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MPI

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International Organization for Medical Physics

MEDICAL PHYSICS INTERNATIONAL
The Journal of the International Organization for Medical Physics

Aims and Coverage:

Medical Physics International (MPI) is the official IOMP journal. It provides a 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. MPI- History Edition is dedicated to History of Medical Physics.

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Dear colleagues and friends,

It is with great pleasure and enthusiasm that we release the publication of Medical Physics International (MPI) Vol.12, No.2; 2024. In this past year of 2024, releases of MPI editions have attracted 1,000+ readers and downloads on MPI website daily.

This current edition of MPI (Vol. 12, No. 2) contains 14 articles in the thematic areas: Collaborating Organizations, Educational Topics, Professional Issues, Invited Research Papers, How-To and Book Reviews. Of special mention is the article by Prof S. Tabakov reviewing the need for educational material in order to boost the number of future medical physicists, and by Prof. A. Chougule on IOMP's accreditation of Medical Physics programmes.

We were fortunate to receive many more than the 14 manuscripts presented in this current edition. Some of the articles received were deemed too similar to the ones we had already accepted and will be considered for future submissions. Others had to be rejected due to a lack of scientific rigor of the data presented. We wish to emphasize that even with the articles that are not published we have continued to provide feedback to the authors in order to help them better prepare their submission for the next round. We sincerely hope that our comments, which we believe are constructive, will help them in this endeavor.

As always, we appreciate the support and research work of all those who have contributed to this current issue. Our journey to make MPI a preferred vehicle of publishing "practical-tips-and- tricks" in medical physics for professionals in the world-wide community continues.

We encourage readers to submit more practical tip or "how-to" articles which can be used by fellow medical physicists around the globe. Kindly visit www.mpijournal.org/index.aspx for latest MPI publications and enjoy reading our exciting publications.

MESSAGE FROM IOMP PRESIDENT

John Damilakis
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Dear colleagues,

This year has been marked by significant progress, impactful collaborations, and inspiring initiatives that continue to advance our profession and strengthen our shared commitment to improving patient care through medical physics. From global events and educational workshops to innovative projects and outreach activities, 2024 has been a year of growth and meaningful contributions from colleagues and partners worldwide. In this message, I would like to highlight a few of the most important events and initiatives that have defined our collective journey.

Medical Physics International (MPI) is a freely accessible journal dedicated to medical physics education, professional development, and global collaboration. It serves as a platform for sharing knowledge, insights, and innovative approaches in medical physics, with a strong emphasis on educational methods, professional growth, and the dissemination of best practices. The journal focuses on publishing general review articles, reports on specific educational strategies, and resources that support the professional development of medical physicists worldwide. In addition to regular issues, MPI introduced this year a designated "Proceedings Series" for the publication of congress abstracts, making it easier for researchers and practitioners to access information from specific scientific events. This initiative enhances the visibility of academic contributions and facilitates the dissemination of key findings from global conferences. Authors interested in contributing to MPI are encouraged to follow the journal's submission guidelines, which outline the requirements for preparing and submitting manuscripts.

The **International Day of Medical Physics (IDMP)**, celebrated annually on November 7th, honors the birthday of Marie Curie. The theme for 2024 was ***"Inspiring the Next Generation of Medical Physicists"*** emphasizing the need to attract young talent in the field. The overarching message of IDMP 2024 reflected a shared commitment to inspiring future generations. A global poster competition was held in preparation for IDMP 2024, and **Dr. Lavanya Murugan** was selected as the winner for her design, which captured the theme's essence. A very successful 24-hour global event titled ***"Around the World in 24 Hours: Celebrating Medical Physics"*** was held on November 7th, bringing together regional and national organizations to share presentations, strategies, and plans.

The **International Medical Physics Week (IMPW)** is an annual global event organized by the IOMP to highlight the critical role of medical physicists in healthcare. IMPW serves as a platform for knowledge sharing, collaboration, and promoting awareness of the contributions medical physics makes to improving patient care and advancing healthcare technologies. In 2024, IMPW was celebrated from **April 22 to April 26**, with a series of online webinars organized by IOMP's regional organizations. This global initiative underscores the importance of collaboration and continuous learning in addressing current challenges and advancing the field of medical physics.

IOMP actively supports the global medical physics community through the **sponsorship and endorsement of events**. IOMP supported many events during 2024 and relevant information was included in my IOMP newsletter messages. By providing official recognition and support, IOMP helps ensure that medical physics events, including conferences, workshops, webinars, and training programs, achieve broader visibility, attract greater participation, and maintain high standards of scientific and educational quality. Endorsed events often provide opportunities for early-career professionals and students to engage with experts, participate in hands-on training, and gain insights into cutting-edge research and technologies. Organizers seeking IOMP sponsorship or endorsement are encouraged to align their events with the organization's mission and objectives. Clear educational goals, relevance to the field of medical physics, and potential for long-term impact are key criteria for consideration.

