honor. Ljubljana holds a special place in his heart, since Prof. Podgoršak not only grew up there, but he also started his prominent career in the Faculty of Mathematics and Physics at the University of Ljubljana. He delivered a lecture on” Professional Issues in Medical Physics”, the ever-important topic in the constantly evolving careers of medical physicists. Special highlight of the course was AAPM TG 100 Workshop given by Saiful Huq. The participants also enjoyed the demos of Virtual Environment Radiotherapy Training (VERT) system for radiotherapy professionals training organized and ran by Andy Beavis.

At the end of the course, practical demonstrations were organized for participants at the Institute of Oncology including patient specific QA/QC procedures for VMAT, IGRT procedures, execution of Winston-Lutz test and presentation of TBI translation coach technique on linear accelerator.

Figure 1 presents the course program. Figures 2-6 show photos of some highlights of the course.

You can find more information about the course (and more photos) on its web page, http://www.aapm-isep.si.

The course progressed very smoothly, which no doubt was due to the excellent Local Committee work, especially Maruša Turk and her fellow medical physics PhD students.

The course had a truly international flair, as its 80 participants came from over 20 different countries and 4 continents. The attendees enjoyed the lectures and interactions with the faculty during coffee breaks and lunches. All lectures and events were diligently recorded by the official course photographer, Ana Marin

Overall the course got excellent evaluations not only for scientific content and quality of the lectures, but also for its organization. What is also important, everybody had fun learning and playing together. The feedback received about the course was overall excellent and we already received some requests about organizing it again, perhaps with more content on proton therapy.

"Challenges in Modern Radiation Therapy Physics"
Special topic: Workshop on TG-100

AAPM - ISEP course, Ljubljana, Slovenia, 3rd - 7th July 2018
Course Directors: Joanna Cygler (AAPM) and Božidar Casar (Host)
Scientific Program Director: Robert Jeraj

Date	Session #1		15 min	Session #2		12:15-12:45	12.45-13.30	13:30 - 14:00	Session #3		15 min	Session #4	
	1 hr 30 min			1 hr 30 min					1 hr 30 min			1 hr 30 min	
	9.00 - 9:45	9:45 - 10.30		10.45 - 11.30	11.30 - 12.15				14:00 - 14.45	14.45 - 15.30		15.45 - 16.30	16.30 - 1'
Tue 03.07.2018	FREE MORNING/ARRIVALS				REGISTRATION			Opening (13.00 - 13.30) RT Physics in Slovenia (BC)	Professional Issues in Medical Physics (EP)	IOMP speaker (ST)	Coffee Break 15 min.	Future of RT and role of physics in it ALL	Debate future of ALL
Wed 04.07.2018	TPS in the clinics today-MC based TPS (JC)	MC based TPS - issues to consider in clinical practice (D_w/D_m) (JC-DR)	Coffee Break 15 min.	non - MC based TPS - issues to consider in clinical practice (D_w/D_m) (RM)	TG-142 (RM)	Vendor IBA	LUNCH	VERT demo 1st group + Exhibition	Reference dosimetry (DR)	Reference dosimetry (DR)	Coffee Break 15 min.	Modern RT dosimetry - review of detectors (JC)	Small fie TRS-483 (
Thu 05.07.2018	Radiochromic film dosimetry (IM)	Overview of IMRT (TG-120) (RM)	Coffee Break 15 min.	Clinical implementation of SRS/SBRT (TG-101) (SH)	Imaging in RT (RJ)	Vendor Elekta	LUNCH	VERT demo 2nd group + Exhibition	IGRT - current practice (SK)	Imaging for precision medicine in RT (RJ)	Coffee Break 15 min.	Exhibition	Social eve picnic (16 22:00)
Fri 06.07.2018	Why protons (TB)	Why not protons (TB)	Coffee Break 15 min.	Particle therapy (TB)	Radiobiology of particle therapies (BK)	Vendor Varian	LUNCH	VERT demo 3rd group + Exhibition	Radiobiology of SBRT and Hypofraction (BK)	TG-100 workshop (SH)	Coffee Break 15 min.	TG-100 workshop (SH)	TG-10 workshop
Sat 07.07.2018	TG-100 workshop (SH)	TG-100 workshop (SH)	Coffee Break 15 min.	TG-100 workshop (SH)	Participants impressions - Course and WS	Vendor Brainlab	LUNCH	VERT demo 4th group + Exhibition	TRANSFER	Visit to the Institute of Oncology (*) - practical demo			Test&clo (lecture r IOL)

* Demo at the Instute of Oncology: 1. Patient specific QA/QC for VMAT, 2. IGRT procedures, 3. Winston-Lutz test, 4. TBI translation couch technique on linac

Fig. 1 AAPM-ISEP/IOMP Therapy Course full programme

Fig. 2 AAPM-ISEP/IOMP Therapy Course participants, Ljubljana, Slovenia, July 2018

Fig. 3 AAPM-ISEP/IOMP Therapy Course, Ljubljana, Faculty photo

Fig. 4 Engaged audience at the AAPM-ISEP/IOMP Therapy Course, Ljubljana,

Fig. 5 Prof. Ervin Podgoršak, Special Lecturer/Guest of Honour Casar

Fig. 6 Joanna Cygler presents the AAPM Recognition Plaque to Božidar Casar

IOMP-IUPAP WORKSHOP "MEDICAL PHYSICS PARTNERING WITH THE DEVELOPING WORLD" AT THE WORLD CONGRESS IN PRAGUE WC2018

The fifth jointly sponsored IOMP-IUPAP Workshop, dedicated to medical physics development in the Low and Middle Income countries (LMIC) – aka developing countries, took place at the World Congress on Medical Physics and Biomedical Engineering WC2018, Prague, Czech Republic.

The Workshop was co-organised by S Tabakov (IOMP President), Y Pipman (Chair PRC of IOMP), L Judas (WC2018 Co-President), F Nuesslin (IUPAP AC4 Chair). The Workshop also included speakers from the International Atomic Energy Agency (IAEA) and the World Health Organisation (WHO).

The Workshop discussed the current situation and professional development in all IOMP Regional Organisations (continents and sub-parts). The programme included an overview of the current global situation and needs of medical physicists. This was followed by presentations from the Regions, delivered by the senior colleagues supported by IOMP/IUPAP grant.

The presented papers from the IOMP Regional Organisations in Asia (AFOMP); South-East Asia SEAFOMP; Middle-East (MEFOMP); Europe (EFOMP); Africa (FAMPO); Latin America and Caribbean (ALFIM) are published here below.

Special emphasis was made to the future inclusion of medical physicists in the healthcare provision in the LMIC, resulting to a need of almost tripling the number of medical physicists globally by 2035. Special concerted actions will be necessary for this huge challenge in front of the profession, especially in LMIC. The need of further partnering with the colleagues from LMIC was underlined and the Workshop was praised as an important step in this direction.

The importance of the latest activities of IOMP was highlighted by all participants – MPI Journal, Accreditation of MSc programmes and IOMP School. These will be accelerated in the years ahead. The importance of the cooperation between the IOMP Regions was also underlined and the activities of the IOMP Regional Coordination Board in this direction were acknowledged. The Workshop also acknowledged the activities of the IOMP Women Sub-Committee, which had a session linked to the Workshop.

The IAEA report presented further opportunities for such partnering, including projects (one of these – in Latin America – have made a meeting just before the Workshop).

Due to the increased interest to the Workshop, it was decided for all materials related to it to be developed as full papers in the present issueof the IOMP Journal *Medical Physics International*.

The IOMP/IUPAP Workshop "*Medical Physics Partnering with the Developing World*" attracted around 90 participants from 23 countries. About 3/4 of the participants were from LMIC, including the most senior medical physicist representatives from Africa, Latin America and Asia.

At the end of the Workshop the IUPAP Chair AC 4, the IOMP Officers and all speakers and participants expressed their sincere gratitude for the support from IUPAP, as well as for these regular IOMP-IUPAP activities dedicated to professional development in the LMIC.

See below*: Papers from the Workshop as per IOMP Regions*

Some of the participants at the IOMP-IUPAP Workshop, WC2018, Prague, Czech Republic

STATUS OF MEDICAL PHYSICS AND ACTIVITIES TO BOOST THE PROFESSIONAL DEVELOPMENT IN THE SEAFOMP REGION

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[1] President, Thai Medical Physicist Society, Past-President SEAFOMP

Abstract — **The paper is part of the IOMP-IUPAP Workshop "MEDICAL PHYSICS PARTNERING WITH THE DEVELOPING WORLD" ay the World Congress in Prague WC2018. The paper presents the status in the IOMP Regional Organization SEAFOMP (Southeast Asian Federation for Medical Physics).**

Keywords— **Medical Physics Professional Development, Medical Physics Education and Training.**

I. INTRODUCTION

Association of South East Asian Nations, ASEAN, comprises of 10 nations located in Southeast Asia. The Association was formed on 8 August 1967 by its five original member countries, i.e. Indonesia, Malaysia, Philippines, Singapore and Thailand. Over the years, the organization grew when Brunei Darussalam joined in as the sixth member on 8 January 1984, Vietnam on 28 July 1995, Laos and Myanmar on 23 July 1997 and Cambodia on 30 April 1999. Its objectives include the acceleration of economic growth, social progress and cultural development among its members, as well as to promote regional peace. (ASEAN Secretariat, 2007). The map of ASEAN country members is displayed in Figure 1.

II. ESTABLISHMENT OF SEAFOMP

The idea of setting up an organization for South-east Asian medical physics societies was first mooted in 1996. During the World Congress of Medical Physics and Bio Medical Engineering in Nice, France, the formation of SEAFOMP (South East Asian Federation of Organizations for Medical Physics) was endorsed by member countries. SEAFOMP was officially accepted as a regional chapter of the IOMP at the World Congress in Chicago, USA, in 2000 with five member countries, Indonesia, Malaysia, Philippines, Singapore and Thailand. At that time, the founding members of SEAFOMP were Anchali Krisanachinda and Ratana Pirabul from Thailand, Kwan-Hoong Ng from Malaysia, Agnette Peralta from the Philippines, Djarwani S Soejoko from Indonesia and Toh-Jui Wong from Singapore.

Three other countries joined subsequently: Brunei (2002), Vietnam (2005) and Myanmar (2016).

Figure 1: The Map of ASEAN Country Members

Figure 2: SEAFOMP Founders: Left-Right Anchali Krisanachinda (THA), Agnette Perata (PHI), Djarwani S. Soejoko (IDN), Makumkrong Poshyachinda, Head of Department of Radiology, Ratana Pirabul (THA), Kwan Hoong Ng (MAL), Toh Jui Wong (SIN). Photo was taken at 2nd SEACOMP in Bangkok, Thailand.

The objectives of SEAFOMP are to promote (i) co-operation and communication between medical physics organizations in the region; (ii) medical physics and related activities in the region; (iii) the advancement in status and standard of practice of the medical physics profession; (iv) to organize and/or sponsor international and regional conferences, meetings or courses; (v) to collaborate or affiliate with other scientific organizations. SEAFOMP has a complementary and synergistic relationship with AFOMP in moving medical physics forward in the region. SEACOMP has initiated the tradition of awarding the best student presentation and this has stimulated much interest among the students. The students were given awards for best student presentations, both oral and poster, to encourage excellence in this field. Book prizes were generously donated by Medical Physics Publishing. The abstracts and full papers were published in Proceedings, in hard and soft copies, and distributed to all the participants.

III. MEDICAL PHYSICS EDUCATION AND CLINICAL TRAINING

Medical physics profession was first started in Thailand in 1959 while the medical physics education was started in 1972, followed by Philippines, Malaysia, Indonesia and Vietnam. The IAEA structured program on clinical training in radiation oncology was piloted in 2007 in Thailand. Diagnostic Radiology clinical training was started in 2008 in Philippines and Nuclear Medicine clinical training was started in Thailand in 2010. Those who successfully completed the program become Clinically Qualified Medical Physicist. In 2016, Thailand piloted the IAEA e-learning of medical physics clinical training in all 3 branches which the residents from Vietnam, Myanmar and Nepal could practice at their own department and obtain the on-line supervision from Thailand.

Table 1. SEACOMP - year of organize, city and country

No.	Year	City	Country	No.	Year	City	Country
1.	2001	Kuala Lumpur	Malaysia	2.	2003	Bangkok	Thailand
3.	2004	Kuala Lumpur	Malaysia	4.	2005	Jakarta	Indonesia
5.	2007	Manila	Philippines	6.	2008	Ho Chi Minh City	Vietnam
7.	2009	Chiang Mai	Thailand	8.	2010	Bandung	Indonesia
9.	2011	Bohol	Philippines	10.	2012	Chiang Mai	Thailand
11.	2013	Singapore	Singapore	12.	2014	Ho Chi Minh City	Vietnam
13.	2015	Yogyakarta	Indonesia	14.	2016	Bangkok	Thailand
15.	2017	Ilo Ilo	Philippines	16.	2018	Kuala Lumpur	Malaysia

Table 2: SEAFOMP country members with the details on population, the year on medical physics establishment, the number of medical physicists, the education and clinical training

Country	Population Million	Medical Physics		Medical Physics Education		Clinical Training
		Year	Number	M.S./M.Sc.	Ph.D.	
Indonesia	265.316	2007	381	Available	Available	2016
Thailand	69.182	1956	200	Available	Available	2007
Malaysia	32.446	1960	308	Available	Available	2010
Singapore	5.661	1953	49	Available	N/A	2013
Philippines	107.018	1963	49	Available	N/A	2008
Vietnam	94.575	1978	140	N/A	N/A	2016
Myanmar	52.832	2003	34	N/A	N/A	2016
Cambodia	16.253	2014	4	N/A	N/A	N/A
Laos	6.777	2017	2	N/A	N/A	2018
Brunei	0.343	N/A	8	N/A	N/A	N/A

AMPLE (Advance medical physics leaning environment) platform had been demonstrated and become available in all branches of medical physics in SEAFOMP country members. The activities are cooperated by national professional societies and university hospitals. The program was quite successful on the establishment of medical physicists with competency in Thailand, Philippines, Indonesia, Malaysia and Singapore. Myanmar, Laos and Malaysia obtained the on-line supervision from Thailand. Certification of medical physics will be available within a couple of years in south-east Asian region. The establishment of ASEAN College of Medical Physics, ACOMP, is well supported at the annual congress-SEACOMP which the venue of the College/Congress is rotating among SEAFOMP country members. 16 SEACOMP in conjunction with ACOMP, AOCMP and ICMP were organized from 2001 to 2018 at different cities and countries as in Table 1. Data about SEACOM current members and education is given at Table2.

IV. ASEAN COLLEGE OF MEDICAL PHYSICS (ACOMP)

ACOMP was formed in October 2014 at the 12th SEACOMP at Cho Ray Hospital, Ho Chi Minh City, Vietnam (Figure 3).

The objectives of the ASEAN College of Medical Physics are

- To enhance the standard and quality of education and training of medical physicists,
- To provide continuing professional development (CPD) programmes, and
- To promote the continuing competence of medical physics practitioners.

Nine ACOMP were organized during 2015-2018

1. AAPM/IOMP/ISEP Imaging Physics Workshop Nov 11-14 2015 Kuala Lumpur, Malaysia
2. Workshop on Digital Radiography (13th SEACOMP) Dec 10 2015 Yogyakarta, Indonesia
3. Interventional Radiology: Safety, Optimization, Dosimetry & Quality Control Aug 5-6 2016 Kuala Lumpur, Malaysia
4. Workshop on Digital Radiography (ICMP 2016) Dec 11 2016 Bangkok, Thailand
5. Workshop on Monte Carlo Simulation of LINAC Head Modeling and Dose CalculationJul 11-14 2017 Bandung, Indonesia
6. Radiofrequency Radiation Protection Dec 4 2017 Iloilo, Philippines
7. Radiation Dosimetry II:- Solid State and OSL Dosimetry: Physics & Applications, Dec 6 2017, Kuala Lumpur, Malaysia
8. UI/ISEP AAPM/ACOMP Imaging Physics Course, Oct 4-7 2018, Jakarta, Indonesia
9. Workshop on diagnostic radiology : Patient dose measurement and monitoring in diagnostic radiology, Nov 11, 2018, Kuala Lumpur, Malaysia

Planned activities for the near future of ACOMP are:

- School on Monte Carlo simulation
- School on advanced radiation dosimetry
- School on radiation emergency and disaster management
- Regional inter-comparison in radiation dosimetry

Figure 3: The Founders of ASEAN College of Medical Physics (AOCMP)
Front row: Sivalee Suriyapee (THA), Anchali Krisanachinda (THA), Djarwani S.Soeharso (IDN), Agnette Peralta (PHI), Yeong Chai Hong (MAL)
Back row: Nguyen Tan Chau (VIE), James Lee (SGP), KH Ng (MAL), Tran Ngoc Toan (VIE), Freddy Haryanto (IDN), Cao Huu Vinh (VIE) Supriyanto Pawiro (IDN) Marlon Raul Z. Tecson (PHI), CHHOM Sakborey (Cambodia)

International Advisory Board was set up in 2015 to support the ACOMP. The Board consists of:

Prof.Hilde Bosmans, Belgium; Dr. Kin Yin Cheung, Hong Kong; Prof. R Chhem, Cambodia; Prof. John Damilakis, Greece; Prof. Kunio Doi, Japan; Prof. Geoff Ibbott, USA; Prof. Willi Kalender, Germany; Prof. Tomas Kron, Australia; Prof. Anthony HL Liu, USA; Dr. Ahmed Meghzifene, IAEA; Prof. Fridtjof Nusslin, Germany; Prof. Madan Rehani, Austria/USA; Prof. Jean-Claude Rosenwald, France; Assoc. Prof. Howell Round, New Zealand; Prof. Tae-Suk Suh, South Korea; Prof. Slavik Tabakov, UK; Prof. Brian Thomas, Australia; Prof. David Townsend, Singapore; Prof. Raymond Wu, USA.

As SEAFOMP members have similar culture/tradition and the geographic boundary is opened, the cooperation among medical physicists in the region has been strengthening lately. With the IAEA support on education in medical physics to Cambodian and Lao at the Universities in Malaysia and Thailand, the medical physics profession has been started in both countries where radiation oncology and cancer centers were firstly established in Phnom Penh and Vientiane. In 2016, AMPLE (Advanced Medical Physics e-Leaning Environment) platform is piloted in medical physics clinical training in the region. The problem on lacking of qualified medical physicists in radiation oncology and medical imaging in clinical training has been solved by sharing clinical supervisors in the region. The regular schedule is commonly planned for follow up on the progress of residency training. Furthermore, SEAFOMP Executive Committee agreed to support Cambodia and Laos on the opportunity to participate SEACOMP annually. Such the activities in the region including ACOMP could improve the medical physics profession in SEAFOMP in terms of increasing number of medical physicists with competency and the clinical training of medical physicists are more uniform in the region where the facilities are available.

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This paper is related to the IOMP-IUPAP Workshop “Medical Physics Partnering with the Developing World” at the World Congress in Prague WC2018. The lecturer and attendees of the Workshop expressed their gratitude to the IUPAP for the supporting grant and to the IOMP for the organization of the Workshop.

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STATUS OF MEDICAL PHYSICS AND ACTIVITIES TO BOOST THE PROFESSIONAL DEVELOPMENT IN THE AFOMP REGION

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Abstract — **The paper is part of the IOMP-IUPAP Workshop "MEDICAL PHYSICS PARTNERING WITH THE DEVELOPING WORLD" at the World Congress in Prague WC2018. The paper presents the status in the IOMP Regional Organization AFOMP (Asia Oceania Federation for Medical Physics).**

Keywords— **Medical Physics Professional Development, Medical Physics Education and Training.**

I. INTRODUCTION

The Asia-Oceania Federation of Organizations for Medical Physics was founded on May 28, 2000 to promote Medical Physics in the Asia and Oceania regions, through the advancement in status and standard of practice of the medical physics profession. It is one of the regional organization for Medical Physics within the International Organization for Medical Physics with 21 member countries that are; Australia, Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Iran, Japan, S. Korea, Malaysia, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, Taiwan, Thailand and Vietnam.

The role and status of Medical Physicists in the AFOMP continue to gain increasing recognition in scientific societies during the past few years. The AFOMP is striving to build a strong relationship between national organizations in the Asia-Oceania region and international bodies. The 17th AOCMP along with the 38th Annual Conference of Association of Medical Physicists of India (AMPI) was successfully organized at Jaipur, India. The active contribution from IOMP, ICTP, AAPM, MEFOMP, and EFOMP during the conference deserves special mention. Further Memorandum of Understanding (MoU) between MEFOMP and of AFOMP was signed on December 12, 2017 to foster more scientific, professional and educational collaboration. AFOMP published 'The Code of Ethics for clinical Medical Physicists' in the year 2017. These were the major achievements of last one year. AFOMP is actively involved in many activities in collaboration with international bodies such as IOMP, IAEA, IUPESM, WHO, ILO etc.

AFOMP newsletter started with its 1st issue in December 2007. It is the of AFOMP, released half-yearly with news about current activities, research outcomes and upcoming events.

The annual conference of AFOMP, Asia-Oceania Congress on Medical Physics (AOCMP) is held every year to provide a platform for the medical physicists to share their research, knowledge, experience and problems so that each one of the member gets opportunity. The 1st AOCMP was held in Bangkok, Thailand in 2001 and since every year held regularly in different countries of AFOMP. The 18th AOCMP will be held in Kuala Lumpur, Malaysia during 11th to 14th November 2018.

One of the Founding members of AFOMP was the late Prof. Kiyonari Inamura who contributed significantly to the sustained development of AFOMP. He had served AFOMP at different capacities over the years. He was Professor Emeritus at Osaka University and longstanding member of the CARS Congress Organizing Committee and Deputy Editor of IJCARS. His pioneering contributions to Medical Physics and Medical Engineering include research and development in radiotherapy treatment planning systems and picture archiving and communication systems. It was always on the forefront of his ideology to educate and motivate the students to advance their understanding of Medical Physics. His efforts in advancing interdisciplinary and international cooperation is without any parallel and, his way of leading by example, has been of great benefit not only to the Medical Physicist community of AFOMP but also for the rest of the world. To recognize and appreciate the outstanding contributions of Prof. Inamura to Medical Physics in AFOMP region, an Oration Award by AFOMP in the name of Prof. Kiyonari Inamura was started during 2018 and Prof. Tomas Kron, Melbourne, Australia will be the first recipient of this oration award.