The IOMP recognizes the importance of **hands-on training and targeted education** in advancing the expertise and skills of medical physicists worldwide. IOMP organized a **significant workshop** held in Malaysia a few days before the **Asia-Oceania Congress of Medical Physics (AOCMP) and the South-East Asia Congress of Medical Physics (SEACOMP)**. The event included expert-led sessions, interactive discussions, and opportunities for hands-on training, offering participants a well-rounded learning experience. The workshop also served as a platform for knowledge exchange and collaboration among professionals from various countries in the Asia-Oceania region.

Looking ahead to February 2025, IOMP, in collaboration with the Middle East Federation of Organizations of Medical Physics (MEFOMP), will organize another key workshop in Kuwait. This event, titled ***"Advances in CT Dosimetry and Machine Learning: Optimizing Patient Safety and Dose Estimation,"*** will take place alongside the **MEFOMP Medical Physics Conference**. The workshop will span four days and focus on both theoretical foundations and hands-on practical training in CT dosimetry, radiomics, and machine learning workflows. Participants will gain exposure to the latest methodologies, tools, and practices aimed at enhancing diagnostic precision, patient safety, and treatment optimization. To ensure effective engagement, practical sessions will be limited to a pre-selected group of participants, allowing for personalized guidance and in-depth training.

The **IOMP Accreditation Board** plays a key role in maintaining and promoting high standards in medical physics education, training programs, and professional development activities worldwide. Throughout 2024, the Accreditation Board has been actively involved in evaluating and accrediting numerous events, including conferences, workshops, residency programs and training courses. This accreditation process ensures that events meet globally recognized standards, provide valuable educational content, and contribute meaningfully to the professional growth of medical physicists. Accreditation by IOMP signifies that an event adheres to rigorous quality benchmarks, including clear educational objectives, scientifically sound content, and relevance to contemporary challenges in medical physics. The IOMP Accreditation Board’s activities in 2024 have contributed significantly to strengthening global collaboration in medical physics.

The **e-Medical Physics World (eMPW)** is the biannual newsletter of the IOMP, serving as a vital communication platform for the global medical physics community. Together with our **Newsletter**, **IOMP’s website and social media**, MPWB delivers updates on the latest advancements, challenges, and achievements in the field, highlighting key initiatives, events, and collaborations led by IOMP and its member organizations. The newsletter features insightful articles from experts, reports on major conferences, updates on ongoing projects, and announcements of upcoming educational opportunities.

The upcoming **World Congress on Medical Physics and Biomedical Engineering** will take place in **Adelaide, Australia, from September 7 to 12, 2025**. This prestigious event, held every three years, is jointly organized by the IOMP, the International Federation for Medical and Biological Engineering, and the International Union for Physical and Engineering Sciences in Medicine. The congress serves as the largest international gathering of medical physicists, biomedical engineers, healthcare professionals, researchers, and industry leaders. Under the overarching theme "Innovating Healthcare through Medical Physics and Biomedical Engineering" the congress will feature a diverse scientific program, including keynote lectures, plenary sessions, parallel tracks, workshops, and poster presentations. Attendees will have the opportunity to explore the latest advancements in areas such as artificial intelligence in medical imaging and therapy, precision medicine, radiation therapy, diagnostic radiology, healthcare technologies, and patient safety initiatives.

I would like to extend my gratitude to all members of the Executive Committee and colleagues around the world for their dedication, support, and commitment. I am deeply appreciative of the time, expertise, and passion you bring to every initiative, meeting, and project. Together, we have created a strong foundation for future growth, inspiring the next generation of medical physicists and improving patient care worldwide. Thank you for your continued collaboration, professionalism, and dedication to our shared mission.

Happy 2025!