To take care of the enormous activities and work of the association for benefit of its members, AFOMP has five committees

1. Education and Training Committee [ETC]
2. Professional Development Committee [PDC]
3. Science Committee [SC]
4. Funding Committee [FC]
5. Awards and Honors Committee [AHC]

The chairs and members of each committee assiduously plan and meticulously execute various aspects to fulfill aim and objectives of respective committees.

Objectives, goals and accomplishments of each committee are as follows.

II. EDUCATION AND TRAINING COMMITTEE [ETC]

The major aims of this committee are to promote activities related to education and training of AFOMP Medical Physics by promoting the education, training and professional development of Medical Physicists, to develop AFOMP policy statement on education and training of medical physics in AFOMP countries to promote and advance the practice of medical physics with the highest quality of medical services for patients care, to support and collaborate with the education and training committees of Regional Chapters on matters relating to education and training, including development of training materials and training methodology, to organize workshops and seminars in conjunction with related international conference meetings, to promote and assist international education and training initiatives and to study ETC activities of other organizations to adapt to AFOMP societies for promoting high quality educational programs at the graduate and postgraduate levels as well as residency programs in medical physics.

III. PROFESSIONAL DEVELOPMENT COMMITTEE [PDC]

This committee aims to promote the professional development of AFOMP Medical Physicists by developing policy and strategic action plan on the promotion of the status and recognition of the Medical Physics profession in AFOMP countries. This committee' roles are pertaining to develop and make proposal for a registration and certification system for AFOMP Physicists, to develop standards, guidelines and protocols on Medical Physics procedures and services, including dosimetry and QA protocols, to develop AFOMP policy statements on definition and roles and responsibilities of Medical Physicists and the Physicist service manning scale for Medical Physics services, to develop codes of practice or standard on radiation safety and protection and to develop a system of Continuous Professional Development (CPD) for AFOMP.

The AFOMP definition of a Medical Physicist coined by PDC is as follows: "A qualified Medical Physicist is a person who possesses a university degree at master level or equivalent in physical science or engineering science and works in alliance with medical staff in hospitals, universities or research institutes. He/she shall also have received clinical training in the concepts and techniques of applying physics in medicine, including training in the medical application of both ionizing and non-ionizing radiation. This person shall have a thorough knowledge and be able to practice independently in one or more sub-fields of medical physics, including imaging physics, radiation therapy physics, nuclear medicine physics and radiation protection."

AFOMP Policy Statement No.1: The roles, responsibilities and status of the clinical Medical Physicists in AFOMP countries.

The main purpose was to give guidance to AFOMP member organizations on the role and responsibilities of clinical medical physicists. A definition of clinical medical physicist has also been provided. The professional aspects of education and training; responsibilities of the clinical medical physicist; status and organization of the clinical medical physics service and the need for clinical medical physics service were discussed in this document.

AFOMP Policy Statement No. 2: Manpower requirements for radiation therapy Physicists.

The main purpose of the document was to give guidance as to how many medical physicists are required to staff a radiation oncology department. Strict guidelines are difficult to define as work practices vary from country-to-country and from hospital-to-hospital. A calculation scheme is presented to aid in estimating medical physics staffing requirements that is primarily based on equipment levels and patient numbers but also with allowances for staff training, professional development and leave requirements.

AFOMP Policy Statement No. 3: Recommendations for the education and training of Medical Physicists in AFOMP countries.

AFOMP recognizes that clinical medical physicists should demonstrate that they are competent to practice their profession by obtaining appropriate education, training and supervised experience in the specialties of medical physics in which they practice, as well as having a basic knowledge of other specialties. To help its member countries to achieve this, AFOMP has developed this policy to provide guidance when developing medical physicist education and training programs. The policy is compatible with the standards being promoted by the International Organization for Medical Physics and the International Medical Physics Certification Board.

AFOMP Policy Statement No. 4: Recommendations for professional development systems for Medical Physicists in AFOMP countries.

Medical physicists need to undertake CPD to keep up-to date in their field. This is for the benefit of the individual, the institution that they work for, and in the case of those who are clinically involved, for the benefit of patients. This should be a legal requirement in all AFOMP countries where there is a legal requirement for physicists to be certified or licensed to practice clinically.

The requirements of a CPD system should equate to the equivalent of approximately one week of full-time equivalent continuing professional educational activity per year. This undertaking may consist of activities such as attending lectures, tutorials, seminars, workshops and self-directed learning.

It is recommended that member countries have points based system to quantify a physicist's CPD participation and achievements.

• Attending courses/seminars/lectures/workshops/scientific meetings etc.

• Formal on-the-job training, interactive learning with the internet or CD ROMs with evaluation, self-directed learning, visits to other institutions, study breaks etc.

• Teaching, lecturing, presenting at seminars and workshops, producing teaching materials and CD ROMs etc.

• Research publication at conferences, in journals, in books etc.

• Editing and reviewing

• Developing new technologies and procedures

• Professional service (i.e. membership in or chairing of task groups, professional society committees, conference committees, etc.)

• Supervision and mentoring of residents and research students

• Thesis examination

• Obtaining higher qualifications

• Employment

Actions to be taken if sufficient points are not achieved

- Become re-certified through the normal examination process or through an oral exam

- Be required to make up their points deficit within a specified period

- Be required to be supervised by a certified or licensed physicist

- Be required to undertake a specified remedial program

- Be given the opportunity to achieve, within a limited time, the minimum number of points normally required to be accumulated in one year

Sharing resources

- The production of training and education resources for CPD is costly.

- All AFOMP member countries shall, where possible, make their resources freely available to other countries.

AFOMP Policy Statement No. 5: Career progression for clinical Medical Physicists in AFOMP countries.

The career progression for clinical medical physicists in AFOMP countries depends on many factors like the status of the place of work whether it's private or Govt. or university and the type of appointment; academic with a hierarchy for promotion or not.

Education and training should be completed with appropriate assessment and written and oral examinations. Also, certification process should be completed. After this the career structure should be taken into consideration.

A career structure with four levels can be used as guidance and be chosen according to local terminology. A Level 1 medical physicist is one who has completed undergraduate degree and who is in clinical training or in the first few years of their career after completion of their certification (first 5-8 years). Their work responsibilities would be of a general nature and shall be under the direction of a medical physicist employed at a higher level.

A Level 2 medical physicist is one who has completed a formal clinical medical physics training program of the duration and standard recommended by the International Medical Physics Certification Board or the International Atomic Energy Agency and has sufficient experience to act independently as a medical physicist (6-15years).

A Level 3 medical physicist is one who has extensive experience post-training, and has a significant level of responsibility, leadership and management in the department in which they are employed (12th years onwards). They would have extensive experience in their area of specialization and would be contributing to research and development.

A Level 4 medical physicist is one who has overall responsibility for planning, organizing and leading the medical physics staff in providing support for therapeutic and diagnostic medical procedures, calibrating and commissioning of equipment, education of medical physicists and other technical and clinical staff, research and development in a hospital or group of hospitals. They are recognized nationally, and possibly internationally, as an expert in all aspects of their specialization (15th Years onwards).

The future of professional development of medical physics in AFOMP region shall be through strengthening the educational, training and professional development of medical physicists through specially designed programmes, promoting research and disseminating knowledge and expertise through the official congress or symposium, developing infrastructure and resources to share information about useful publications, libraries, and data, promoting guidelines of practice standards and accreditation for medical physicists in collaboration with IMPCB and IAEA etc., strengthening a strong relationship and the exchange of information with other sub-regional organizations in Asia-Oceania and maintaining a close relationship with international bodies such as IOMP, IAEA, WHO etc.

IV. SCIENTIFIC COMMITTEE [SC]

The Scientific committee is to explore and identify the need for international scientific symposia, research meetings, regional meetings and/or research workshops and assist the individual medical physics organizations with effective preparation and management of these activities in AFOMP member countries, to enhance the cooperation of member state medical physics organizations in exchanging the information about scientific activities planned in their respective countries and putting this information in the AFOMP calendar of scientific activities, to promote co-operation and communication with other medical physics organizations outside Asia to support the quality of patient care through research, education and training, to organize and/or sponsor regional and international conferences in the AFOMP region, to encourage research, education and training in medical physics in order to maintain quality of medical physics and patient care in the AFOMP region, to promote exchange of knowledge and research, to promote international cooperation in addressing the science needs in medical physics, including participation in the scientific programs of other organizations, to encourage medical physicists to share information about their research, publications so that the AFOMP members can get to know and benefit from each other, and to explore possibilities of exchange programmes for young medical physicists to increase their knowledge and skills.

V. FUNDING COMMITTEE [FD]

The funding committee recruits Corporate Members from industry for the purpose of providing funds to assist AFOMP activities. This committee aids to get grants from international organizations such as IOMP for AFOMP in its primary role of training and promotion of medical physics.

VI. AWARDS AND HONORS COMMITTEE [AHC]

The roles of awards and honors committee is to promote activities related to education and training of AFOMP medical physics by promoting the education, training and professional development of medical physicists, to develop AFOMP policy statement on education and training of medical physics in AFOMP countries to promote and advance the practice of medical physics with the highest quality of medical services for patients care, to support and collaborate with the education and training committees of Regional Chapters on matters relating to education and training, including development of training materials and training methodology, to organize workshops and seminars in conjunction with related international conference meetings, to promote and assist international education and training initiatives and to study ETC activities of other organizations to adapt to AFOMP societies for promoting high quality educational programs at the graduate and postgraduate levels as well as residency programs in medical physics.

VII. INTERNATIONAL MEDICAL PHYSICS CERTIFICATION BOARD (IMPCB)

With the goal to improve the quality of clinical medical physicists and the profession, the concept of formation of the International Medical Physics Certification Board (IMPCB) was originated and IOMP has established the IMPCB on 23rd May 2010. The objectives and purposes were to establish minimum standards and improve the practice of medical physics, to develop standards and procedures for the certification of medical physicists, to establish the infrastructure, requirements and assessment procedures for the accreditation of medical physics certification programmes, to establish and evaluate qualifications of candidates requesting examination for certification in the field of medical physics, to arrange, and conduct examinations to test the competence of candidates for certification in the field of medical physics, to grant and issue certificates in the field of medical physics to applicants who have been found qualified by the Board and to maintain a registry of holders of such certificates. The IMPCB model programme, developed in accord with IOMP Policy Statement No. 2 include guidelines for basic requirements for education and training of medical physicists, minimum educational qualifications, professional training requirement, clinical training, professional certification and maintenance of certification.

The Table below lists the current number of medical physics educational courses in the AFOMP member countries

VIII. CONCLUSION

The economic, social, linguistic, cultural and educational backgrounds of AFOMP countries are substantially diverse and comprise more than half of the world population. As there are fewer medical physics training programmes, there is a shortage of qualified medical physics professionals in many of the AFOMP countries. Though the professional role of medical physicists in routine clinical practice increased and the status improved over the past years, there is still a long way to go. The activities of AFOMP are designed to bring solid and steady improvement to the professional status of medical physicists in Asia Oceania region. AFOMP activities could bring about heartening progress in the standard of practice of medical physics profession. Regional collaboration for education, training, research and sharing of knowledge and experience is established and fostered. Most countries are yet to establish professional certification/ accreditation system, and it will further boost the official recognition of the status of medical physicists.

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IUPAP for the supporting grant and to the IOMP for the organization of the Workshop.

Below is listed the current number of medical physics educational courses in the AFOMP member countries

Australia- 06	Indonesia -01	Japan -03	Malaysia -02	India- 22
Mayanmar - 00	Mangolia - 00	Nepal -00	Hongkong -01	New Zealand -01
Pakistan -01	Philipines -01	China -07	Singapore - 00	South Korea -04
Taiwan -01	Bangladesh -01	Thailand -03	Vietnam -01	

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STATUS OF MEDICAL PHYSICS AND ACTIVITIES TO BOOST PROFESSIONAL DEVELOPMENT IN THE MEFOMP REGION

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Abstract — **The paper is part of the IOMP-IUPAP Workshop "MEDICAL PHYSICS PARTNERING WITH THE DEVELOPING WORLD" at the World Congress in Prague WC2018. The paper presents the status in the IOMP Regional Organization MEFOMP (Middle East Federation of Organizations for Medical Physics).**

Keywords— **Medical Physics Professional Development, Medical Physics Education and Training.**

I. INTRODUCTION

The Middle East Federation of Organizations of Medical Physics (MEFOMP) was born in 2009 as one of regional organizations of Medical Physics in the world. There are twelve (12) countries involved, namely Qatar, Oman, Iraq, Syria, Jordan, Kuwait, Lebanon, Saudi Arabia, Palestine, Bahrain, United Arab Emirates and Yemen. The process of activities for establishing local Medical Physics Societies varies among the 12 countries, and this creates a wide divergence among medical physics programs in the Middle East. Most of the medical physics programs have succeeded since its establishment; whereas others have not due to the conditions beyond the control of medical physicists; although, a few are still trying to survive.

In spite of the instability in the region, there are enormous efforts and achievements from fellow medical physicists who continuously work and support for the development of the Medical Physics Profession in the Middle East. It is vital that such efforts be sustained to further accelerate the growth of Medical Physics profession in the region.

The MEFOMP Constitution was reviewed and adjusted by most of the MEFOMP Members and Ex-Officers from AAPM and IOMP. It is then been approved by the majority of the MEFOMP members during the World Congress of Medical Physics and Biomedical Engineering (WC2009) that took place in Munich, Germany from 7 to 12 September 2009.

The aims and purposes of the Federation are:

a) To promote the co-operation and communication between medical physics Organizations in the region.

b) To promote medical physics and related activities in the region.

c) To promote the advancement of the status and standard of practice of the medical physics profession.

d) To Organize and/or sponsor international conferences, regional and other meetings or and courses.

e) To collaborate or affiliate with other scientific Organizations worldwide.

The process of activities in for establishing local Medical Physics Society varies among the twelve (12) member countries (see Table-1), and this generates a wide divergence among medical physics programs in the Middle East. Most of the medical physics programs have succeeded since its establishment; whereas others have not due to conditions beyond the control of medical physicists; nevertheless, a few are still on process.

II. CHALLENGES IN MIDDLE EAST REGION

Although the number of Medical Physicist in the Middle East has been constantly increasing, the demand for more qualified medical physicist increases as well. It is good to note that the local authorities started to realize it's the importance of this profession in healthcare. However, it is a challenge to acquire qualified medical physicists due the following:

1. limited number of universities offering this specialty;
2. limited awareness on how vital this profession is within the medical practice and within the society in general; and
3. Absence of or under-recognition of the profession by the local authorities.

In view of this, there is a strong need to establish and formulate new rules, guidelines and standard specific to this field. Improvement of professional recognition which would promote interest within the new generation of professionals is essential. A Medical Physicist Education System and Certification Board in the region would further establish the profession, and this can be made possible through a collaborative effort between the MEFOMP and local/regional authorities.

The need for education and training of clinical medical physicists is fundamental in defining role, responsibilities and status; hence, it is important that senior academic positions of medical physics at universities be established in every country; in such a manner that they should have dual responsibilities in the faculty of Medical Physics and hospitals.

The mission of the Middle East Federation of Medical Physics (MEFOMP) is to advance medical physics practice throughout Middle East by disseminating scientific and technical information, fostering the educational and professional development of medical physics, and promoting the highest quality medical physics services for patients.

The Goals of The MEFOMP are to, educate, train, and promote research within local society members, to promote advancement in medical physics, and to encourage exchange of expertise and information among societies by continuous professional development through organizing regional conferences and symposiums. The goals and objectives of MEFOMP are directed by the Executive Officers supported by the Chairs of the Committees (see Table-2: The Executive Officers and Chair of Committees of MEFOMP 2018-2021).

Table-1: List of Medical Physics Societies in the MEFOMP and number of Medical Physicist and female Medical Physicists

Country	Name of Society	Established	No. of Medical Physicists	No. of Female Medical Physicists
Bahrain	Bahrain Society for Medical Physics and Bio-Engineering (BSMPB)	2008	7	6
Iraq	Iraqi Medical Physics Society (IMPS)	2013	44	30
Jordan	Jordanian Association for Medical Physics (JAMP)	2006	197	40
KSA	Saudi Medical Physics Society (SAMPS)	2006	380	84
Kuwait	Kuwait Association for Medical Physics (KAMP)	2016	27	7
Lebanon	Lebanon Association for Medical Physics (LAMP)	2005	20	8
Oman	Onam Medical Physics Society (OMPS)	2018	30	24
Palestine	Palestine Medical Physics Society (PMPS)	2014	9	5
Qatar	Qatar Medical Physics Society (QaMPS)	2009	28	8
Syria	Syrian Association for Medical Physics (SyMPA)	2009	36	12
UAE	Emirate Medical Physics Society	2005	61	43
Yemen	Yemen Medical Physics Society	2012	8	1
Total			**847**	**268**

Table-2: The Executive officers and chair of committees of MEFOMP 2018-2021

COUNCIL EXECUTIVE OFFICERS		
President	Huda Al Naemi	Qatar
Vice President	Meshari Al Naemi	Kuwait
Secretary General	Mohammad Hassan Kharita	Syria
Past President	Abdalla Al Haj	KSA
Treasurer	Rabih Hammoud	Lebanon
COMMITTEES' CHAIRPERSONS		
Educaion and Training Committee	Refat Al Mazrou	KSA
Science Committee	Adnan Al Watban	KSA
Professional Relations Committee	Zeina Elbalaa	Lebanon
Publications Committee	Anas Abasneh	Jordan
Awards and Honours Committee	Afkar Al Farsi	Oman
Website & Newsletter Committee	Nabil Iqellian	Jordan
Women in MedicalPhysics Committee	Hanan Al Dossari	Kuwait

Table-3: List of universities and institutions in MEFOMP member countries offering medical physics programs.

Country	Name of Society	Established	No. of Medical Physicists	No. of Female Medical Physicists
Bahrain	Bahrain Society for Medical Physics and Bio-Engineering (BSMPB)	2008	7	6
Iraq	Iraqi Medical Physics Society (IMPS)	2013	44	30
Jordan	Jordanian Association for Medical Physics (JAMP)	2006	197	40
KSA	Saudi Medical Physics Society (SAMPS)	2006	380	84
Kuwait	Kuwait Association for Medical Physics (KAMP)	2016	27	7
Lebanon	Lebanon Association for Medical Physics (LAMP)	2005	20	8
Oman	Onam Medical Physics Society (OMPS)	2018	30	24
Palestine	Palestine Medical Physics Society (PMPS)	2014	9	5
Qatar	Qatar Medical Physics Society (QaMPS)	2009	28	8
Syria	Syrian Association for Medical Physics (SyMPA)	2009	36	12
UAE	Emirate Medical Physics Society	2005	61	43
Yemen	Yemen Medical Physics Society	2012	8	1
Total			**847**	**268**

Graduate Medical Physics educational and training programs offering PhD and/or MSc degrees are currently available in 5 (five) countries, i.e., Iraq, Jordan, Lebanon, Saudi Arabia, and Syria. One undergraduate medical physics program, offering BSc Degree, is also available in the IBB University in Yemen. See Table-3: List of universities and institutions in MEFOMP member countries offering medical physics programs. The table also shows a total number of Medical Physicists (male and female) with PhD, MSc, and BSc degrees is approximately 847 physicists from both genders.

In addition to teaching and training, Medical Physicists are often involved in research and technical development in most academic settings. While the type of research conducted in most universities and institutions varies, research in radiation dosimetry is the most common one in the 3 (three) main subspecialties of the Medical Physics: therapy, radiology, and nuclear medicine. In some institutions, Medical Physicists are also engaged in radiation biology and biomedical research in collaborations with other hospitals and centers. Though research is required from all the PhD students, students in MSc programs are also encouraged to have optional research projects.

In most countries, continuing education and training are offered in annual conferences, seminars, and workshops. In some countries Medical Physicists often participate in training courses and workshops organized by MEFOMP, IAEA, AAPM and Arab Health conferences in the region. Since 2013, a one-day symposium is organized in most countries on the occasion of the International Day of Medical Physics (IDMP) on November 7th of each year. Honors and recognitions are given to Medical Physicists during national and international symposiums and conferences.

ACKNOWLEDGMENTS

This paper is related to the IOMP-IUPAP Workshop "Medical Physics Partnering with the Developing World" at the World Congress in Prague WC2018. The lecturer and attendees of the Workshop expressed their gratitude to the IUPAP for the supporting grant and to the IOMP for the organization of the Workshop.

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STATUS OF MEDICAL PHYSICS AND ACTIVITIES TO BOOST THE PROFESSIONAL DEVELOPMENT IN THE AFRICAN REGION

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Abstract — **The paper is part of the IOMP-IUPAP Workshop "MEDICAL PHYSICS PARTNERING WITH THE DEVELOPING WORLD" at the World Congress in Prague WC2018. The paper presents the status in the IOMP Regional Organization FAMPO (Federation of African Medical Physics Organizations).**

Keywords— **Medical Physics Professional Development, Medical Physics Education and Training.**

FAMPO as the youngest regional federation of IOMP has come a long way in the nearly one decade of her existence to fulfill the aspirations and yearnings that informs her existence in the first instance. Established in 2009, the federation currently has members in 27 African nations including Algeria, Angola, Botswana, Burkina Faso, Cameroon, Cote D'Ivoire, Egypt, Ethiopia, Gabon, Ghana, Kenya, Libya, Madagascar, Mauritania, Mauritius, Morocco, Namibia, Niger, Nigeria, Senegal, South Africa, Sudan, Tunisia, Uganda, United Republic of Tanzania, Zambia and Zimbabwe.