COLLABORATING ORGANIZATIONS

IDMP 2024 – 24-HOUR GLOBAL WEBINAR ON INSPIRING THE NEXT GENERATIONS OF MEDICAL PHYSICISTS

M. Stoeva[1]

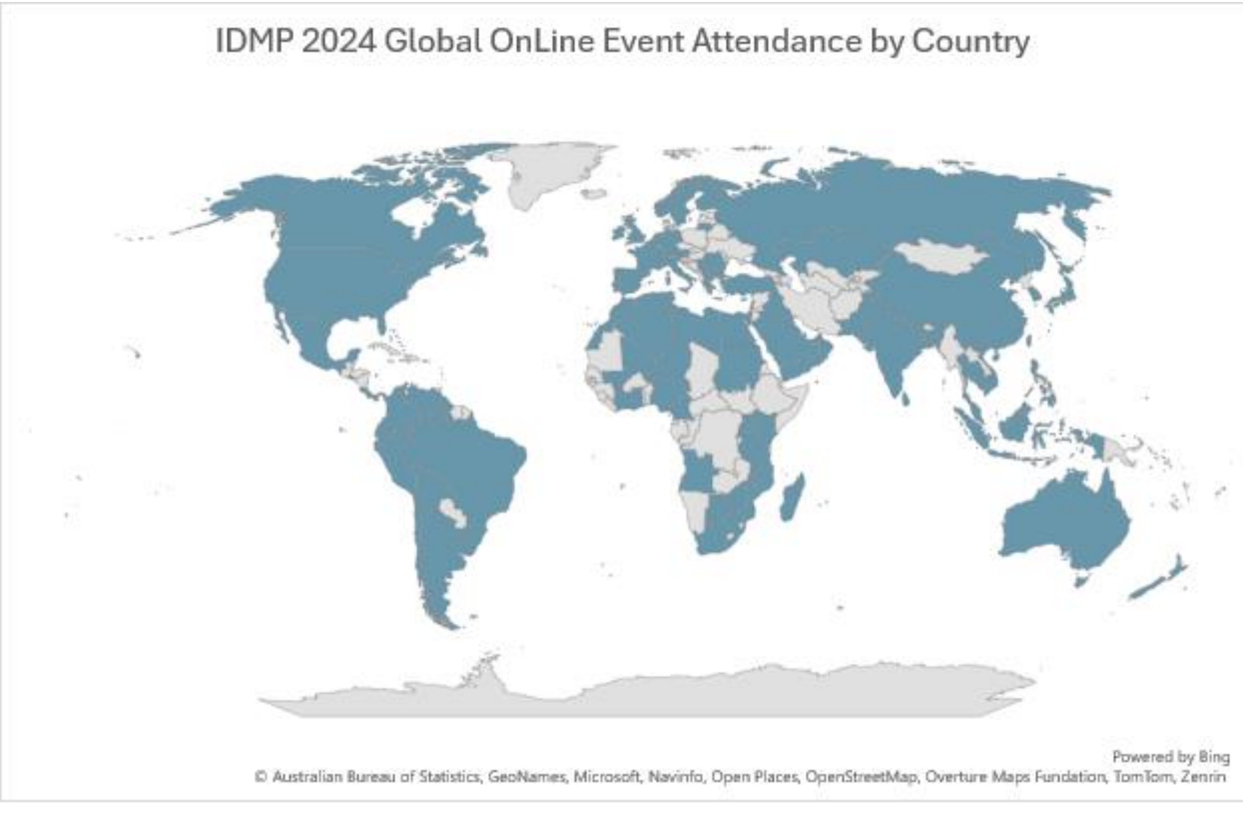
[1] Secretary General, International Organization for Medical Physics

Global collaboration in medical physics plays a pivotal role in advancing our profession and enhancing healthcare worldwide. For over a decade, the International Organization for Medical Physics (IOMP) and medical physicists across the globe have marked November 7th as the International Day of Medical Physics (IDMP). What began as a special occasion has evolved into a global platform for uniting medical physicists, fostering professional development, raising awareness, sharing knowledge, and strengthening networks.

IDMP 2024 was one of the most extraordinary events in our profession—featuring a 24-hour global webinar on the theme, "Inspiring the Next Generation of Medical Physicists."