AFRICA – Is the World's second largest and second most populous continent. At One Billion people – It accounts for about 15% of the World's human population, It has 55 fully recognized sovereign states - 49 are UN members, 38 are IAEA member states and 32 are AFRA (regional) member states ; Algeria is the largest African country by Area (2.382 x 10 6 Sq. Km.) and Nigeria is the largest by Population (198 M – 2018 Estimate)

The aim and functions of FAMPO include among others - promotion of improved quality service to patients and the community in the region ; the co-operation and communication between Medical Physics Organizations in the region, and where such Organizations do not exist between Individual Medical Physicists. To promote appropriate use of technology to the benefit of rural populations, to organize and/or sponsor international conferences, regional and other meetings, to collaborate or affiliate with other Scientific Organizations and overall, the activities of the Federation are not aimed at profit.

The African imaging infrastructure is such that most countries have only basic radiology equipment, only 20 countries have access to nuclear medicine, fewer medical physicists are dedicated to imaging than to RT, high end imaging (e.g. mammography, MRI, PET/CT) is available in the public sector in only 10 countries and Tele-radiology is limited by telecommunications infrastructure.

The Radiotherapy facilities exist in 25 countries and 12 of this number have one centre only, with just 5 adjudged to have a 'basic' radiotherapy service as defined by the IAEA. About seven countries including Angola, Benin, Rwanda, Mauritania, Senegal and Uganda have recently commissioned new projects. A detailed analysis of the status of radiotherapy in Africa could be summarized as: Twenty-eight (28) countries do not have radiotherapy services, 14 have three or fewer machines and only seven have more than 10 machines. Cobalt machines represent 30% of the equipment. There is an average of 3.8 million people per machine, which varies a lot between different income groups. Between 22 and 28% of the needs are covered depending on the benchmark used. Countries without radiotherapy are slowly setting up their first departments. Sustainability is a problem and expansion is mainly happening in countries with a larger number of machines.

The number of Clinically Qualified Medical Physicists in the region hovers around 550 to 600 and only 3 countries (Egypt, Morocco and South Africa) accounts for more than 50% of the CQMP's . The recently published Global Work-force Data for MP's clearly under report the data from Algeria, Morocco, Sudan and Tunisia. There are some few other NMO's that were not mentioned albeit with less than 10 members. DR, NM and RT sub-specialization are under gradual implementation in the region and some MP's also work in more than one of the three disciplines, and they do move between as well. At least 30% MP's are females and 75% are government employees. MP baseline data in Africa is now available and can gradually be improved upon. The database can serve as the formal reference for competent agencies in an attempt to create harmony in the uses of resources that will be invested in the continent. The database will help in planning for future programs and launching projects that could be of benefit to all the MP's in the region.

Efforts to raise awareness and activities to boost professional development in the region have been promoted through education and training, information dissemination especially via the federation's website (www.fampo-africa.org) , the yearly celebration of the International Day of Medical Physics (IDMP), accentuating the efforts at recognition of the MP's and international partnerships. FAMPO has endorsed some IAEA/AFRA publications which include among others - Regional Postgraduate Medical Physics Syllabus for Academic Programmes (2013), Regional Clinical Training Programme for Radiotherapy Medical Physics (2013) and Template Portfolio for the Regional Clinical Training Programme in Radiotherapy Medical Physics (2013). These publications have largely harmonized standard of MP academic education in the region. Ongoing attempts to implement FAMPO accredited clinical training for MP's have resulted in two task force meetings (TFM's) held in Vienna. Survey to assess capability and willingness of RT centres to provide full/partial accreditation of clinical training programme were conducted and the workplan for implementing accredited clinical training is aligned with workplan for IAEA's TC Project RAF 6050 on Improving Access to Quality Cancer Management through Sustainable Capacity Building. Countries with post-graduate academic programmes include Algeria, Egypt, Ghana, Libya, Morocco, Nigeria, South Africa, Sudan and Tunisia.

On recognition of MP's , countries with proper legislation (national recognition) of MP's include Ghana (through her Allied Health Professional Council – AHPC) and South Africa (HPCSA – Health Professional Council of South Africa). Other countries are at various stages of legislative processes. Professional Development Committee (PDC) of FAMPO is mandated to establish regional mechanism by which CQMPs can be recognized through formal process of certification and registration, working closely with E&T Committee to help increase the number of accredited academic training programmes and establish accredited clinical training programmes in the region. This is necessary for developing MP profession in the Africa region and also to ensure that trained MPs from accredited institutions automatically receive registration from FAMPO.

The concept of Audits and Continuous Professional Development (CPD's) are also being espoused and arising from a recent TFM recently hosted by the IAEA, the Agency has been graciously tasked to make documentation available from Coordinated Research Projects (CRP's) related to audit to all member states, support National Workshops in the region to initiate audits, to make available relevant phantoms as suggested in the audit CRPs and support changes in the design (remote to on-site dosimetry) if requested, to encourage SSDLs to work closely with Medical Physicists to establish and sustain audits and to encourage regulatory bodies to include the implementation of QMS in radiotherapy as their licence requirements. Also, FAMPO have been mandated to encourage Medical Physicists to organise internal audits within their hospitals, to encourage Medical Physicists to organise external independent audits within their region. To encourage Medical Physicists to engage with their heads of oncology department to request QUATRO audits. AFRA (the regional cooperative agreement) was to support audit activity through the regional projects such as radiotherapy, SSDL, radiation protection and safety of patients.

In summary, FAMPO roles in promotion of E&T have been encapsulated as establishment of a regional MPs competencies data base, establishment of an inventory of Institutes delivering academic programmes, establishment of an inventory of Institutes delivering Clinical Training programmes, drafting accreditation criteria for Academic and Clinical Training programmes, drafting certification criteria for MP profession, organizing activities to support CPD of MP's and launching a regional journal of MP (African Journal of Medical Physics).

In conclusion, FAMPO's role is key to achieve harmonized and high standard of education and training programmes in Africa, which leads to: improved quality and quantity of trained MPs who would readily be in position to practice competently and independently and improved medical imaging and radiotherapy treatment delivery in the region.

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This paper is related to the IOMP-IUPAP Workshop "Medical Physics Partnering with the Developing World" at the World Congress in Prague WC2018. The lecturer and attendees of the Workshop expressed their gratitude to the IUPAP for the supporting grant and to the IOMP for the organization of the Workshop.

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STATUS OF MEDICAL PHYSICS AND ACTIVITIES TO BOOST THE PROFESSIONAL DEVELOPMENT IN THE ALFIM REGION

Dr. Rodolfo Alfonso, Cuba, President ALFIM

Abstract — **The paper is part of the IOMP-IUPAP Workshop "MEDICAL PHYSICS PARTNERING WITH THE DEVELOPING WORLD" at the World Congress in Prague WC2018. The paper presents the status in the IOMP Regional Organization ALFIM (Latin American Medical Physics Association).**

Keywords— **Medical Physics Professional Development, Medical Physics Education and Training.**

During the last decade, Latin America has witnessed an accelerate development in the available radiation medicine technologies, both for diagnosis and therapeutic purposes. In several countries of the region, governments have promoted investment in high-end technologies for increasing the coverage of Radiotherapy and Nuclear Medicine public services. So currently, although large inequities in distribution and accessibility still prevail, the access to advanced diagnosis and treatment radiation facilities is continuously growing. In parallel, the private health sector is also introducing very sophisticated radiation technologies, even in low-income countries. While in 1990 there were about 400 MV units (25% linacs, 75% Cobalt machines) and 260 medical physicists (MPs) in Latin America (0.65 MPs/MV machine), 25 years later the numbers grew to 1000 machines (75% linacs and 25% Cobalt) and 650 MPs. Therefore, although the proportion MPs/MV did not changed, the significant increase in complexity of technology and sophistication of procedures means that the gap in demand of MPs has broaden.

This boom has pushed forward the demand of highly qualified medical physicists in the region, stimulating universities to establish academic training programs; in 2017 there were 19 master programs in medical physics, and even 16 programs at bachelor level (which is not the approach supported by ALFIM). Most of the academic programs do not have enough hours of supervised clinical practice to be able to meet the minimum training requirements required for the clinically qualified MP. Recognition of the MP as a health professional is still an issue in most of the countries; this could be partly the cause of the shortage of residency type, clinical training programs. In general, clinical institutions, even university hospitals or national cancer institutes are not prone to hire medical physics residents. Consequently, there is not balance between the number of graduates from academic programs and the availability of positions for clinical training. Recently, some universities have started an intermediate solution, the so-called professional master, which combined the academic and the clinical training in the same program. Regarding certification, in many countries this process has been fulfilled by the national nuclear regulatory bodies, which requires a minimum education and training for providing the corresponding license for working in radiation medicine practices. Recently, for the first time in the region, the International Medical Physics Certification Board (IMPCB) performed Part I and Part II examinations in Mexico City, where six medical physicists passed successfully both exams and are pending to perform Part III. Implementation of such examination board in the region should contribute to establishing a regional medical physics certification board.

The Latin American Association of Medical Physics (ALFIM) is working jointly with the Latin American Association of Therapeutic Radiation Oncology (ALATRO) and the Latin American Association of Societies of Biology and Nuclear Medicine (ALASBIMN), in order to gain support from our medical counterparts, for the recognition of the MP as a health professional, as well as understanding the role of MP resident in corresponding departments.

ALFIM is promoting a network of educational programs in medical physics in the region, using as starting point the existing Latin American Network for Education of Nuclear Technologies (LANENT) and the Latin American Network for Radiation Protection in Medicine (LAPRAM). ALFIM which to promote, in coordination with IOMP and the IMPCB, the accreditation of a regional certification body and its recognition by national regulatory and health authorities.

Finally, ALFIM is closely working with the IOMP and the Chilean Society of Medical Physics (SOFIMECH) in the organization of the 24th International Conference on Medical Physics (ICMP) shall be held in Santiago, Chile, 8-11 September 2019, which will take place in conjunction with the 8th Latin American Congress of Medical Physics and the 2nd Chilean Congress of Medical Physics.

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STATUS OF MEDICAL PHYSICS PROFESSION IN THE LOWER-MIDDLE AND UPPER-MIDDLE-INCOME COUNTRIES OF THE EFOMP REGION

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Abstract— **Due to the growing demands on the Medical Physics service in the national healthcare systems in the region of the European Federation of Organisations for Medical Physics (EFOMP), there is a strong need for harmonised and developed Medical Physics Profession in Europe. However, significant differences in the status, level of development and harmonisation of the Medical Physics profession across Europe and especially in the upper-middle-income (UMI) and lower-middle-income (LMI) countries of the EFOMP region are still considerable. A short survey was conducted with the aim of gaining an insight into the status of profession and activities needed to boost the professional development of Medical Physics in the European UMI and LMI countries. These countries are Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Romania, Russian Federation Serbia and Moldova. The survey reveals significant differences among the UMI and LMI member countries of the EFOMP region and lack of the structure of the Medical Physics profession. While the number of Medical Physicists working in healthcare is strongly growing in all UMI and LMI countries (on average more than 100% in last ten years), the structure of the Medical Physics profession remains incomplete. In most countries, training and education programme in Medical Physics does not exist, and in some of the countries, Medical Physics is not recognised as an independent profession in healthcare. In these countries, strong activities are needed in the management of the Medical physics profession to boost the development and harmonisation of the profession with the EFOMP guidelines.**

Keywords—**Medical Physics profession, EFOMP, IOMP, training and education, healthcare.**

I. INTRODUCTION

In most of the European countries, Medical Physics is a well-defined profession. The importance of medical physicists in the development and clinical application of different healthcare technologies is well known, and medical physicists roles, responsibilities, and education and training requirements are defined in the International Atomic Energy Agency (IAEA), International Organisation for Medical Physics (IOMP) and European Federation of Organisations for Medical Physics (EFOMP) documents and policy statements [1-6]. As the number of new cancer cases is increasing globally and as projected by the World Health Organisation (WHO) this number will rise from 14.1 million in 2012 to 24.6 million by 2030 [7], Medical Physics will play even more important role in diagnostics and treatment of cancer than today. Clearly, in the EFOMP region, there is a strong need for harmonised and developed Medical Physics Profession. However, differences in the status, level of development and harmonisation of the Medical Physics profession across Europe are still considerable. The differences are especially prominent for the upper-middle income (UMI) and lower-middle-income (LMI) countries. According to the World Bank country classification [8], EFOMP member UMI countries are Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Romania, Russian Federation and Serbia, while LMI country is Moldova. For those countries, the status of the Medical Physics profession is ranging from the unrecognised profession without appropriate qualification framework to fully recognised independent profession. A short survey was conducted to get an insight into the status of profession and activities needed to boost the professional development of Medical Physics in the European UMI and LMI countries.

II. MATERIALS AND METHODS

A questionnaire was prepared and sent to the National Member Organisation (NMO) for Medical Physics of each UMI and LMI country member of the EFOMP (Fig.1 and Fig.2), with the aim of collecting the necessary information for the survey. The questionnaire was divided into six parts: General, Requirements to enter Medical Physics education, Training and education programme in Medical Physics (Fig. 1), National health system requirements and position of Medical Physicists, Medical Physicists registration and Medical Physics profession management and communications (Fig. 2).

EFOMP

Questionnaire on Status of Medical Physics Profession

IOMP/IUPAP Workshop on Medical Physics Partnering, Prague 6 June 2018

GENERAL

Country of:_______________

Name of the medical physics Society/Association in English (abbreviation):____________________

An approximate number of medical physicists in 2018:

- working in RT: _____________
- working in DIR: _____________
- working in NM: _____________
- working in RP: _____________

An approximate number of medical physicists in 2008 (ten years ago):

- working in RT: _____________
- working in DIR:_____________
- working in NM: _____________
- working in RP: _____________

Approx. number of new MPs expected to enter the national health system in next ten years: ________

REQUIREMENTS TO ENTER MEDICAL PHYSICS EDUCATION

Basic education requirement/degree to enter medical physics education:

- basic education/university degree required: ________________________
- how many years of studies does it represent:________________________

TRAINING AND EDUCATION PROGRAMME IN MEDICAL PHYSICS

Is there established national training and education program in MP? YES NO

How long is the programme and when it was established? ________________________

Is there a separated programme for each speciality (RO, DIR, NM)? YES NO

Does the programme lead to any official diploma/qualification? YES NO

If yes, what is the name of diploma/qualification in English? ________________________

If the programme is established, is it official, recognised and approved? YES NO

If approved, who and when approved it? :_____________________________________

If no, is there an unofficial training and education programme
or programme in the status “waiting for approval”? YES NO

Where does the training programme take place? Hospital University both

Are the training centres (University, Hospital) accredited and who gives
the accreditation? ____

Fig.1. Questionnaire on Status on Medical Physics Profession, page 1.

Does the training and education programme follow the recommendations given in
the European Guidelines for Medical Physics Experts (EC RP 174)? YES NO

Does the programme follow the EFOMP Policy Statement No. 12.1? YES NO

Did you use help from EFOMP/IOMP/IAEA experts during the program setup? YES NO

NATIONAL HEALTH SYSTEM REQUIREMENTS AND POSITION OF MEDICAL PHYSICISTS

Is there legal requirements for Medical Physicist
involvement in medical procedures? YES NO

Is there a license or diploma required to work as Medical Physicist? YES NO

If yes, is it officially provided (i.e. by Ministry of Health, Government etc.)?______________________

Is Medical Physics recognised at the national level
as an independent profession in health care? YES NO

Is your national legislation harmonised with the EU Directive EURATOM 2013/59? YES NO

Is your national legislation harmonised with the requirements of the International Basic Safety Standards
for protection against ionizing radiation? YES NO

MEDICAL PHYSICISTS REGISTRATION

Is there a Register of Medical Physics Professionals in the country? YES NO

If yes, is it officially recognised by the authorities? YES NO

If yes, who is in charge of Register (i.e. Ministry of Health, national board)? ______________________

Is there a renewal mechanism in the Register? YES NO

Does the organisation of Register follow the EFOMP Policy Statement No. 6.1? YES NO

If yes, is it based on a Continuing Professional Development system (CPD)? YES NO

If yes, does it follow the EFOMP Policy Statement No. 10.1? YES NO

MEDICAL PHYSICS PROFESSION MANAGEMENT AND COMMUNICATIONS

Is there established communication between
medical physics Society and Ministry of Health? YES NO

Is there established communication between Medical Physics Society and other professional societies
(radiation oncology, nuclear medicine, diagnostic radiology)? YES NO

In the most of the cases, who is initiating changes in legislation and provisions regarding medical physics
profession (MP Society, Ministry of Health, State Office for Radiation Protection etc.)

____

Please return the Questionnaire to: hhrsak@kbc-zagreb.hr

Thank you for your contribution to the collecting of data for the IOMP/IUPAP Workshop

Hrvoje Hrsak, Croatian NMO delegate

Dept. of medical physics, UHC Zagreb

Fig.2. Questionnaire on Status on Medical Physics Profession, page 2.

III. Results and discussion

A questionnaire was sent to the following country members of the EFOMP: Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Moldova, Romania, Russian Federation and Serbia. 5 out of 8 country members responded (Bosnia and Herzegovina, Bulgaria, Croatia, Moldova and Serbia).

In all countries that responded to the questionnaire, the number of Medical Physicists working in healthcare was significantly increased in the last ten years (Fig. 3). The increase in the number of medical physicists is ranging from the 20 % in the countries with the highest number of medical physicists (Bulgaria and Serbia) to 330 % in the countries with the lower number of medical physicists (Bosnia and Herzegovina). A special case is Moldova in which ten years ago no medical physicists were working in healthcare.

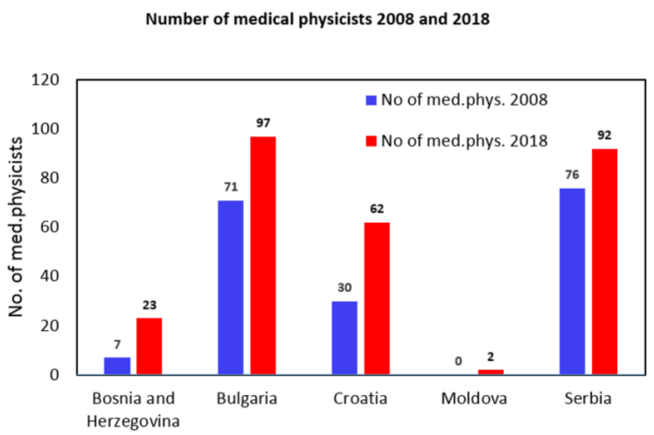

Fig. 3 Number of medical physicists working in the healthcare 2008 and 2018 for UMI and LMI country members of the EFOMP

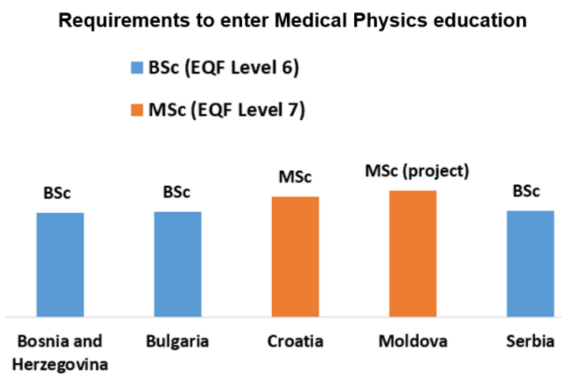

Fig.4 Basic requirements to enter medical physics education for UMI and LMI country members of the EFOMP

The basic educational requirements to enter Medical Physics education is a university degree in physics or equivalent (Fig 4), which complies with the European Guidelines on Medical Physics Expert Radiation Protection No 174 (RP174) [9].

National training and education program in Medical Physics exists in two countries (Bulgaria and Serbia) (Fig 5), resulting in the qualification "Medical Physics Specialist". However, the program is approved at the national level only in Bulgaria. Only Bulgarian program follows the recommendations given in the European Guidelines for Medical Physics Experts RP174 [9] and EFOMP Policy Statement No. 12.1 [6]. In three countries this program is in the status of the ongoing project (Bosnia and Herzegovina, Croatia, Moldova).

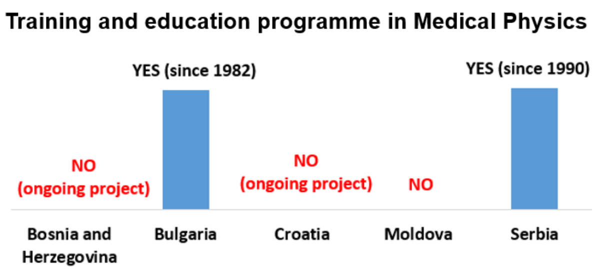

Fig. 5 Established national training and education program in Medical Physics

In all countries except Moldova, there are legal requirements for Medical Physicist involvement in medical procedures (Fig 6). Usually, these requirements are imposed by the State offices for radiological and nuclear safety. However, only in Bulgaria and Serbia Medical Physics is recognised as an independent profession.

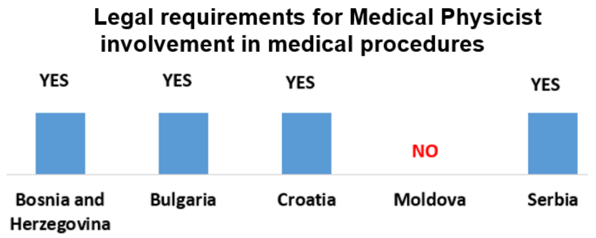

Fig. 6 Existence of national legal requirements for Medical Physicist involvement in medical procedures

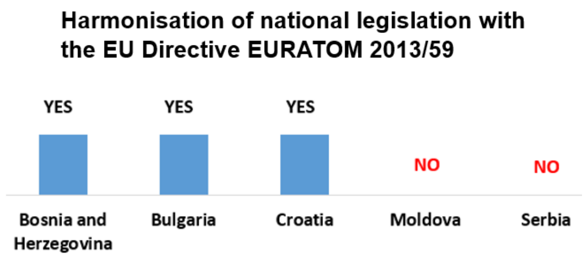

Fig. 7 Harmonisation of the national legislation with the EU Directive EURATOM 2013/59

National legislation is harmonised with the EU Directive EURATOM 2013/59 [10] in Bulgaria, Bosnia and Herzegovina and Croatia (Fig 7). The harmonisation is usually provided within the national law on radiological and nuclear safety. Usually, State offices for radiological and nuclear safety are in charge of preparing the proposal of harmonisation of national legislation with the EURATOM 2013/59.

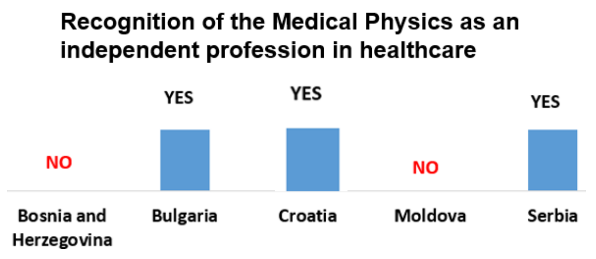

Fig. 8 Recognition of the Medical Physics as an independent profession in national healthcare

In Bulgaria, Croatia and Serbia Medical Physics is recognised as an independent profession (Fig 8). No register of Medical Physics professionals exists in any of the UMI and LMI member countries in the EFOMP region (in Bulgaria national register of Medical Physics professionals is in the status of a project). A formal Continuing Professional Development programme (CPD) exist only in Bulgaria.

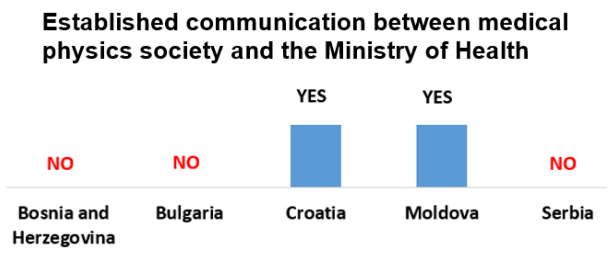

Fig. 9 Established communication between the national medical physics society and the Ministry of Health

Systematic communication between the national medical physics society and the Ministry of Health exists only in Croatia and Moldova (Fig. 9) in the form of advising in the medical equipment procurement or the legal issues regarding the use of ionising radiation in medical procedures.

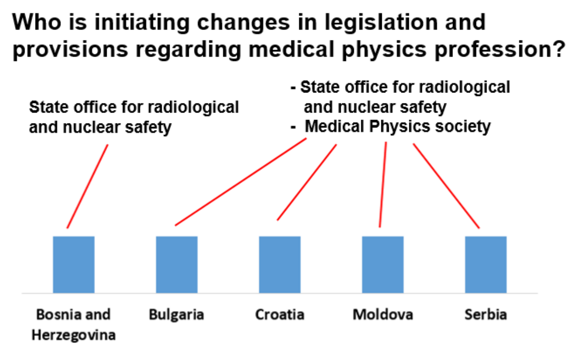

Fig. 10 The changes in the legislation and provisions regarding the Medical Physics profession are mostly initiated by the State office for radiological and nuclear safety

Usually, the changes in the national legislation and provisions regarding the medical physics profession, such as recognition of the profession, the involvement of medical physicists in medical procedures or similar, are initiated by the State offices for radiological and nuclear safety and Medical Physics societies throughout the mutual communication and the procedure of advising (Fig 10).

It is clear that the Medical Physics Profession in the UMI and LMI member countries of the EFOMP region is far from being harmonised with the EFOMP guidelines and at the satisfactory level. The differences are considerable, and for these countries, the status of the Medical Physics profession is ranging from the unrecognised profession without appropriate qualification framework to fully recognised independent profession.

The international guidelines and policy statements, given by IAEA, IOMP, EFOMP and EU Council, are providing a clear path for establishing a well-defined profession to the benefit of the patient and healthcare. However, it seems that somehow these guidelines are not reaching the national healthcare stakeholders (Ministry of Health, Government), responsible for making decisions on the healthcare future. As the need for the profession capable of providing a high-quality medical physics service to healthcare is growing, the number of medical physicists working in healthcare is rapidly growing, but the profession itself does not transform along with the growing need, and there is a gap between the demands on the profession and structural capacity of the profession. Strong activity in the Medical Physics profession management is needed in the UMI and LMI member countries of the EFOMP region to boost the development of the profession. NMOs should be more active in networking with the national Healthcare stakeholders, Medical Physics societies and hospitals to boost the development of Medical Physics profession.

IV. Conclusions

There is a significant increase in the number of Medical Physicists in the European UMI and LMI countries (on average more than 100% in last ten years) due to the growing demands of the national healthcare systems. However, there is a lack of structural changes and development of the medical physics profession along with the IAEA, IOMP, EFOMP and EU Council guidelines and provisions. As a result, the status of the Medical Physics profession for those countries is ranging from the unrecognised profession without appropriate qualification framework to fully recognised independent profession. There is a growing gap between the structural capacity of the profession and healthcare demands. Strong activity in the Medical Physics profession management is needed in the UMI and LMI member countries of the EFOMP region to boost the development of the profession.

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HOW TO

SELECTING A CT SCANNER FOR CARDIAC IMAGING

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Abstract — **Coronary angiography to assess the presence and degree of arterial stenosis is an examination now routinely performed on CT scanners. Although developments in CT technology over recent years have made great strides in improving the diagnostic accuracy of this technique, patients with certain characteristics can still be 'difficult to image'. The various groups will benefit from different technological enhancements depending on the type of challenge they present.**

Good temporal and spatial resolution, wide longitudinal (z-axis) detector coverage and high x-ray output are the key requirements of a successful CT coronary angiography (CTCA) scan. The requirement for optimal patient dose is a given. The different scanner models recommended for CTCA all excel in different aspects. The specification data presented here for these scanners and the explanation of the impact of the different features should help in making a more informed decision when selecting a scanner for CTCA.

Keywords— **CT scanner, Coronary angiography, Selection of Imaging equipment, BJR.**

I. INTRODUCTION

Clinical interest in the application of computed tomography for the imaging of coronary vessels dates back to 1998 with the introduction of '4-slice' CT scanners. These early multislice models posed limitations for performing coronary angiography, therefore their use in cardiac applications was confined to coronary calcium scoring, a technique established on electron beam CT (EBCT) scanners and which has less demanding image quality requirements.

Following the introduction of '16-slice' scanners CT coronary angiography (CTCA) became clinically feasible and improved results were achieved as scanner technology progressed through to '64-slice' systems and beyond. Currently, most CT manufacturers offer scanners capable of acquiring more than 64-slices simultaneously with features that facilitate high quality cardiac imaging. Despite this, obtaining a successful CTCA scan can still be challenging in some patients.

Selecting a CT scanner is a demanding process, and particularly if the scanner is to be used for cardiac applications. In the UK it is relatively uncommon to purchase a dedicated cardiac scanner, but a large percentage of scanners will be used for cardiac applications, and because this is usually the most demanding application it will often define the scanner's specification requirements.

Many factors need to be considered in the selection exercise, including cost, existing CT equipment, power and space requirements, usability (including ergonomics) and post-processing software. Ideally procurement teams should include radiologists, radiographers, medical physicists and facilities managers. The aim of this paper is to discuss only the fundamental technical requirements of a cardiac CT scanner with CTCA in mind and how comparisons should be made in order to make a fair evaluation of the systems.

II. CT SCANNERS FOR CORONARY ARTERY IMAGING: THE CHALLENGES

Due to the rapid motion of the heart, and the small structures to be imaged, CTCA is one of the most challenging clinical applications of computed tomography. Recent CT scanner developments have focused on overcoming these challenges, particularly with respect to gantry rotation speeds and z-axis coverage, such that the majority of patients requiring a CTCA scan can now be imaged successfully. However, patients with certain characteristics still present difficulties. Recent guidance published by the National Institute for Health and Care Excellence (NICE) [1] identified these patient groups and recommended that they should be imaged using particular CT scanner models. Four scanners were identified in the guidance, which at the time represented the highest specification model from each of the four major CT manufacturers, and these were termed 'new generation cardiac CT scanners'. Since the publication of the NICE guidance, technology has continued to evolve, and there are now additional scanner models that can be considered to meet the brief.

The patient groups identified in the NICE report, in which imaging was assumed to be difficult on previous generations of CT scanners, are those with one or more of the following characteristics:

- Calcium score greater than 400 Agatston units;
- Coronary artery stents;
- Coronary artery bypass grafts;
- Heart rate greater than 65 bpm;
- Arrhythmia (heart rate variation not specified); and
- Obesity - BMI greater than 30 kg/m2.

The above patient characteristics pose specific imaging challenges. For example, to successfully scan a patient with a fast heart rate places a different demand on the technology to that of a patient with coronary artery stents. Although each of the ‘new generation CT scanner’ models offers particular technological advantages, currently no single scanner model has the optimal specifications to best overcome all of the challenges posed by the above patient groups.

III. IMAGING REQUIREMENTS IN CORONARY CT ANGIOGRAPHY (CTCA): BEATING THE CHALLENGES

The technical CT scanner specification parameters that are considered key to successful CTCA imaging, and how each one of these might provide advantages in specific clinical challenges, are shown in Figure 1 and discussed further below. More detail on how each of these parameters can be enhanced is provided in the technical specifications section.

•*Spatial resolution: The devil is in the detail*

The evaluation of coronary artery stenosis requires the accurate depiction of small structures and so a high spatial resolution in three dimensions (Figure 2) is a key requirement.

•*Temporal resolution: In the blink of an eye*

The coronary arteries move rapidly in a complex manner throughout the cardiac cycle. To avoid significant image blur not only requires a CT scanner with a good spatial resolution, but also one with a good temporal resolution (analogous to a fast shutter speed on a photographic camera).

•*Longitudinal (Z-axis) coverage: The long and the short of it*

The length of cardiac anatomy that has to be covered in a CTCA scan is typically around 120 mm to 140 mm. As the majority of high-end CT scanners have a z-axis detector length shorter than this they generally cannot image the whole cardiac volume within a single gantry rotation. Coverage of the full anatomy is commonly acquired as a series of slabs over several heartbeats (Figure 3).

•*X-ray output: A little less noise please*

The high temporal resolution requirements of CTCA scans require short gantry rotation times. This necessitates powerful x-ray generators capable of delivering high tube currents [600 – 1000 mA] to provide a sufficient number of photons for adequate image quality.

•*Patient dose: How low can you go?*

The holy grail of imaging modalities utilizing ionizing radiation is a satisfactory image quality at a minimum radiation dose to the patient. As well as the image quality requirements for successful CTCA imaging, national and European legislation requires that radiation doses from medical examinations adhere to the ALARP (as low as reasonably practicable) principle and that the benefit of the

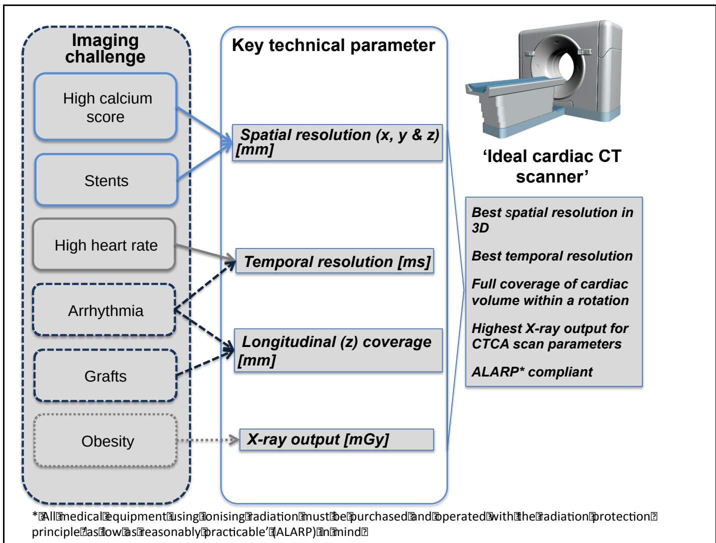

Figure 1. Diagram showing the relationship between the imaging challenge of different patient groups and the technical specification parameter that may help to meet that challenge (adapted from [2])

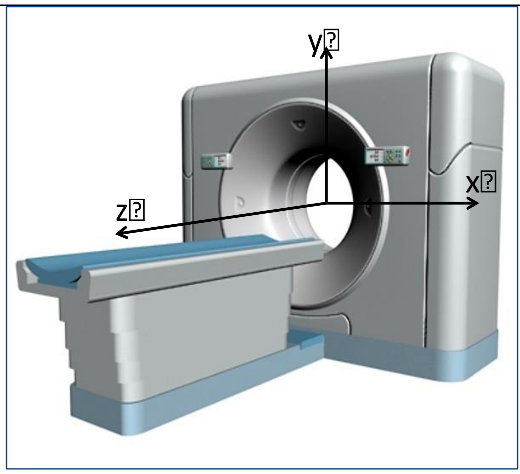

Figure 2. Co-ordinate system used in CT scanning

examination outweighs the risk from it [3].

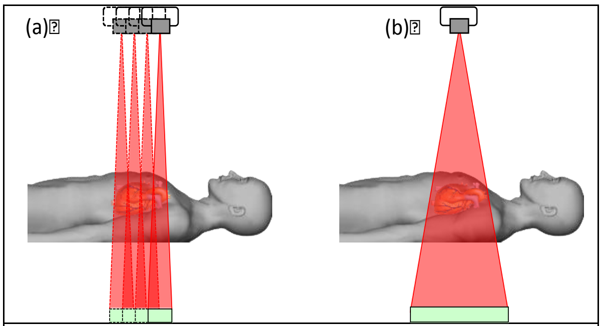

Figure 3. Number of gantry rotations required to cover the cardiac volume is dependent on z-axis detector array dimensions.
(a) on the majority of scanners several gantry rotations are required to cover the whole cardiac anatomy
(b) scanners with an 160 mm detector array, or above, can acquire the full cardiac anatomy in a single axial rotation

IV. TECHNICAL SPECIFICATIONS: *UNDERSTANDING THE NUMBERS…*

Each CT scanner manufacturer has a portfolio of CT scanner models covering a range from basic to high specification. The high-end scanners generally have capabilities for more complex examinations including cardiac and perfusion scanning, and specialised features such as dual energy scanning.

The scanner models from each manufacturer that would generally be considered in the UK when purchasing a scanner for cardiac applications are listed in Table 1 together with some of the technical specifications regarded as being key to a successful CTCA scan.

The recommendations that exist for the performance requirements of a 'cardiac' CT scanner are fairly non-specific. An expert consensus document from 2010, states that such a CT scanner must be capable of simultaneous acquisition of 64 slices and of covering the cardiac volume in a breath hold time of less than 20 seconds [4]. A joint (ACR/NAsSCI/SPR) practice parameter document on performance and interpretation of cardiac CT [5] gives the following minimum specifications:

• spatial resolution ≤ 0.5 x 0.5 mm in x-y plane and ≤ 1 mm in z-axis;

• temporal resolution ≤ 250 ms;

• an 'adequate' tube capacity;

• minimum section thickness ≤ 1.5 mm.

Otero et al compared the ideal technical requirements of a scanner for performing CTCA against the capabilities of multislice CT scanners as of 2010 [6] Their adapted table is presented (Table 2) with the CT scanner capabilities updated, where relevant, to reflect scanner specifications in 2015.

CTCA scans on patients with the characteristics that place them in the 'difficult to image' categories present greater demands for the technology. In the last decade CT manufacturers have taken different approaches to enhance the performance of scanners, and many of the developments has been focused towards cardiac CT. Some have directed their efforts at improving temporal resolution, whereas others have made advances in volume coverage. This makes the process of scanner comparison and selection even more challenging, particularly as technical specifications are not always presented in a comparable format. This section attempts to clarify some of the confounding areas to enable a more informed and equitable comparison of scanner models.

•*z-axis volume coverage and number of slices*

The cardiac volume needs to be covered in as few heartbeats as possible, ideally within a single heartbeat, so the length of the detector array in the z-axis is a key specification. CT scanners are often classified in terms of 'number of slices', such that a '64-slice' scanner' is regarded as superior to a '32-slice scanner'. However, it is important to understand the distinction between 'number of slices' and 'number of detector rows'. It is primarily the number of detector rows together with the z-dimension of each detector row that determines the total z-axis coverage per gantry rotation. Some scanners can provide two overlapping sets of data per detector row, thereby doubling the number of slices relative to the number of detector rows. So, for example, a 32-detector row scanner may have the capability of producing 64 reconstructed slices per gantry rotation.

Increasing the number of slices over the number of detector rows can be achieved either through hardware or software methods. The hardware approach utilises the so-called 'z-flying (dynamic) focal spot' to acquire two sets of data [7] whereas the software approach makes uses of three dimensional (3-D) reconstruction algorithms to create overlapping slices [8]. Increasing the number of slices over the number of detector rows can be achieved either through hardware or software methods. Both these methods can enhance the z-axis spatial resolution through z-over-sampling, but do not to reduce the overall scan time.

Figure 4 shows a schematic representation of the z-axis detector configurations of current high-end multislice CT scanners that range in z-axis coverage from just under 40 mm to 160 mm.

The '160 mm scanners' can acquire the cardiac volume in a single heartbeat and this has a number of significant advantages in CTCA. Firstly, misregistration artefacts are completely avoided, a particular issue in patients with irregular heart rates. Secondly, the volume of iodine-based contrast agent can be reduced, and thirdly the scanners are ideally suited to performing dynamic myocardial perfusion studies [9]. In addition, if a better temporal resolution is required the use of multisegment reconstruction is likely to be more robust.

Another approach to achieving single heartbeat cardiac coverage is with dual x-ray tube systems available from Siemens. A high pitch, prospectively ECG-triggered helical mode ('Flash' mode) is employed, but this is generally limited to patients with low heart rates, typically less than 65 bpm.

X-ray beam divergence is a particular consideration on scanners with wide volume coverage as it can lead to 'cone beam' artifacts. Therefore, more sophisticated 3-D reconstruction algorithms are required to mitigate these [10].

•*Spatial resolution*

In CT, the limiting spatial resolution is governed by focal spot size and detector element size in both the x-y plane and z-direction, but is also influenced by a number of other factors, primarily the data sampling interval. In the x-y plane it is also highly dependent on the type of reconstruction kernel (filter) applied and its cut-off frequency. Some GE scanners can employ a HD (high definition) mode, in which the detectors are double-sampled in the x-y plane, resulting in a higher scan plane spatial resolution.

It is important that the z-axis spatial resolution is matched to that in the x-y plane in order to obtain equivalent image quality (i.e. isotropic resolution) in all planes. Despite z-axis detector dimensions of 0.5 – 0.625 mm, manufacturers are currently quoting z-axis resolution values of less than 0.3 mm, achieved by z-over-sampling (described in the previous section) as well as more advance reconstruction algorithms and improved detector and data acquisition system characteristics.

Table 2 gives the ideal spatial resolution of a CTCA scanner as 0.1 mm in all three axes for precise evaluation of coronary artery stenosis, as compared to values of around 0.35 mm currently quoted, so there is still room for improvement in this area.

Vendor	Scanner model	x-ray source – detector design	No. of detector rows	Detector element z-dimension (mm)	Total detector z-axis coverage (mm)	Min. gantry rotation time (ms)	Intrinsic temporal resolution (ms)	x-ray generator power (kW)
GE Healthcare(1)	Optima 660	Single	64	0.625	40	350	175	72
	Revolution HD/GSI	Single	64	0.625	40	350	175	107
	Revolution CT	Single	256	0.625	160	280	140	103
Philips Healthcare(2)	Ingenuity	Single	64	0.625	40	420	210	80
	iCT Elite	Single	128	0.625	80	270	135	120
	IQon Spectral CT (5)	Single	64	0.625	40	270	135	120
Siemens Healthcare(3)	Somatom Definition Edge Stellar	Single	64	0.6	38.4	280	142	100
	Somatom Definition Flash Stellar	Dual	64	0.6	38.4	280	75	2 x 100
	Somatom Force	Dual	96	0.6	57.6	250	66	2 x 120
Toshiba Medical Systems(4)	Aquilion PRIME	Single	80	0.5	40	350	175	72
	Aquilion ONE	Single	320	0.5	160	350	175	72
	Aquilion ONE Vision	Single	320	0.5	160	275	137	100

Table 1. Key specifications of current CT scanners recommended by vendors for CTCA
(1) Chalfont St. Giles, UK
(2) Guildford, Surrey, UK.
(3) Frimley, Surrey, UK.
(4) Crawley, West Sussex, UK.
(5) As of April 2016 Philips IQon spectral CT is not yet CE marked

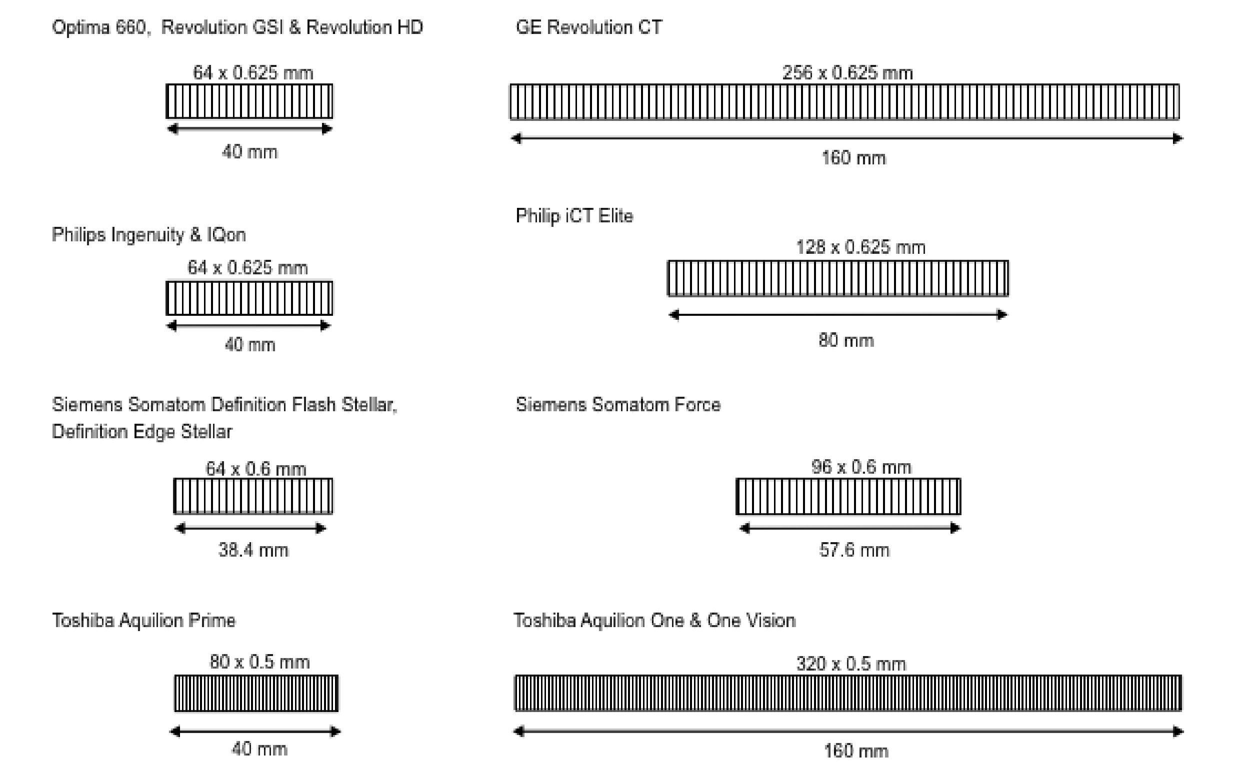

Figure 4 z-axis detector array configurations of modern high-end CT scanners (adapted from [2])

•*Temporal resolution (TR) and gantry rotation time*

As stated earlier, good temporal resolution (short data acquisition window) is a fundamental requirement of a scanner for CTCA, and the intrinsic TR can be defined as half or a quarter of the gantry rotation time on single source and dual source systems, respectively. Comparison of intrinsic TR specifications should therefore be relatively straightforward.

A good intrinsic TR is the most robust method of achieving motion-free images, and enabling scanning of patients with high heart rates without the necessity for beta-blockers to stabilize the hear rate. It also allows a higher heart rate cut-off for scanning in lower dose modes, such as prospectively ECG-triggered axial (PTA) scan mode. Dual source scanners have a good intrinsic TR as they acquire the required data for image reconstruction in one quarter of a rotation time (Figure 5c). Patients with mild arrhythmia should also benefit from good temporal resolution as this allows more flexibility in the cardiac phase used for image reconstruction. Without a sufficient intrinsic TR, other approaches can be used to improve the effective temporal resolution where required.

One such approach, available on all scanners, is multi-segment reconstruction, where data are taken from successive heartbeats to reconstruct images at a particular anatomical location. For example, in two-segment reconstruction, the 180° of data required is taken from two consecutive heartbeats instead of from a single heartbeat (Figure 5a & b). The optimal effective TR is achieved if 90° of data is taken from each of the two beats and in this case it will be equal to half the scanner's intrinsic TR. Data from three successive heartbeats can achieve an optimal TR of one third of the intrinsic TR. Manufacturers may quote TR values as low as one tenth of the gantry rotation time, which would be the optimal value achieved for five segment reconstruction. However, there are a number of drawbacks associated with the use of multisegment reconstruction, including higher radiation doses.

Another approach to improving the intrinsic TR is the use of software motion correction algorithms to correct for cardiac motion. General Electric (GE) has such an algorithm available on its scanners and claims an effective TR as low as 24 ms [12]. Early studies using this approach show promising results [13], but the results of a prospective, international trial (VICTORY) are still awaited [14].

Technical feature	Ideal requirement	Best currently available performance
Spatial resolution: x, y, z (mm^3)	0.1 x 0.1 x 0.1	0.35 x 0.35 x0.35 (1)
Temporal resolution (intrinsic): Time to acquire 180° of data (ms)	30	66
z-axis detector coverage: Total z-axis detector dimension (mm)	Whole cardiac volume coverage	160
Radiation dose	Minimum to answer specific clinical question	Sub-mSv in ideal patient but varies according to patient characteristics

Table 2. Comparison of technical requirement and current capabilities of CT scanners in CTCA (adapted from Otero et al [6])
(1) No systematic comparison data available, but values of this order are reported

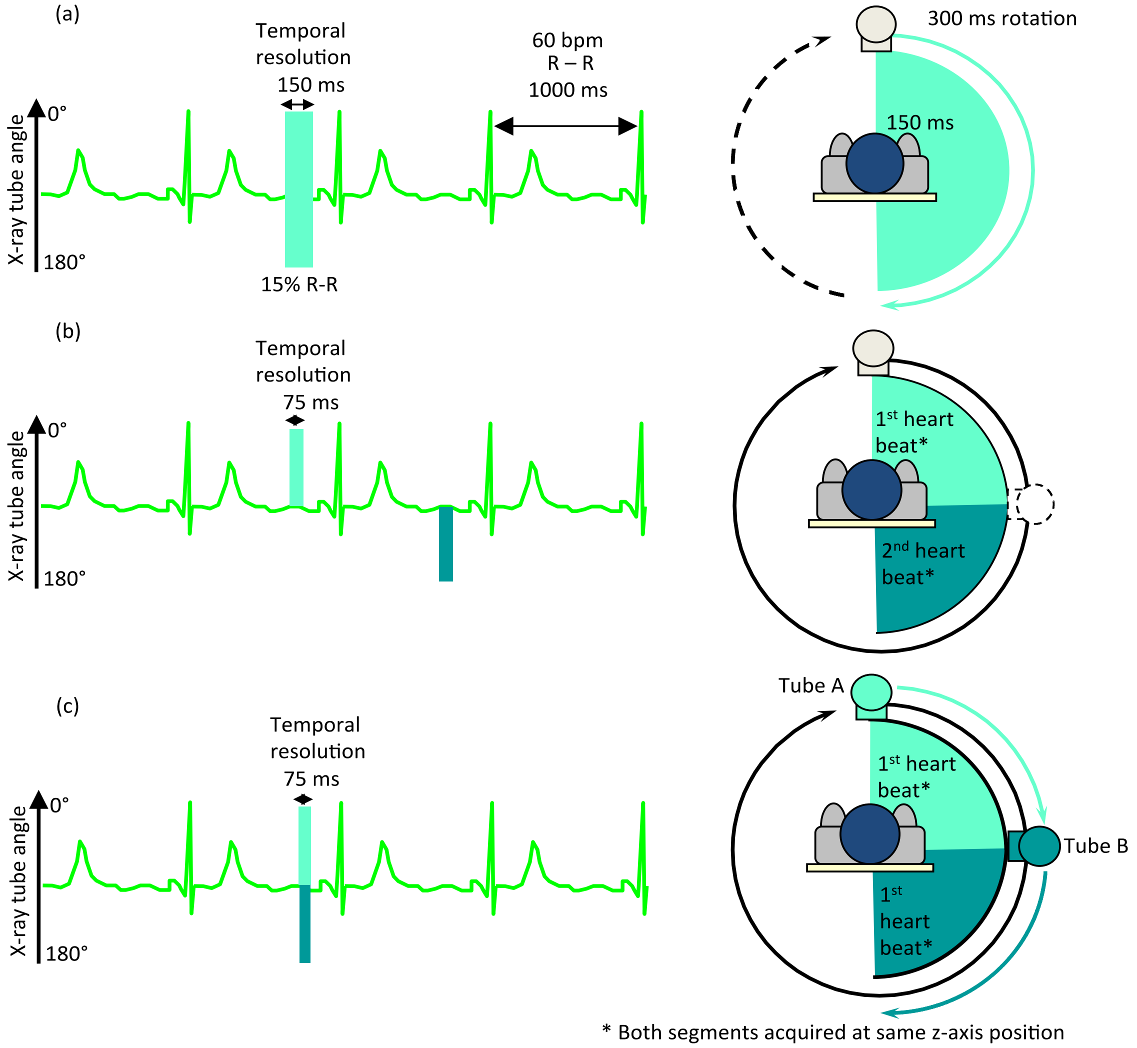

Figure 5. Temporal resolution in cardiac CT scanning: (a) with 'half-scan' reconstruction algorithm; (b) with 'multi-segment' reconstruction algorithm (2 segment); (c) with dual source CT scanner the two 90° segments of data are acquired simultaneously (adapted from [11])

•*X-ray output and generator power*

Powerful generators are required to provide the high x-ray tube currents needed with the short image acquisition times used in CTCA. However, generator power alone cannot be taken as an indicator of good performance in this respect. Other specifications that need to be considered alongside generator power are the scanner geometry and the gantry rotation time. Scanners with a shorter geometry (focus to detector distance) will require a lower generator power to achieve the same photon flux at the detectors, all other things being equal. Also, scanners with slower rotation times will obviously achieve the same tube current – time product (mAs) at a lower tube current (mA) so a lower generator power may be adequate but at the expense of a reduced temporal resolution.

•*Effective dose and CTDI*

CT scanner technical specifications usually include data on the radiation dose in terms of the CTDI. This is one of the few performance specifications that can be directly compared because standards exist for the measurement of this quantity [15]. However, in the form that it is specified, the normalised CTDI (mGy.mAs-1), provides no information on patient dose. A high, normalised CTDI value does not represent a high dose scanner. For radiation risk comparisons, the CTDI value for the scan parameters employed clinically must be known, as well as the length of the volume scanned, to calculate the dose length product (mGy.cm).

Information on scan parameters used for CTCA scans is difficult to obtain because of the various scan modes that can be implemented, the choice of which is highly dependent on patient characteristics and user preference.

Noise reduction software, particularly the recent introduction of iterative reconstruction (IR) methods in CT, will achieve a given SNR at a lower radiation dose. All manufacturers now have iterative algorithms available, however, some methods are more refined, leading to greater noise reduction. The availability of other dose reduction features such as automatic tube current and tube potential selection and dynamic collimators to reduce the dose in helical scanning should be ascertained.

V. Discussion and summary

Based on CT scanner technology currently available, the ideal CT scanner for CTCA examinations would be a dual source scanner with 160 mm detector dimension in the z-axis and the highest spatial resolution in all planes, whilst achieving satisfactory images at the lowest radiation dose. This is a simplistic approach, as many other scanner features need to be considered. However, the purpose here has been to demonstrate that the main imaging requirements in CTCA, namely temporal and spatial resolution, volume coverage and x-ray output, are important considerations when purchasing a CT scanner and that no single existing scanner model has the highest specification for each of these parameters.

There is plentiful evidence showing the advantages of the high intrinsic temporal resolution achieved on dual source systems in the various ‘difficult to image’ patient groups, and the benefits of this are indisputable for patients with high heart rates [16,17,18]. Where this is not available the TR can be improved using multi-segment reconstruction and this is most effectively implemented on scanners where the detector banks extend over the whole cardiac volume. An alternative approach, implemented by, one manufacturer, is the use of motion correction software to correct for cardiac motion.

Similarly, publications exist showing the advantages of scanners with z-axis detector array dimensions covering the full cardiac anatomy and thereby avoiding misregistration artefacts that can occur when acquiring the cardiac volume over several heartbeats [19,20].

Spatial resolution specifications quoted by manufacturers are not easily comparable. Fpr example, one manufacturer has a ‘high definition’ (HD) mode available for improved x-y plane spatial resolution. However, it is important to ascertain whether equivalent resolution can be achieved in the z- direction and all manufacturers provide methods of over-sampling in the z-axis to try to meet this aim.

To achieve an adequate signal to noise ratio with the fast rotations needed in CTCA requires high tube currents and so scanners now have more powerful generators. This allows use of low tube kilovoltage settings that can enable dose reduction through improved contrast-to-noise ratios. Powerful generators also enable improved image quality on obese patients. A fairer comparison than high generator power is the CTDI value obtained with appropriate scan parameters as the latter primarily determines the achievable signal to noise ratio. The level of noise reduction obtained with various iterative algorithms should also be ascertained.

Comparison of patient radiation dose on different CT scanners models is arguably the most challenging issue, as this is highly dependent on the scan mode used and the numerous scan parameters selected. In turn these will be dependent on the patient characteristics. Manufacturers are often reluctant to quote typical doses even when the patient characteristics are specified. However, it is important to ascertain which dose reduction features are available on each scanner model and whether they can be utilized in cardiac mode.

Although coronary angiography is currently the most common cardiac examination performed on CT scanners, further applications are being explored. Functional imaging, to assess the haemodynamic status of the myocardium and complement the anatomical assessment of coronary stenoses, is a developing application [21]. Another emerging area is the application of dual energy CT in cardiac investigations [22]. In these areas manufacturers have again used different approaches to achieve the same aim, and different aspects of scanner technology need to be considered if the efficacy of these applications is to be compared.

Although the selection of the 'ideal' scanner for CTCA is challenging, systematic comparison of specification data and a proper understanding of their implications will allow fairer comparison and lead to a more informed choice of CT scanner model.

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INVITED PAPER

IMPROVING ACCESS TO RADIATION THERAPY BY REIMAGINING TECHNOLOGY

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Abstract — **The paper outlines some of the technology-associated challenges associated with delivering high-quality care in the LMIC environment. It describes an unique redesign of radiotherapy delivery technology aiming to address the specific needs of the LMIC setting.**

Keywords— **Radiotherapy, Healthcare in Low and Middle Income Countries (LMIC).**

I. GROWING GLOBAL NEED FOR CANCER CARE AND RT

Oncology is a growth area for healthcare on the global scale. The World Health Organization (WHO) estimates that there were 9.6 million cancer deaths worldwide in 2018 and continuing to grow [1]. This burden falls disproportionately on low- and middle-income countries (LMIC) as shown in Table 1. There are many factors driving this change such as population growth, aging and a shift in the burden of disease toward non-communicable diseases. Now a majority of cancer cases appear in LMICs, and also the mortality rate in these countries is much higher as shown in Figure 1. The cancer-specific mortality rate is nearly twice as large in a low-income country as in a high-income country (Figure 1).

Year	% of newly reported cancers in LMI-countries
1970	15 %
2008	56 %
2030 (expected)	70 %

Table 1: The proportion of newly reported cancers case in low- and middle-income countries by year (adapted from [2-4])

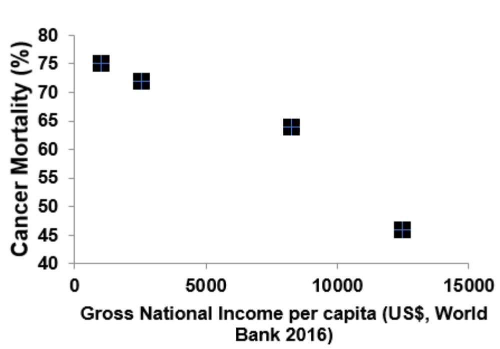

Figure 1: Cancer mortality vs. gross national income per capita as defined by the World Bank. Rates are estimated as the ratio of mortality to incidence per year (adapted from [2])

Globally more people die each year from cancer than from tuberculosis, malaria and AIDS combined [2].

This bleak picture is driven by many factors, arguably the most important of which is access to care. Of the global resources invested in cancer care, it is estimated that less than 5% are spent in LMICs [3]. This is especially true for radiation therapy which is one of the key pillars of oncology care. Studies indicate that overall more than 50% of cancer patients should receive radiotherapy based on evidence and guidelines [5]. However, this rate is determined by the way diseases present in Australia and other high-income countries and is likely a large underestimate of the need in LMICs [6]. For example, the recommended utilization rate in head and neck cancer is 78% and 76% for lung cancers [5], both of which are prevalent in LMICs.

Not only is radiotherapy clinically important in the management of disease, it is also cost-effective. It is non-invasive, allows for organ preservation and has a lower risk profile for morbidities such as infection or lymphopenia which can be challenging to manage. A 2015 report from the Global Task Force on Radiotherapy for Cancer Control studied the potential impact of providing radiotherapy in LMICs from the economic impact point of view [6]. The report concluded that a benefit of US$11 billion to $280 billion per country could be realized if radiotherapy access were scaled up to full need over the 2015-2035 period.

For the above discussion it is clear that there is a strong and growing need for cancer care especially in LMICs, that radiotherapy plays a key role and that it is a particularly cost-effective modality to employ. In spite of all this, however, access to radiotherapy is extremely limited in many LMICs. A 2013 report from the IAEA, for example, noted that of the 52 countries in African only 23 were known to have radiotherapy services available [7]. In India, a country of 1.3 billion people, there are 438 centers providing radiotherapy and 650 treatment units [8]. To fulfill the World Health Organization recommendation of 1 treatment unit per million people, India would need to approximately double the capacity to 1,300 treatment units.

Against this picture of unmet need, however, is a ray of hope. Access continues to grow. In 1991 there were 63 radiotherapy treatment units in Africa. By 2010 there were 277 and continuing to grow [7]. This article outlines some of the technology-associated challenges associated with delivering high-quality care in the LMIC environment and asks the question "can we do better by reimagining the technology"?

II. CURRENT RT TECHNOLOGY IN THE LMIC ENVIRONMENT

Since the Clinac-4 was introduced in 1968, the technology for external beam radiation therapy has evolved in a stepwise fashion., although there are also specialized technologies that pre-date the C-arm linacs (e.g. Leksell Gamma Knife unit for stereotactic radiosurgery) the machines that one would see in a modern radiotherapy clinic look largely like the 1968 commercial C-arm unit from Varian Inc. At various points over the intervening decades the technology has been re-imagined in various ways. In 1994 the Cyber Knife radiotherapy system was introduced and commercialized by Accuray Inc., incorporating a robotically-mounted X-band linear accelerator along with co-planar imaging [9]. In 2003 a helical tomotherapy unit was introduced by Tomotherapy Inc. (later Accuray Inc.), using a modified CT ring gantry with a binary MLC and megavoltage CT imaging [10]. More recently radiotherapy units with MR-guidance have become available such as the system from ViewRay Inc [11].

While these technologies have been made to function well in North America, Europe and other countries, there are many challenges that arise when employing them in the LMIC environment. They are dependent on the local infrastructure in many ways. McCarroll et al [12], for example, have studied the effect of power outages on the efficiency of treatment. An average daily power outage of 2 hours can cause patient throughput to drop to approximately 60%. The effect is dependent on technique and technology, with the biggest impact being with the more complex techniques such as intensity modulated radiation therapy (IMRT) delivered with a linear accelerator. Interestingly, simpler technologies such as conformal therapy with 60-Cobalt teletherapy device are much less subject to such effects according to this study and can maintain throughputs of over 90% even with average power outages of 8 hours per day. There are also infrastructure-related safety concerns with some technologies. The well-known 2001 radiation therapy accident in Poland [13], for example, was precipitated by a failure in the power grid.

There are also requirements in terms of staffing and expertise that are needed to deliver high-quality care. One key component of this is quality assurance, typically performed by a medical physicist. An enormous effort is required, however, to adhere to adhere to IPEM 81 and other best-practices. A 2012 survey of radiotherapy centers in the UK, for example, found that the average time required from a medical physicist for quality assurance is 19.5 hours per month per machine and 1.5 hours per patient [14].This difficult to achieve in any environment and is all but impossible in the LMIC setting.

One might ask the question of whether all this quality assurance from highly trained specialists is really necessary. To put it simply, can't we do "good enough" by simply "pushing the button"? The answer, unfortunately, is no. We know from cooperative group trials that treatments with inferior dosimetry and treatment planning have much worse patient outcomes [15] and this is not just an effect in one trial is borne out when one looks across trials [16, 17]. We also know that the commissioning and validation of treatment planning system is crucial and even with highly-trained staff many systems are flawed. In validation tests from the Imaging and Radiation Oncology Core-Houston (IROC-H) over 20% of institutions have failed relatively simple measures [18].

III. THE CASE FOR INTENSITY-MODULATED RADIATION THERAPY (IMRT)

The above considerations provide strong motivation for re-imagining radiation therapy technology in a way that is less dependent on the expertise and availability of highly trained staff including engineers, the ready availability of maintenance equipment, and the reliability of the local infrastructure. In considering technology requirements, the first task is to determine what is needed. In particular, is the ability to provide intensity modulated radiation therapy (IMRT) a requirement? We argue that it is.

IMRT allows for complex dose distributions that allow for organ preservation. The use of IMRT emerged in the late 1990's and the evidence for its use has been well-established [19, 20]. In head-and-neck cancer therapy, for example, IMRT allows for sparing of the salivary glands. If these glands are not spared xerostomia results after a dose of approximately 23 Gy [21, 22] and this results in morbidities for patients such as fissures, infections and osteonecrosis which can be very debilitating and costly to manage [23-25]. In North America IMRT is offered in essentially every radiotherapy center [26, 27] and is used in approximately 50% of treatments [28].

If IMRT is necessary the question is how best to deliver it? The technique that has evolved from the 1990's onward employs moving multileaf collimators (MLCs) to modulate the radiation fluence. There are, however, many disadvantages to using MLCs for IMRT deliver. These include mechanical failures (leading to downtime and reduced throughput), stringent requirements for quality assurance and highly trained staff, challenges with commissioning including the measurement of small treatment fields, and inefficient use of dose leading to long treatment times. One of the possible approaches explored in the next section is the elimination of the MLC.

IV. IMRT TECHNOLOGY RE-IMAGINED

There are many possible alternative ways to modulate fluence for the purposes of IMRT. The approach that we are exploring is the use of physical compensators, i.e. metallic objects inserted in the beam to modulate the dose. Compensators-based IMRT is not new. It was employed to deliver IMRT in the 1990's[29-32]. There were, however, some limitations to the way that compensator-based IMRT was implemented in the 1990's and it was largely abandoned in favor of MLC solutions. Our thesis is that these limitations are not fundamental, that compensator-based IMRT designs were never explored to their full potential, and compensator-based IMRT is an especially attractive option for IMRT delivery in resource-limited settings. Because compensators have fewer moving parts, they should lend themselves to a simplified quality assurance approach that is based on some form of mechanical measurement. This could be automated in some way and may not require the presence of a medical physicist or other highly trained staff.

There are, however, many challenges to employing compensators. One is the need to perform block exchanges for each field. If this requires entering the room after each beam the treatment delivery time will be negatively impacted (see McCarroll et al. [12]). This is not a fundamental limitation, however. Several groups have explored mechanisms that would provide an automatic exchange of devices between fields [33, 34]. These were envisioned as add-ons to a C-arm gantry design. We are exploring a more extensive redesign which involves a ring model and associated exchange mechanism.

A second potential challenge is in the production of the patient-specific compensators themselves. The approach that found favor in the 1990's was a mail-order system whereby one would provide the compensator design specifications for each plan and a company would mill the required compensators out of metal (typically brass) and mail them to the clinic. This had many disadvantages, all of which would likely be amplified in the LMIC setting. A possible alternative of milling the compensators on-site at the clinic is also not attractive as this is outside the typical expertise in a clinical setting and would require a large shift in practice.

We are exploring a system whereby negative molds for the compensator are made out of plastic and these molds are then filled with metal beads. The technologies for forming plastic are more widely available and could be implemented on site. Other groups have explored such an approach[32, 35] but it has not become widespread likely because the associated technology was not widely available until quite recently. Figure 2 shows a Monte Carlo simulation of the device (60-Cobalt based in this case) and the associated transmission through a thin, flat compensator. Clearly the solid metal offers less transmission, but a bead formulation is acceptable at the expense of extra thickness. The disadvantages of thicker compensator can be partially obviated by the fact that they can be made divergent with the beam.

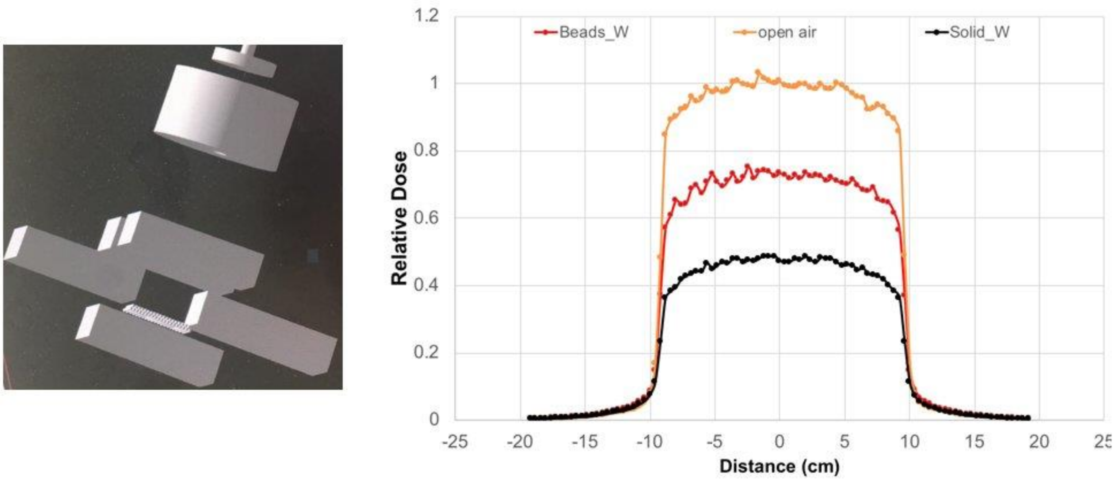

Figure 2:Monte Carlo simulation of the proposed device showing the geometry (left) and the transmission results (right) through 1 cm-thick tungsten either in sold for solid material (black) or beads (red).

Our initial simulations of treatment plans with this system [36] show that even with a 60-Cobalt source acceptable tumor coverage and organ-at-risk sparing can be achieved, that treatment times are reduced by approximately a factor of two compared to even linac MLC-based IMRT, and that the increase in skin dose is not clinically significant. The main reason for these gains is that compensators do not have the mechanical limitations of MLCs (they can be made with high resolution and fully divergent) and they also use radiation dose extremely efficiently, as opposed MLCs which are closed over many parts of the beam for long periods of time.

V. TECHNOLOGY AND BEYOND

The redesign of radiotherapy delivery technology described here aims to address the specific needs of the LMIC setting. To our knowledge this has never been done before in a deliberate way and the potential impact is enormous. As important as technology is, however, it is also important to consider the whole care path when imaging a large-scale conversion to IMRT delivery. There will be educational needs and potentially a different mix of staffing. Key infrastructure components in the healthcare system will also be required. For example, a CT scanner and a treatment planning system. The conversion is well-justified, however, given the clear need for cancer therapy and radiotherapy in particular, the enormous benefit of IMRT in many disease sites and the potential health and economic benefits. Our hope is a thoughtful redesign of treatment technology will allow for high-quality cancer care in areas of the world where it is desperately needed.

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TUTORIALS

AN UPDATE VIEW IN MEDICAL IMAGES ANALYSIS

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Abstract— **In this paper is made a collection of the latest published works on the quality of medical image formation using Convolutional neural networks. Convolutional neural networks have recently achieved impressive results in pattern recognition, moreover, various studies have successfully applied them in medical images analysis, such as image segmentation, artifacts removal, image denoising, resolution improvement and contrast saliency detection. We have divided into sections for better visualization of the impact on the several areas that influence the reconstruction of the image.**

Keywords— **deep learning, image quality, convolutional neural networks.**

I. INTRODUCTION

From the earliest moments of computer history, scientists have been dreaming about the idea of creating an "electronic brain." Among all modern technological research, this search for artificially intelligent computer systems has been one of the most ambitious. Doctors were also captivated by the potential that this might have when applied in medicine.

The first information on neuro computation dates back to 1943, in articles by McCulloch and Pitts, which suggested the construction of a machine based on the human brain. Donald Hebb, in 1949, was the first to propose a specific learning law for neuron synapses.

In 1957, Rosenblatt conceived the "perceptron", which was a neural network of two layers, used for the recognition of characters.

The artificial neural network is a system of neurons connected by synaptic connections divided into incoming neurons, which receive stimuli from the external environment, internal or hidden neurons, and output neurons, which communicate with the outside. The way to arrange layered perceptrons is called Multilayer Perceptron. The multilayer perceptron was designed to solve more complex problems, which could not be solved by the basic neuron model. The internal neurons are of great importance in the neural network, since it has proved that without these it becomes impossible to solve linearly non-separable problems. In other words, it can be said that a network is composed of several processing units, whose operation is quite simple. These units are usually connected by communication channels that are associated with certain weights. The intelligent behavior of an Artificial Neural Network comes from the interactions between the network processing units.

Most neural network models have some training rules, where the weights of their connections are adjusted according to the presented patterns. In other words, they learn through examples. Neural architectures are typically layered, with units that can be connected to the back-layer units.

The neural network undergoes a training process from the known real cases, acquiring, from there, the systematic necessary to properly execute the desired process of the data provided. Thus, the neural network is capable of extracting basic rules from actual data, differing from programmed computation, where a set of rigid rules is required and algorithms.

The most important property of neural networks is the ability to learn from their environment and thereby improve their performance. This is done through an iterative process of adjustments applied to their weights, training. Learning occurs when the neural network reaches a generalized solution to a class of problems.

A learning algorithm is defined as a set of well-defined rules for solving a given problem. There are many types of learning algorithms specific to particular neural network models, these algorithms differ mainly by the way weights are modified.

The neural network relies on the data to extract a general model. Therefore, the learning phase must be rigorous and true, in order to avoid spurious models. All knowledge of a neural network is stored in the synapses that are, in the weights assigned to the connections between the neurons. About 50% to 90% of the total data must be separated for neural network training, randomly chosen data, in order for the network to learn the rules. The rest of the data is only presented to the neural network in the test phase, so that it can correctly deduce the relationship between the data.

Neural Networks are a family of computationally biologically inspired brain models, forming a series of processing units, called neurons, which program nonlinear functions of their inputs. Neurons are organized in layers, which are interconnected with each other. The processing of an input through a neural network occurs through the passage through several layers of neurons, to the output layer that provides the final response. In general, the greater the number of layers, the greater the power of the network, and the greater the computational cost.

Convolutional neural networks (CNNs) are neural networks where connections between layers are organized as in a convolution operation. All the neurons of a CNN are associated with a specific spatial position, and each neuron is connected only to the neurons of the anterior layer that are in a near spatial position. The layers of an CNN are organized in planes, which are called feature maps. All neurons on the same feature map share the same set of parameters. In this way, each feature map is equivalent to the application of a convolution operation on the result of the previous layer. These characteristics allow a reduction in the number of network parameters, which facilitates the training of very deep networks.

Neural networks have been applied to various problems in the area of medical image analysis, such as image classification, character recognition, object detection, noise removal and colorization of black and white images.

"Deep Learning" technology is based on the concept of neural networks where this technology can be used from digital diagnostics through image recognition to retrieval of unstructured information from patients' medical records.

II. DEEP LEARNING APPLIED TO MEDICAL IMAGES

In the last four years there has been a huge expansion in the usage of deep learning algorithms for medical images analysis. An increasing number of papers are being published on the topic and several of them have reached human expert-level performance [1]. The most explored tasks so far are image classification, object detection, segmentation and registration, but many more are being investigated. Compared to other computer algorithms, deep learning has the crucial advantage of finding the informative representations of the data by itself. Therefore, the complex and time-consuming step of manual features engineering can be avoided. Nowadays a major challenge in applying deep learning to medical images analysis is the limited amount of data available to researchers. This can lead to an over fitting of the training data with a final low performance in the test dataset. To treat this problem, several strategies are being investigated. Some of them artificially generate more data applying affine transformations to the initial dataset (data-augmentation), others attempt to reduce to total number of parameters of the models or initialize those with pre-trained models from non-medical images and then fine-tune them on the specific task. However, the data itself exists, as millions of medical images are stored in the hospital archives. Gaining access to those archives is the main problem nowadays because of the various regulations present. Each image is also generally stored with patient information, so a process of data anonymization is required as well before a study can be undertaken. In the last years several datasets have been made publicly available and this trend is expected to accelerate in the future. Convolutional neural networks (CNNs) are a type of deep neural networks and have recently achieved excellent results in several areas of knowledge. CNNs have drawn a great interest on the topic because of their intrinsic capability of accepting images as input. They can perform a classification or segmentation task and have proved to be the most successful type of artificial neural network for image analysis problems. Deep learning offers exciting solutions and perspectives for medical image analysis. There is room for improvements regarding both the algorithms and the way to acquire large training datasets. As this last challenge will be overcome, in the next years deep learning will really play a key role also in medical imaging.

III. CONVOLUTIONAL NEURAL NETWORKS

Convolutional neural networks are a type of feed-forward artificial neural networks successfully employed today to tackle a wide range of problems. They are inspired by the animal visual cortex. Convolution is the name of the mathematical operation mainly employed by these networks. CNNs are very similar to common neural networks, but they make the important assumption that the input data is arranged in a grid-like topology. The most straightforward example of this kind of data are images, having pixels in a 2D grid. The architecture of CNNs takes advantage of this fact in order to optimize the learning. Convolutional neural networks are multi stage architectures, where each stage usually consists of a convolution layer, a nonlinearity layer and a pooling layer, see figure 1. CNNs use relatively little pre-processing, since the network learns the filters that in traditional algorithms were hand-engineered. This independence from prior knowledge and human effort in feature design is a major advantage.

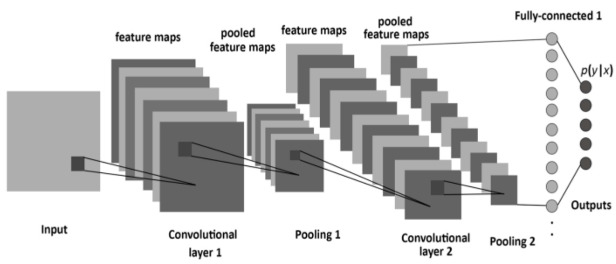

Fig. 1 Convolutional Neural Network.

IV. CNNS FOR MEDICAL IMAGE SEGMENTATION

Image segmentation is the process of automatically or semi-automatically subdividing an image into significant regions. Image segmentation provides a more meaningful representation of the data and it is a crucial step for fully understanding the content of medical images. In the last years CNNs have been the most common technique applied to image segmentation. Convolutional neural networks (CNNs) take as input an image and give as output a vector containing the probabilities of the image to belong to each possible class. Those methods are called end-to-end training. Thus, end-to-end approaches reduce the human effort and they have achieved great results in medical imaging segmentation tasks [2, 3]. The CNN architectures can indeed be easily adapted for a segmentation task, where each single pixel or voxel is assigned to a class. In this approach, the network learns mostly local features, ignoring global patterns and the convolutions are computed redundantly. A different approach, proposed to overcome these limitations, employs the common CNN architecture replacing the fully connected layers with convolutions. The output of the network, however, ends up smaller than the input, due to the convolutions and pooling layers. To deal with this issue, Long et al. [4] introduces deconvolution operations to up sample the reduced size feature maps. This type of network, without fully-connected layers, is commonly referred to as fully-convolutional network. Ronneberger et al. [5] developed another architecture, called U-Net, for biomedical image segmentation. It consists of a contracting path, made of a common CNN, followed by an expanding part where deconvolution is used to restore the initial size of the image. Due to its structure, this type of network is also known as encoder-decoder. A recent study proposed a CNN for different segmentation tasks in images acquired with diverse modalities [6], where a single convolutional network which performed well in the segmentation of tissues in MR brain images, of the pectoral muscle in MR breast images and of the coronary arteries in cardiac CTA. Another study has described a CNN with a U-Net inspired architecture performing an automatic segmentation of the proximal femur from MR images [7].

V. CNN FOR IMAGE ARTIFACTS

Artifacts may be defined as any content or object of the image, which does not coincide with the arrangement of the scanned object or occasional noise, i.e., artifact, is an artificial feature appearing in an image that is not present in the original investigative objects. The most common sources of artifacts in medical image are movement artifact, caused by the movement of the patient during examination, including breathing, heartbeat, and blood flow. Artifacts can arise from the inherent physics of the image system: beam hardening, streak artifacts, chemical shift artifacts, susceptibility or metal artifact, black boundary artifacts, aliasing artifacts. In the presence of patients with metal implants, metal artifacts are introduced to x-ray CT images. There are a large number of metal artifact reduction techniques in the literature, but this is still a major problem in medical image. Recently the convolutional neural network (CNN) has been applied to medical imaging for low dose CT reconstruction and artifacts reduction [8–17], including application in metal artifact reduction [12–14], [35–39]. Zhang et al [20] proposed a convolutional neural network-based metal artifact reduction (CNN-MAR) framework that is able to distinguish tissue structures from artifacts and fuse the meaningful information to yield a CNN image. In x-ray computed tomography (CT) the use of sparse projection views is a recent approach to reduce the radiation dose. However, insufficient projection views in sparse-view CT produces severe streaking artifacts in filtered back projection reconstruction. To tackle this, very recently, Kang et al [23] provided the first systematic study of deep convolutional neural network (CNN) for low-dose CT and showed that deep CNN using directional wavelets is more efficient in removing low dose related CT noises. Since the streaking artifacts are globally distributed, CNN architecture with large receptive field network was shown essential in these works [24–25], and their empirical performance was significantly better than the existing approaches.

VI. DEEP NEURAL NETWORKS FOR IMAGE DENOISING

X-ray CT is a crucial medical imaging tool. However, the potential radiation risk is a critical issue. Lowering the radiation dose tends to significantly increase the noise and artifacts in the reconstructed images, which can compromise diagnostic information. Noise is a generally undesirable image characteristic that reduces the visibility of low contrast objects and structures. In x-ray CT is determined by the photon fluence. In the last years, deep neural networks have made great advances in CT imaging denoising. Dong et al. [26] developed a convolutional neural network for image super resolution and demonstrated a significant performance improvement compared with other traditional methods. At the same year Chen et al [27] published a paper using a CNN to low dose CT denoising with similar results. More recently Yang et al [28] propose a new method for CT image denoising by designing a perceptive deep CNN that relies on a perceptual loss as the objective function. Zhang et al [29] designed a deep convolutional neural network where the batch normalization [30] and residual learning are integrated to speed up the training process as well as boost the denoising performance.

VII. DEEP NEURAL NETWORKS FOR RESOLUTION

Generative adversarial networks (GANs) are a class of unsupervised machine learning algorithms that can produce realistic images from randomly sampled vectors in a multi-dimensional space. GANs have been used to generate synthetic images of unprecedented realism and diversity [31]. Applications in imaging, including biomedical imaging, have flourished, but have been confined to relatively small image sizes [32]. Recently, Karras et al. devised a training scheme for GANs called progressive growing of GANs (PGGANs) that can create photorealistic images at high resolutions, with images up to 1024 × 1024 pixels [33]. This method (PGGAN) can be applied to two classes of medical images: retinal fundus photographs with retinopathy of prematurity (ROP), and two-dimensional magnetic resonance images taken from a publicly-available, multi-modality glioma dataset (BraTS). According to studies, its application will open new avenues for synthetic image generation in medical imaging, which has thus far been limited by an inability to synthesize images at native resolution.

VIII. Deep neural network for contrast saliency detection

Contrast is the ability to distinguish between differences in intensity in an image and visual saliency attracts the most attention of the human visual system. Recently, deep convolutional neural networks have emerged in this research field, which can generate high level image features from CNN. It can surpass human level performance on object recognition [34]. CNNs have been largely used in salient object detection [35–37] because of their powerful feature representations and have achieved substantially better performance than traditional methods. Deep convolutional neural networks methods are based on either patch-wise training and inference, which can be very time consuming, or fully convolutional networks [38–40] category that directly map an input image of arbitrary size to a saliency map with the same size. However, pixel-level correlation is not considered in such fully convolutional networks, which usually generates incomplete salient regions with blurry contours. To tackle these obstacles Guanbin Li and Yizhou Yu [41] proposed an end-to-end contrast-oriented deep neural network for localizing salient objects using multi scale contextual information. They incorporate a fully convolutional stream for dense prediction and a segment wise spatial pooling stream for sparse inference.

IX. Conclusions

This work provides an idea of the importance of the use of deep learning, specifically convolutional neural networks for medical image analysis. Feature extraction is feasible for the primary detection of any type of disease and its use is more than necessary to generate reliable data. Such data may be incorporated by some *Machine Learning* technique, which is capable of detecting and highlighting certain desired pixels with some learning technique, or even classifying the images as possessing or not certain agent.

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A CASE STUDY OF CONTRAST INVERSION AND MODULATION TRANSFER RELATED TO THE FINITE X-RAY TUBE FOCAL SPOT SIZE

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Abstract— **The paper presents a case study – explanation of the Contrast Inversion phenomenon in Radiography. This explanation is related to understanding and interpretation of the Modulation Transfer Function (MTF). Its derivation, in the case of blur related to the finite focal spot size of the X-ray tube, is presented as an element of the educational process, which could be used in MTF – related lectures and discussions of artefacts.**

Keywords— **Contrast Inversion, MTF, Image quality assessment, artefacts.**

I. Contrast inversion manifestation

One phenomenon which can be seen during Quality Control (QC) tests is Contrast Inversion. It exists in anatomical images, but is difficult to be detected visually. The image on Fig.1 shows a test object (phantom) with its typical resolution pattern. With the increase of spatial frequency, one can clearly observe Contrast Inversion – instead of representing the test object with three cuttings thought the phantom material (represented by three dark lines of the bars in the lower frequencies region), on the Fig.1 image the high frequency patterns are visualized with two dark lines of the bars (as if we have two cuttings only).

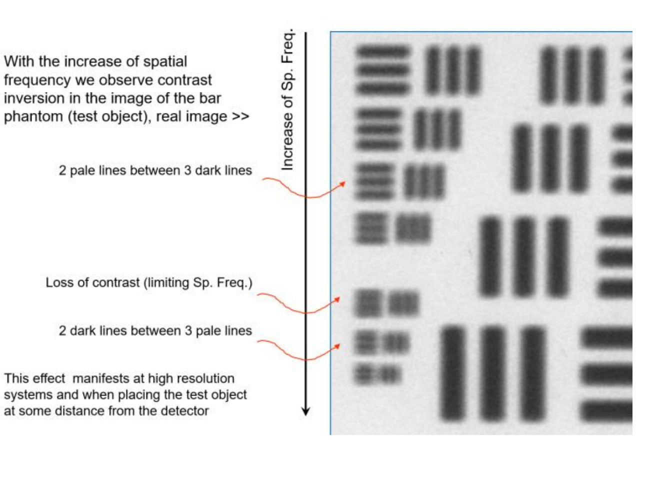


Fig.1 The phenomenon of Contrast Inversion observed in the two highest frequencies patterns/bars of the test object. The right site of the test object image (with low frequencies) is cropped to allow better zoom of the phenomenon (explained on figure: before and after its manifestation – see the arrows).

II. Contrast inversion explanation

In order to simplify the explanation of this phenomenon we shall assume that the phantom patterns/bars are not rectangular, but sinusoidal (i.e. with gradually changing attenuation, instead with sharp changing of it). This approximation is often made in MTF discussions.

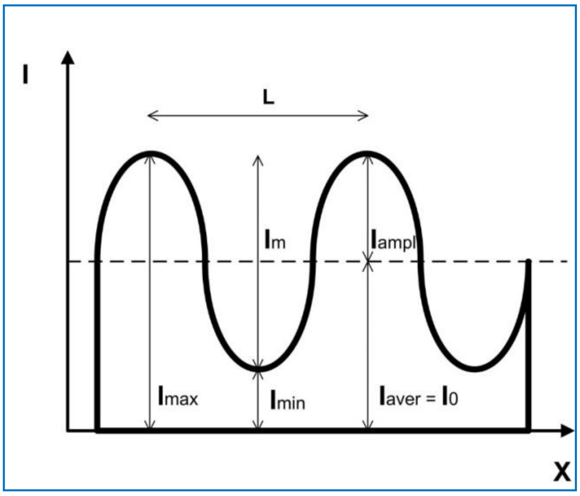


Fig.2 Intensity (I) of the X-rays after their modulation by a hypothetical phantom with the above sinusoidal shape. X is related to the dimensions of the phantom. L is the period of the phantom structures.

Fig. 2 shows part of such a hypothetical sinusoidal test object (phantom) with period L. Equation 1 describes the spatial frequency (ϑ) of this pattern, and also the relation of it with the angular spatial frequency (ω)

$$\vartheta = \frac{1}{L} = \frac{\omega}{2\pi}$$

Eq. 1

Assuming a homogeneous test object, the signal amplitude at any point of the object will depend on its average signal (I_0) plus the change of the amplitude (I_{ampl})

with the angular spatial frequency (ω) - i.e. with the position. Using the intensities shown on Fig.1, we can describe the modulated intensity (I) at a point after the phantom with Equation 2. This way we have the signal (X-ray beam intensity after its modulation by the phantom) separated in two imaginary parts: *fixed* and *variable* (i.e. as if the test object is rectangular block with +/- sinusoidal changes of the shape – hence, the attenuation).

$$I = Io + Iampl\ \sin \omega x = Io + \frac{Im}{2}\ \sin \omega x$$

Eq. 2

Let us place this phantom (test object) in a planar X-ray imaging (radiography) system, where (F) is the size of the Effective focal spot of the X-ray tube. Also, let us assume that we have ideal detector (i.e. no detector blur) – Fig.3

The described imaging system will have magnification (M), depending on the geometry of the system positions: focal spot, object and detector. See from Figure 2 the expression of magnification (M), depending on the distances between focal spot / phantom / detector (A and E).

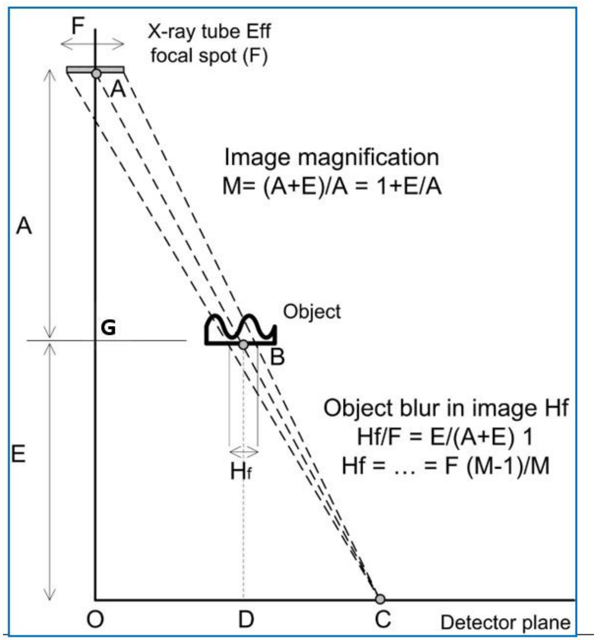


Fig.3 Placing the phantom (object) in a radiographic system. The Effective focal spot size of the X-ray tube has dimension (F) and the detector plane includes an ideal (non-blur) detector.
The expressions on the Figure describe the magnification of the system (M), as well as its influence over the area of the phantom (H_f) projected at point C of the detector.

The focal spot of the X-ray tube (F) is not a point source. It has certain dimension, hence one point of the detector (C) will receive photons from all parts of the focal spot.

The central X-ray beam (from the middle of the focal spot to point C) will pass through point (B) of the object. The spread of B - the irradiated area of the phantom (H_f) - will depend on focal spot size (F). See from Fig.3 the relation between (H_f), focal spot (F) and magnification (M).

Let us observe the similar triangles ACO and ABG on Fig. 3.

In ACO we have: A is the central point of the Focal spot (F); C is the projection of point B from the phantom over the Detector (a composite projection); O is the perpendicular from the central point of the focal spot to the detector. In ABG we have additionally G – the projection of point B over the perpendicular from the focal spot (i.e. the position of the phantom in the system). From these triangles we have:

$$OC = x\ ;\ OD = \frac{x}{M}$$

Eq. 3

Now let us look at the triangle (with dotted lines) made of the whole size of the Focal spot (F) and the projection point over the detector (C), and its similar triangle form by the same point (C) and (H_f) – the irradiated part of the phantom. From these triangles we can express (H_f) as a function of the focal spot size (F) and the magnification of the image (M) – Equation 4

$$\frac{Hf}{E} = \frac{F}{A+E} \quad \gg \quad Hf = F\ \frac{M-1}{M}$$

Eq. 4

Obviously the size of the irradiated part of the phantom (H_f) is directly related to the Focal spot size (F) and the magnification (M) – i.e. position of phantom in the system.

The intensity of the X-rays at point (C) is (I_c). It is related to (I_b) the intensity in point (B), through the inverse square law – i.e. the intensity (I_c) has decreased M^2 times – Equation 5.

Using (Eq. 2) the intensity in point B, (I_b) will be as in Equation 6.

$Ic = \frac{Ib}{M^2}$	$Ib = Io + \frac{Im}{2} \sin \omega x$
Eq. 5	Eq. 6

The intensity (I_b) is actually not in a point, but distributed over the spread (H_f). To describe it, we have to normalize it per unit of length of (H_f), and after this integrate over the length of (H_f). This way the relative change of intensity for the whole (H_f) length will be expressed through an integral from the middle of (H_f) - what is OD from Eq. 3, +/- half of the irradiated area (H_f) - Equation 7

$$Ib = Io + \frac{Im}{2\,\mathrm{Hf}} \int_{\frac{X}{M}-\frac{Hf}{2}}^{\frac{X}{M}+\frac{Hf}{2}} \sin \omega x \,\mathrm{d}\, x$$

Eq. 7

If we further use (Eq.5) to describe (I_c), the intensity in point (C), also using (Eq.7) , we shall have as a final solution of the integral for (I_c) – Eq. 8

$$Ic = \frac{Ib}{M^2} = \frac{Io}{M^2} + \frac{Im}{2\,\omega\mathrm{Hf}\,M^2} \int_{\frac{X}{M}-\frac{Hf}{2}}^{\frac{X}{M}+\frac{Hf}{2}} \sin \omega x \,\mathrm{d}\, \omega x = \ldots$$

$$\ldots = \frac{Io}{M^2} - \frac{Im}{2\,\mathrm{Hf}\,M^2}\left[\cos\omega\left(\frac{x}{M}+\frac{Hf}{2}\right) - \cos\omega\left(\frac{x}{M}-\frac{Hf}{2}\right)\right] = \cdots$$

$$\ldots = \frac{Io}{M^2} + \frac{Im}{\frac{\omega\mathrm{Hf}}{2}\,2\,M^2}\,\sin\frac{\omega Hf}{2}\,\sin\frac{\omega x}{M}$$

Eq.8

Equation 8 presents the intensity in (I_c), what is in fact the signal getting to the detector from the whole length of the focal spot, after being modulated by the irradiated phantom area in (H_f).

This signal will be "ideal" (without modulation related to fact that the effective focal spot is not a point source) when the size of the focal spot (F) is close to zero - in this case also the spread (H_f) is close to zero. This will affect the *variable* part of the phantom (Eq. 2) - Equation 9:

$$\lim_{\mathrm{Hf}\to 0} \frac{\sin\frac{\omega Hf}{2}}{\frac{\omega Hf}{2}} = 1$$

Eq. 9

This means that, after applying (Eq.8) and (Eq.9) , the maximal signal intensity (I_{cmax}) will be as in Equation 10:

$$\mathrm{Ic\ max} = \frac{Io}{M^2} + \frac{Im}{2\,M^2}\,\sin\frac{\omega x}{M}$$

Eq.10

The Modulation Transfer Function (MTF, or M_f) represents the system modulation – in broad terms: the ratio between the output modulated signal and the input "ideal" signal - i.e. the change of the signal amplitude (per spatial frequency) due to the modulation of the system.

In case of point source Focal spot (assuming all other parameters "ideal"), there will be no influence of the system over the signal due to Focal spot size, hence MTF=1. However the real modulation of the signal, related to Focal spot size influence, will be the ratio of the real signal (I_c) in point (C), and the "ideal" signal, which is equal to the maximal input signal (I_{cmax}) - in the ideal case of (F)=0. Thus dividing (Eq.8) to (Eq.10), we have Equation 11 (the difference is only in the *variable* part of the signal):

$$\mathbf{M}f = \frac{\mathrm{Ic}}{\mathrm{Icmax}} = \cdots = \frac{\sin\frac{\omega Hf}{2}}{\frac{\omega Hf}{2}} = \frac{\sin\frac{\pi Hf}{L}}{\frac{\pi Hf}{L}} = \frac{\sin\pi Uf}{\pi Uf}$$

$$Uf = \frac{Hf}{L} = \frac{F}{L}\cdot\frac{(M-1)}{M}$$

Eq.11

In (Eq. 11) (U_f) is a composite parameter, depending on the focal spot size (F), the magnification (M) – i.e. the place of the object between tube and detector, and the test object period (L) - i.e. spatial frequency. (U_f) is minimal when: (F) is minimal, (M) is minimal (object close to detector) and (L) is maximal (ϑ is min).

Using Eq.11 we can present MTF with a function of an attenuating sine (*sinc* function, or *sinus cardinalis*) – Fig. 4.

Here the changing of the sign (+/-) of the sinc function is in fact Inversion of the Contrast. This way the areas (set of spatial frequencies) A and C will have positive contrast, while the areas B and D will have negative contrast, etc. In fact this change of contrast becomes negligible with the increase of spatial frequency ϑ (due to the very small amplitude of the signal) and in reality, apart from area A, we can only see B and very rarely C (i.e. a well-trained eye could observe up to 2 contrast inversions in case of significant focal spot size and magnification). Also, our visual observation usually cannot detect the small changes of the contrast amplitude inside areas B, C, etc.

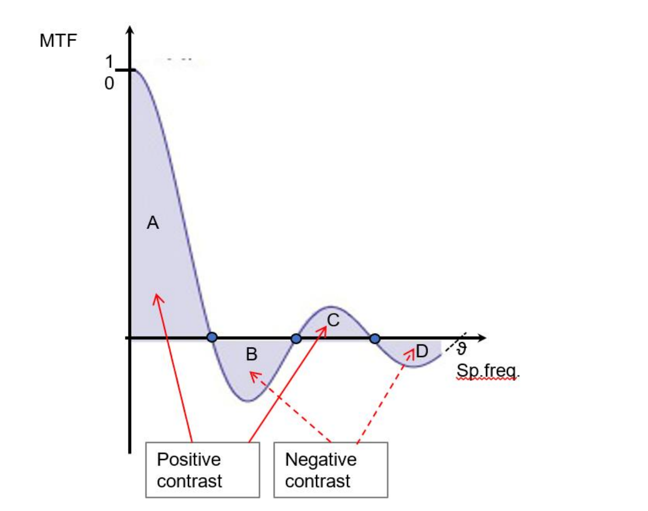


Fig. 4 A real MTF sinc function with contrast inversion areas, visualizing Positive (true) and Negative contrast. At the inflections points the contrast of the object bars disappears, i.e. limiting sp. freq. after area A – see Fig.1

For all image assessments we are normally interested only in area A – where we have the "normal contrast" in the image. Due to this reason the assessment of MTF is limited to only area A, where the Modulation Transfer Function (MTF) has a true meaning - i.e. we use the modulus of the Fourier Transformation (FT) of the Line Spread Function (LSF), or respectively the Point Spread Function:

MTF(f) = | FT{LSF(x)} |

However in reality Contrast Inversion exists – in the presented case study it is due to the blur associated with the geometric size of the Effective Focal spot (or could be from other components of the image system). When the sinc function, associated with the MTF, is presented using the modulus of the Fourier Transformation of the LSF, the modulations after area A (i.e. B, C, D, etc) are presented with positive sign (as if the signal is "rectified"), what may confuse students, unless explained as above.

III. Conclusion

The Contrast Inversion can present a false image of **small object** with larger magnification (i.e. far away from the detector). The image of this object will be with inversed contrast (e.g. pale grey, instead of dark grey and vice versa).

The size of the object, seen with "inversed" image, depends on the size of the X-ray tube effective focal spot and the magnification. This may lead to increase of noise, and what is more important, could mislead the observation of the finding, speaking not for the fact that the pixel values (densities) of such small objects will be completely wrong.

During QC assessment of Image Quality with a Spatial Resolution Test Object (e.g. Hüttner type) the object is usually very close to the detector (i.e. minimal magnification) and due to this reason Contrast Inversion is not observed (unless indicated at the denso-profile – Fig.5). However the anatomical objects within the human body are at different positions – hence with different magnifications. **This may lead to visualizing of small objects, further away from the detector, with inverted contrast.**

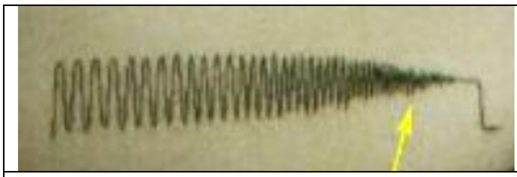


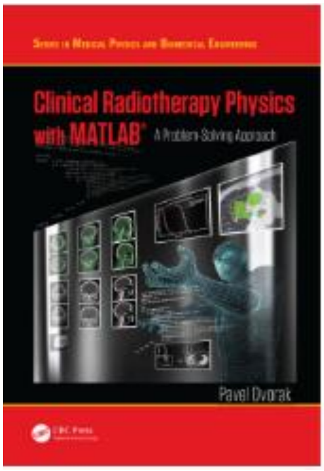
Fig.5 Contrast inversion manifested at the denso-profile of test object with gradually increasing spatial frequencies (plot of pixel values along a line through the image of the test object). The arrow indicates the Contrast Inversion.

The phenomenon Contrast inversion is most obvious when it is related to the blur arising from the finite size of the effective focal spot of the X-ray tube, but it can be related to other "imperfections" of the imaging system. The case study presented here has educational aim, both for students and medical colleagues, while explaining various artefacts or technical reasons for potential misinterpretation of medical images.

Author: Slavik Tabakov, PhD, Dr h.c., FIPEM, FHEA, FIOMP, Past-President IOMP, Vice-President IUPESM, Institute: King's College London, UK, slavik.tabakov@emerald2.co.uk

BOOK REVIEW

A BOOK REVIEW
CLINICAL RADIOTHERAPY PHYSICS WITH MATLAB: *A PROBLEM-SOLVING APPROACH*
BY PAVEL DVORAK



Introduction and purpose

This book provides a “dummy” for beginner’s guide to using MATLAB® to solve common problems in DICOM and imaging post-processing. It also provides guidance on how to manage the preliminary problems of dose calculation and the extrapolation of data from instruments and devices available in modern radiation

Audience

The book is intended as an introductory guide to managing simple problems and code in MATLAB® which will be useful in radiation therapy environments. The added value of the book is its many recent references and publications in the field of radiotherapy about the discussed topic.

The book can contribute to the training of students or stimulate professionals to improve the state of the art of technology, solving everyday clinical problems related to software and technology, and developing what is not available in their own radiotherapy department.

Content/Features/Assessment

The book is organized into ten chapters, as the author guides the readers through the problems in DICOM and the typical domain of the TPS, LINAC and images systems available in modern radiation therapy. The author tries to provide the reader with the initial tools to understand which parameters, script, or complex codes should be written and how to integrate industrial data with simple interfaces developed in MATLAB®. In particular the book provides a dummy for programmers, in the field of image co-registration, management and dose calculation and addresses the problems of quality assurance and data analysis through gamma index with examples of breaking down the problem and assembling the information necessary to achieve the goal.

A much needed addition to current literature in the field, this book is tailored to the needs of medical physicists who are problem-solving using scripts and codes in MATLAB. Dr. Dvorak has provided scripts as dummy codes and summarized a sample of problems typically present in radiotherapy related to the use of advanced systems for treatment plans, such as the management of ROIs and Volumes in images and the automation of quality controls of LINAC, through dedicated toolbox developments and useful codes in daily clinical practice, to have an online control of the LINAC parameters and / or interpretations of the ROIs and Volumes reported in the images and on which accurate dose calculations are possible.

The book can be used to support MSc programs in medical physics or early-career professionals from different disciplines (physics, engineering, software and medical instruments design, etc.…) who need to understand the approach of using MATLAB® codes for problem solving in radiation therapy.

Reviewed by Gabriele Guidi, Ph.D., M.Sc.

Director of Medical Physics
Az. Ospedaliero-Universitaria di Modena, Italy
His research interests are in Adaptive Radiation Therapy, workflow automation and predictive methods in medicine.

HISTORY AND HERITAGE

A BRIEF HISTORY OF THE AAPM: CELEBRATING 60 YEARS OF CONTRIBUTIONS TO MEDICAL PHYSICS PRACTICE AND SCIENCE

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Abstract — **A short article tracing the history of American Association of Physicists in Medicine (AAPM), reprint with permission from the Journal *Medical Physics*.**

Keywords— **AAPM, Medical Physics History.**

I. INTRODUCTION

To celebrate the 60th anniversary of the founding of the American Association of Physicists in Medicine, the Editor-in-Chief Jeffrey Williamson and President-Elect Bruce Thomadsen asked us to write this brief commemorative history reviewing its formation in 1958 and presenting some of the more important activities and achievements over the ensuing 60 years.

II. THE FORMATIVE YEARS

The need to form a national medical physics society in the U.S. grew out of discussions to form an international medical physics federation (ultimately to be called the International Organization for Medical Physics).

Senior U.S. medical physicists involved in the formation of the IOMP proposed that this new international organization be comprised of national societies, not individuals; but the U.S. did not have such a society, hence the urgent need to establish one.
In June1958, a Steering Committee was formed with the task to develop a proposal to form a national society and present it to medical physicists nationwide, firstly by mail, with a formal proposal to be made to those medical physicists attending the RSNA meeting in November of that year, this being the major single conference that medical physicists had been attending each year. After considerable discussion at the meeting, a motion to form the American Association of Physicist in Medicine was made and unanimously approved. A Temporary Constitution was presented and approved. Interestingly, the Constitution stated that the objectives of the new association were:

• To promote the advancement of all branches of physics as they may be related to biology and medicine
• To secure and to maintain high professional standards for scientists in these fields
• To serve the professional interests of those so engaged.

Clearly, the intent was for this to be an organization

FIG. 6. Board Meeting, December 1966, Chicago. *Seated, left to right:* Clarence Karzmark, Rosalyn Yalow, Paul Goodwin, Wayne Meyers, Robert Gorson, Arnold Feldman, Robert Shalek (president), Lawrence Lanzl, Moses Greenfield, James Kereiakes, Walter Mauderli, Kenneth Wright, Leonard Stanton, and Charles Simons. *Standing, left to right:* Past presidents John Laughlin, Warren Sinclair, and Marvin Williams.

Figure 1: AAPM Board of Directors, 1966

concerned primarily with the professional needs of its members. The Steering Committee believed that the scientific needs of the members (meetings and journals in which they could present their research, etc.) would be met through other societies which had medical physicists as members, such as the RSNA, Nuclear Medicine Society, Health Physics Society, etc. However, two years later, the Board of Directors decided that the AAPM should have a strong scientific program in addition to the professional one.

This was discussed at several meetings of the Board of Directors (see Fig. 1) and this culminated in 1969 with the publication of revised Articles of Incorporation within which the term "professional" had been removed. There were two reasons for doing this. The first was that we were, at the time, an Affiliated Society of the American Institute of Physics, and the AIP were not supposed to be involved with professional matters. The second being that we were applying for tax free-status with the Internal Revenue Service, for which we had to demonstrate that we were strictly a "scientific and educational" society. The growth of the organization in the since it was formed in 1958 is illustrated in Figure 2.

III. Meetings of the organization

Prior to 1969, all Annual Meetings of the AAPM had been held in conjunction with the RSNA Annual Meetings in Chicago. With the new emphasis on science, however, the Board felt that there was a need for the AAPM to have its own Annual Meeting during the summer months, with the meeting at the RSNA becoming a midyear meeting. The 1st standalone AAPM Annual Meeting was held in Washington DC in 1969 and the tradition of having the Annual Meeting in the summer and the midyear meeting in the winter at the RSNA continues to this day. The impact of the Annual Meetings can be ascertained from their growth (Figure 3). The early meetings were held in hotels with conference facilities but, for the past several decades, they became too large for hotels and had to be held in Congress Centers. Most recent data show the overall attendance is over 4,000, with about 20% of attendees being from outside North America. This is by far the largest annual medical physics meeting in the world. Of special note is that all the presentations at the Annual Meeting are recorded and available free to all AAPM members through the Virtual Library, and to all others after a one-year embargo.

Figure 2: Growth of the AAPM since it was formed in 1958.

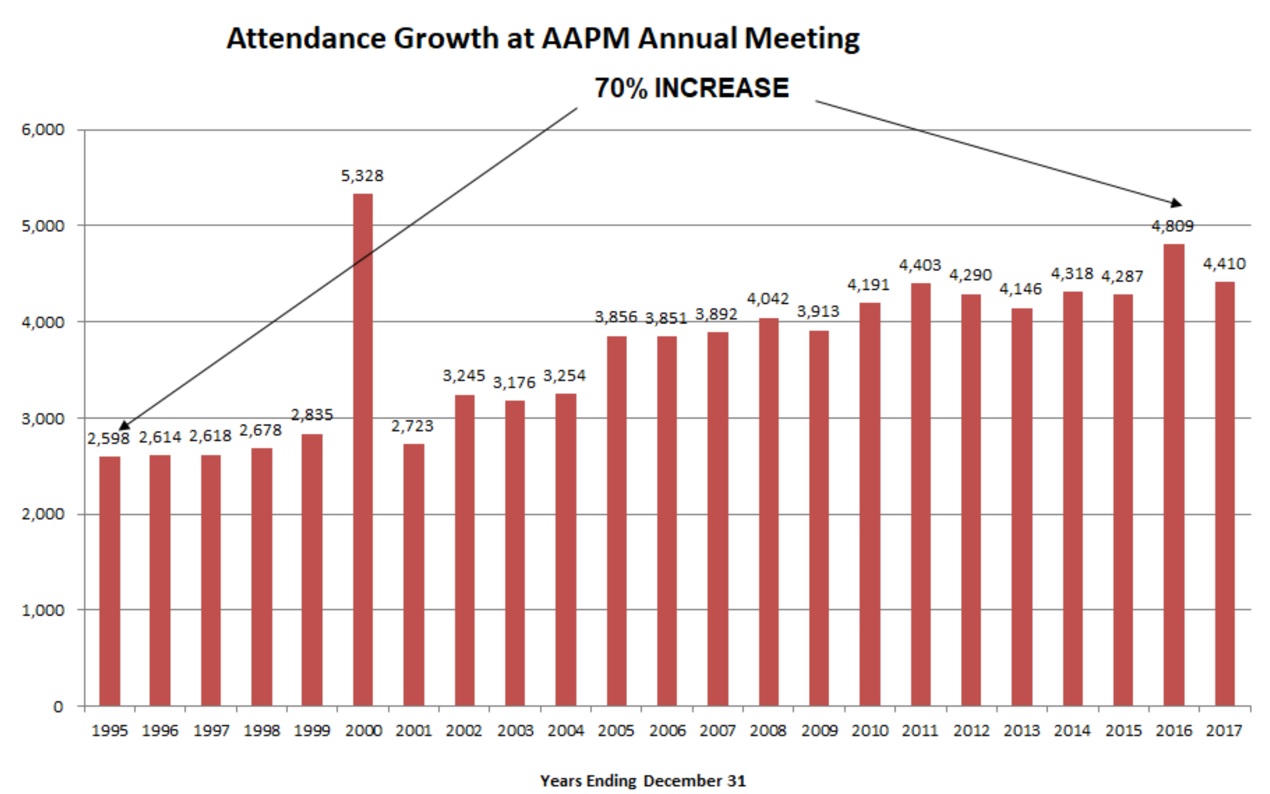

Figure 3: Recent growth in attendance at the AAPM Annual Meeting

In 2012, the AAPM launched another meeting held annually, the Spring Clinical Meeting, which replaced the Annual Meeting of the American College of Medical Physics when the AAPM absorbed many of the functions of the ACMP when it was dissolved. As its title suggests, this is mainly a clinical physics meeting, leaving scientific, educational and professional matters to the Annual Meeting. Current attendance is about 400 each year. As with the Annual Meeting, all presentations are recorded and available free to all AAPM members through the Virtual Library, and to all others after a one-year embargo.

In order to meet the educational needs of members, annual Summer Schools on specific specialty topics were introduced in 1969, the 1st being held at Trinity College, Burlington VT. These Summer Schools are designed primarily for practicing medical physicists to keep them apprised of the latest developments. They are a continuing education opportunity with current attendance typically about 250 each year. Proceedings of all Summer Schools have been published and are available from Medical Physics Publishing, Madison, WI and, like the Annual and Spring Clinical Meetings, all the presentations can be viewed by AAPM members through the AAPM Virtual Library, and by all others with a one-year embargo.

With the early Annual Meetings and Summer Schools being devoted primarily to clinical, scientific and educational endeavors, members were concerned that the AAPM was not meeting their professional needs and consideration was given to formation of a separate professional society. This was discussed at length at the 1973 Annual Meeting but the decision to form a new professional organization was tabled and, instead, a new Professional Council was formed in 1973. At the same time the Science and Educational Councils were formed and many of the existing Committees were assigned to the appropriate Councils.

The major roles of the Councils were to oversee the activities of the Committees within their purview and to act as the liaison between these Committees and the Board of Directors. Of special importance were the Reports that were being written by Task Groups within the Committees.

Without question, AAPM Task Group Reports have defined the practice of medical physics in the U.S. and have strongly influenced practice on the international level. Some of these were published in Medical Physics and some have been standalone in hardcopy format, but ALL are available in digital format from the AAPM website. They are published "open access" to anyone. As such, they not only define the practice of medical physics in the USA, but do so for countries all over the world. Following are some of the most influential of these TG Reports:

- TG-21: A protocol for the determination of absorbed dose from high-energy photon and electron beams (1983), now replaced by:
- AAPM Report 68: TG-51: A protocol for clinical reference dosimetry of high-energy photon and electron beams (1999)
- AAPM Report 13: Physical aspects of quality assurance in radiation therapy (1984), now replaced by:
- AAPM Report 46: TG-40: Comprehensive QA for radiation oncology (1994)
- AAPM Report 32: TG-25: Clinical electron-beam dosimetry (1991)
- AAPM Report 44: Academic program for Master of Science degree in medical physics (1993)
- AAPM Report 51: TG-43: Dosimetry of interstitial brachytherapy sources (1995), now replaced by:
- AAPM Report 84: Update of AAPM Task Group No. 43 Report: A revised AAPM protocol for brachytherapy dose (2004)
- AAPM Report 59: TG-56: Code of practice for brachytherapy physics (1997)
- AAPM Report 68: TG-64: Permanent prostate seed implant brachytherapy (1999)
- AAPM Report 79: Academic program recommendations for graduate degrees in Medical Physics (2002)
- AAPM Report 82: Guidance document on delivery, treatment planning, and clinical implementation of IMRT (2003)
- AAPM Report 142: Quality assurance of medical accelerators (2009)
- AAPM Report 197: Academic program recommendations for graduate degrees in Medical Physics
- AAPM Report 229: Dose calculation for photon-emitting brachytherapy sources with average energy higher than 50 keV (2012)
- AAPM Report 249: Essentials and guidelines for clinical Medical Physics residency training programs (2013)
- AAPM Report 258: Monitor unit calculations for external photon and electron beams (2014)
- AAPM Report 151: Ongoing quality control in digital radiography (2015)
- AAPM Report 283: TG-100: Application of risk analysis methods to radiation therapy quality management (2016)

IV. ROLE OF THE AAPM IN JOURNAL PUBLISHING

Another major activity of the AAPM has been publication of two journals, Medical Physics and the Journal of Applied Clinical Medical Physics.

Medical Physics

By 1971, it became obvious that there were enough members publishing papers that the AAPM needed to consider having its own scientific journal. Members had been publishing their work in either radiology journals or Physics in Medicine and Biology which, since 1962, had been designated the official journal of the AAPM. A Journal Exploratory Group was formed, which polled the membership on the need for establishment of AAPM's own journal. The response was overwhelmingly positive, and the Board of Directors voted to begin publication of its new journal Medical Physics in 1974. It was agreed that the journal would replace the AAPM Quarterly Bulletin, which at the time was being published by the AIP with AIP support staff, so arrangements were made for the AIP to continue as the publisher of Medical Physics. Initially, there were just six issues published per year, but demand for more pages led to this being increased to the present number of 12 issues/year in 1985. This has turned into a truly international journal, with about half the authors coming from outside the USA. Medical Physics is currently receiving about 1,400 manuscripts/year, with over 6,000 pages published /year. A large number of articles are now being published open access so that anyone in the world can access them free of charge. These include:

- Editor's Choice
- Editorials
- Medical Physics Letters
- Review Articles
- Future of Medical Physics (formerly Vision 20/20)
- Point/Counterpoint
- Focus Series
- Award Winning Papers

Journal of Applied Clinical Medical Physics

This is a by-monthly online only, open access journal, so is available for anyone to read for free. This makes it a truly international journal, especially since about 50% of the papers published are from outside North America. The JACMP was first published in 2000 by the American College of Medical Physics but was taken over by the AAPM in 2015. Currently, the JACMP website records over one million views/year. This is an average of about one visit/week for every medical physicist in the world!

Since 2013, the JACMP has been publishing the AAPM's Medical Physics Practice Guidelines, which provide information on the minimal levels of medical physics support (staffing levels, equipment, etc.) for a variety of medical physics services. The eight MPPGs published thus far are:

- CT protocol management and review

• Commissioning and quality assurance of X-ray-based image-guided radiotherapy systems
• Levels of supervision for medical physicists in clinical training
• Development, implementation, use and maintenance of safety checklists
• Commissioning and QA of treatment planning dose calculations - megavoltage photon and electron beams
• Performance characteristics of radiation dose index monitoring systems
• Linear accelerator performance tests
• SRS-SBRT

V. Role of the AAPM in the Education of the Next Generation of Medical Physicists

AAPM's educational contributions go beyond its Education Council and its associated task group reports and refresher courses presented at the Summer and Spring Meetings. For example, an important program developed by the AAPM was the Commission on Accreditation of Medical Physics Education Programs (CAMPEP), which was formed and administered by the AAPM in the mid-1980s although, since 1994, it has been an independent organization. The stated purpose of CAMPEP is to review and accredit medical physics graduate and residency training programs. Currently, over 50 graduate programs and over 110 residency programs have received CAPMEP accreditation. Without question, CAMPEP has improved the teaching and training of medical physicists, and assures that medical physicists who graduate from these programs have being properly educated and trained. Indeed, graduation from a CAMPEP-accredited residency program is now a requirement for certification by the American Board of Radiology (ABR).

Another outgrowth from the Education Council and AAPM members resulted in the 2008 formation of the Society of Directors of Academic Medical Physics Programs (SDAMPP). SDAMPP promotes coordination between academic Medical Physics programs, to establish best practices, to aid in monitoring the production of students relative to the job market, and to serve as a voice for academic program directors. SDAMPP along with the AAPM, CAMPEP, and ABR, aims to effectively and efficiently define, implement, and monitor the education of medical physicists so as to yield clinically-qualified medical physicists for the healthcare environment. (Figure 4)

Educational activities of the AAPM also include the aspect of professionalism and leadership. The Medical Physics Leadership Academy Working Group currently oversees and organizes leadership and management training and experience specific to medical physicists. Training and experience will be accomplished through various meetings and activities all based on the Medical Physics Leadership Academy Curriculum, including collaboration with other related professional leadership programs.

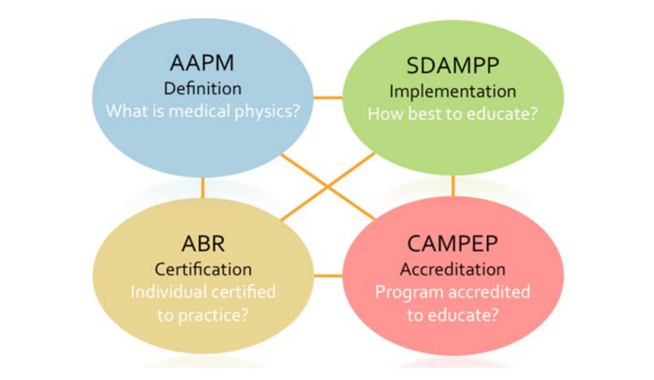

Fig. 4: Relationship between AAPM, CAMPEP, SDAMPP, ABR

VI. Role of the AAPM in Scientific Research Pursuits of Medical Physicists

AAPM scientific research contributions are overseen by the Science Council and enhanced through the annual AAPM meetings, specialized Focused Research (FOReM) meetings, special sections within the Journals, as well as by the various committees and working groups. The Science Council examines specific areas of medical physics, especially those in emerging technologies, addresses scientific questions, and collates and assesses data, and is responsible for the vast majority of clinical and scientific guidance documents and Task Group Reports. For example, Science Council diligently studies the content of the annual summer meeting to both learn and provide suggestions for subsequent years. In order to stay at the forefront of medical physics, it is crucial that AAPM members are kept aware of emerging technologies in imaging science and therapy physics. For example, almost a decade ago, given the rising need for technology assessment, the Technology Assessment Committee (TAC) was initiated as a Presidential ad-hoc committee and ultimately incorporated into Science Council. Most recently, given the rapid rise of big data, radiomics, machine learning, and artificial intelligence in imaging and therapy, Science Council is now creating an Ad Hoc Committee on Big Data, Radiomics, and Machine Learning in order to integrate the needs from both imaging and therapy medical physicists.

For summaries of the role of the AAPM in the development of various scientific and technological advances, Medical Physics published "50th anniversary papers", which can be found at http://aapm.onlinelibrary.wiley.com/hub/issue/10.1002/(ISSN)2473-4209.50thAnniversaryPapers/.

VII. THE FUTURE

Constant review of an organization allows for continued growth. Currently an AAPM effort known as "Medical Physics 3.0" is focusing on goals for the clinical, educational, research, and administrative leadership aspects of medical physicists (http://www.aapm.org/org/charges/MP30.asp).

The goals of the AAPM remain to:

- Promote the highest quality medical physics services for patients.
- Encourage research and development to advance the discipline.
- Disseminate scientific and technical information in the discipline.
- Foster the education and professional development of medical physicists.
- Support the medical physics education of physicians and other medical professionals.
- Promote standards for the practice of medical physics.
- Govern and manage the Association in an effective, efficient, and fiscally responsible manner.

It is clear that the role of the AAPM in the field of medical physics is expanding as is the coverage of the field itself.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

Information:

This paper is reproduced with permission from Colin G. Orton Maryellen L. Giger: A brief history of the AAPM: Celebrating 60 years of contributions to medical physics practice and science, J. Medical Physics, vol. 45, Issue 2, February 2018, pages 497-501

Go to https://doi.org/10.1002/mp.12738 to view the original paper in Medical Physics.

OBITUARY: OSKAR ADOLF CHOMICKI (IOMP PRESIDENT 2000-2003)

(20.05.1931-25.10.2018)

Prof. Dr Oskar Adolf Chomicki was a fundamental figure in international medical physics. He was the first Eastern-European medical physicist to be elected President of the International Organization for Medical Physics (IOMP). He was especially known for supporting the professional development in Low and Middle Income Countries (LMIC, aka Developing countries).

Prof. Chomicki graduated in 1949 secondary school Staszic's in Warsaw. Following this he did his MSc diploma at the Faculty of Physics and Mathematics, University of Warsaw, Poland. He started his career at the Institute of Experimental Physics, University of Warsaw (1952-1957). Later he established the Radioisotope Laboratory and was senior lecturer at the Bielanski Hospital in Warsaw and at the Postgraduate Medical Education Center in Warsaw.

Prof. Chomicki was one of the creators of the Polish Society of Medical Physics (PSMP) and for many years was Secretaty of the General Board of the PSMP. He was also Member of the American Association of Physicists in Medicine (AAPM). From 1991 he worked for the IOMP, initially Editing the IOMP Bulletin for Developing Countries (at that time an activity of the IOMP Developing Countries Committee, which was renamed in 1997 to Professional Relations Committee).

In 1997 Prof. Chomicki was elected President of IOMP, a position he took in the period 2000-2003. During this period he supported the introduction of the first IOMP Awards at the WC2000 in Chicago - an initiative of Prof. John Cameron and Prof. Azam Niroomand-Rad, with whom he had very good professional relations.

Prof. Chomicki was the first IOMP President after the inclusion of our professions in the International Council for Sciences (ICS, formetly ICSU), in this position he supported the first steps and links with other scientific and professional organizations.

Prof. Chomicki was author and co-author of many scientific papers. He was co-author and translator of books on the subject of application accelerators in medicine. He was Honorary Member of the Polish Society of Medical Physics and Honorrary Member of the European Federation of the Organizations for Medical Physics (EFOMP). In 2013 he was made Fellow of IOMP. In his home country Prof. Chomicki was made Cavalier of the Gold Merit Cross and of the Medal Well Deserved for Warsaw.

Prof. Chomicki passing away is a loss for the whole profession. During events associated with the International Day of Medical Physics (7 November 2018) in Poland, he was honoured with a minute of silence.

My first meeting with Oscar was related to our passion to help colleagues from LMIC – this was at the WC1997 in Nice, France, where he invited me to co-chair with him the session for education in developing countries. I had just completed the establishment of one of the first medical physics MSc courses in Eastern Europe (project ERM) and we discussed the development of another such course for the three Baltic states. This project was later materialised and Oscar came at the special Workshop associated with this Baltic MSc in Tallin, Estonia, 1999. From these meetings, from our collaboration and from our many emails, I shall remember him as an outstanding person, a true gentleman of highest intellectual calibre.

After his retirement Prof. Chomicki wrote books related to the history of his well known family in Poland and was supporting us with advice on many occasions (he wrote one of the papers in the first issue of the MPI Journal).

With his open-hearted smile and consensus-seeking approach, Prof. Chomicki helped many of us in our first steps in the international professional development. IOMP included Obituaries for him on its web site and its eMPW Newsletter, informing all our members in 86 countries. Deep condolences were sent to his family from all ExCom.

Prof. Oscar Adolf Chomicki was one of the international pillars of our profession and we shall never forget his contribution to the development of medical physics.

On behalf of IOMP: Prof. S. Tabakov, IOMP President 2015-2018, with contributions from Prof. M Radwanska, Prof. P Kukolowicz, Prof. M Rehani (current IOMP President), EFOMP and IOMP web sites.

INFORMATION FOR AUTHORS

PUBLICATION OF DOCTORAL THESIS AND DISSERTATION ABSTRACTS

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

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

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

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

INSTRUCTIONS FOR AUTHORS

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

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

MANUSCRIPT STYLE

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

The style should follow the template that can be downloaded from the website at:

http://mpijournal.org/authors_submitapaper.aspx

ILLUSTRATIONS SPECIAL REQUIREMENTS

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

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

REFERENCE WEBSITES

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

EDITORIAL POLICIES, PERMISSIONS AND APPROVALS

AUTHORSHIP

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

CONFLICT OF INTEREST

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

All submitted manuscripts must be supported by a document (form provided by MPI) that:

• Is signed by all co-authors verifying that they have participated in the project and approve the manuscript as submitted.

• Stating where the manuscript, or a substantially similar manuscript has been presented, published, or is being submitted for publication. Note: presentation of a paper at a conference or meeting does not prevent it from being published in MPI and where it was presented can be indicated in the published manuscript.

• Permission to publish any copyrighted material, or material created by other than the co-authors, has been obtained.

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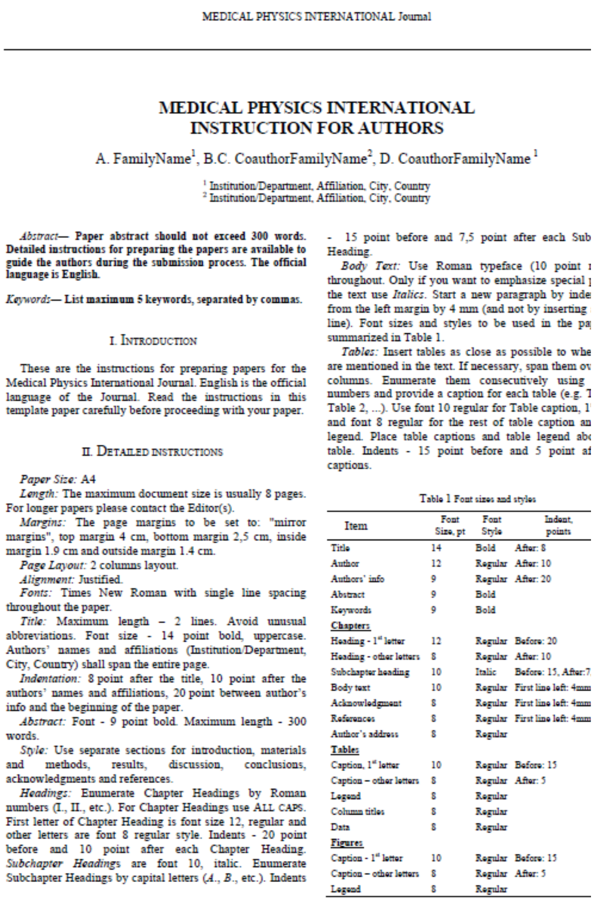

MEDICAL PHYSICS INTERNATIONAL Journal

MEDICAL PHYSICS INTERNATIONAL
INSTRUCTION FOR AUTHORS

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

[1] Institution/Department, Affiliation, City, Country
[2] Institution/Department, Affiliation, City, Country

Abstract— **Paper abstract should not exceed 300 words. Detailed instructions for preparing the papers are available to guide the authors during the submission process. The official language is English.**

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

I. INTRODUCTION

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

II. DETAILED INSTRUCTIONS

Paper Size: A4

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

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

Page Layout: 2 columns layout.

Alignment: Justified.

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

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

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

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

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

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

Body Text: Use Roman typeface (10 point r throughout. Only if you want to emphasize special p the text use *Italics*. Start a new paragraph by inde from the left margin by 4 mm (and not by inserting line). Font sizes and styles to be used in the pa summarized in Table 1.

Tables: Insert tables as close as possible to whe are mentioned in the text. If necessary, span them ov columns. Enumerate them consecutively using numbers and provide a caption for each table (e.g. T Table 2, ...). Use font 10 regular for Table caption, 1 and font 8 regular for the rest of table caption an legend. Place table captions and table legend abo table. Indents - 15 point before and 5 point af captions.

Table 1 Font sizes and styles

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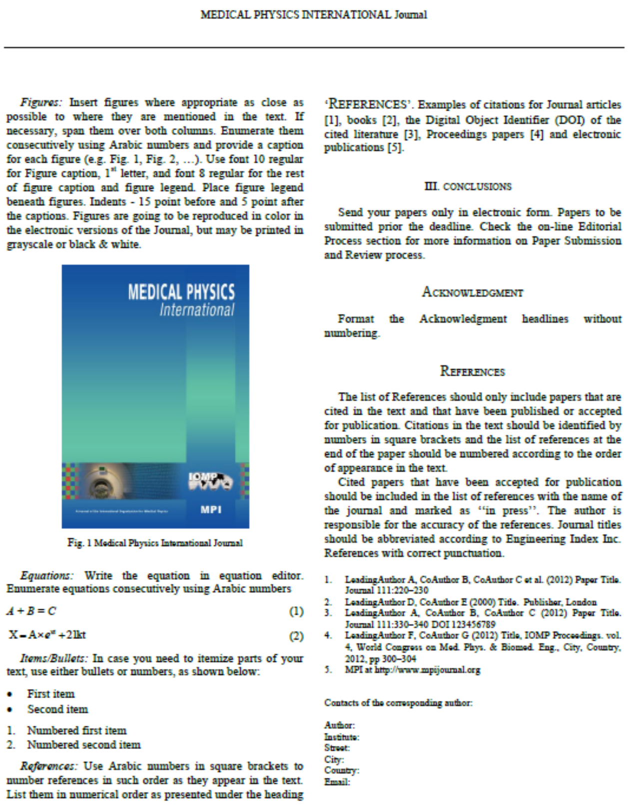

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Equations: Write the equation in equation editor. Enumerate equations consecutively using Arabic numbers

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

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