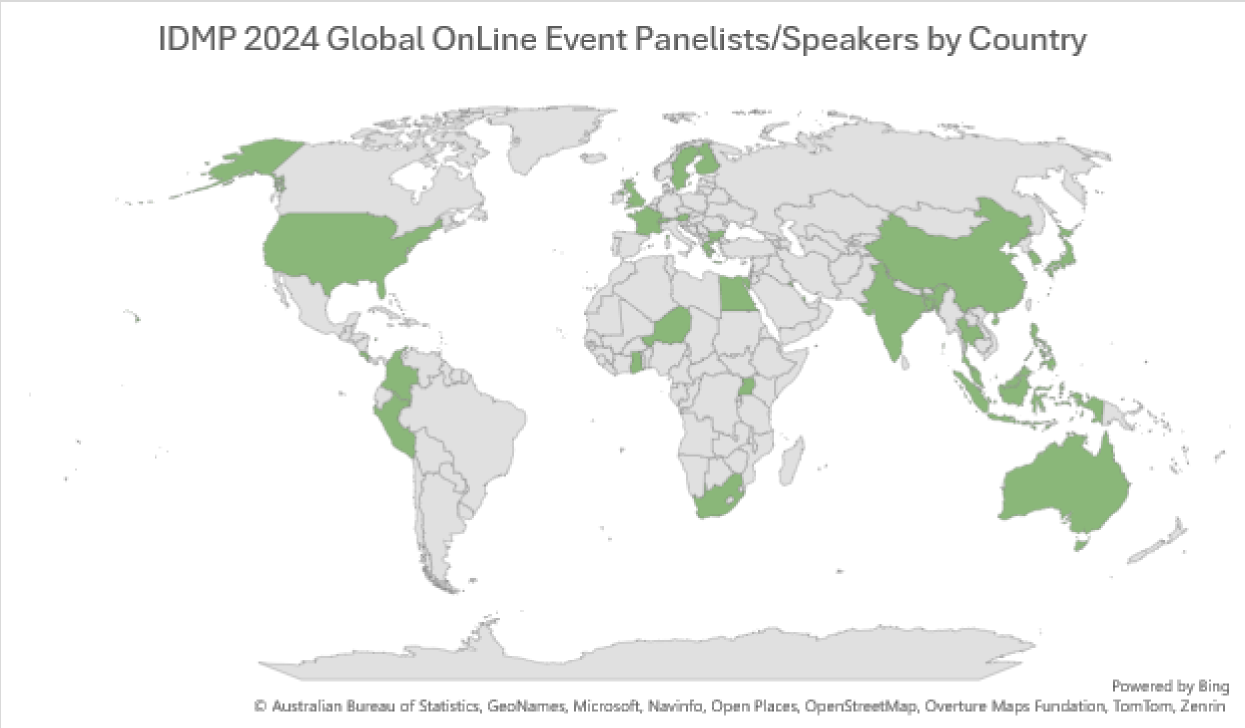
With a focus on regional, national, and international collaboration, IOMP coordinated a series of events that showcased presentations from our six regional organizations and national member bodies. AFOMP, SEAFOMP, MEFOMP, FAMPO, EFOMP, and ALFIM highlighted key issues related to the professional, scientific, educational, and organizational aspects of medical physics in their respective regions. These sessions were enriched by contributions from National Member Organizations within those regions.

A central highlight of the celebration included two webinars organized by the IOMP Executive Committee (ExCom) and IOMP's partner organizations, alongside the announcement of the prestigious IDMP awards.



Members of the IOMP ExCom presented brief reports on their activities and extended congratulations to the global medical physics community and partners on the occasion of IDMP 2024.

The global webinar also gained inaugural support from some of the world's leading organizations, including the IAEA, ICRP, IRPA, ISR, IUPESM, and WHO. A live session brought together the representatives from IOMP's partner organizations to discuss strategies and initiatives aimed at inspiring the next generation of medical physicists—particularly in regions and scientific domains where their presence is most urgently needed.



The panel featured global experts, including M. Carrara (IAEA), C. Martin, M. Djukelic, Luz Olarte (ICRP), Claire-Louise Chapple & B. le Guen (IRPA), B. Allen & D. Frush (ISR), M. Rehani (IUPESM), F. Shannoun (WHO), and J. Damilakis & M. Stoeva (IOMP).

The event attracted participants from 97 countries, with a total of 2,516 man-hours of attendance.

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THE IMPACT OF LOCAL-GLOBAL PARTNERSHIPS ON CANCER CARE IN LOW-RESOURCE SETTINGS: A CASE STUDY OF THE CICL, TOGO

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Abstract— **In 2020, a landmark private partnership between local and foreign entities resulted in the creation of Togo's first radiation therapy facility (CICL), which began operations in 2021. With a focus on delivering same advanced cancer care as the developed countries, the center invested in cultivating a skilled workforce from within Togo and the broader West African region. To achieve VMAT center status, a concerted effort was made to develop and maintain local and regional human resources through targeted training, online networking technology and upskilling initiatives. The Centre International de Cancerologie de Lomé (CICL) over the past four years have treated a little over 900 cancer patients with VMAT technology and built local expertise that offer training to newly established radiotherapy centers across Africa.**

Keywords— **Partnership, VMAT, CICL, Togo.**

I. INTRODUCTION

According to the GLOBOCAN 2020 database [1] of the International Agency for Research on Cancer, it is estimated that there will be 24 million new cancer cases per year globally from 2020 to 2030. Out of these cancer incidence, approximately 75% of estimated cancer mortalities will occur in the developing countries. Radiotherapy (RT) is a vital and effective method for treating and managing cancers. However, many countries in Africa still lack access to radiotherapy as part of a comprehensive cancer care. Advanced forms of treatments in low and middle-income countries (LMICs) is limited due to lack of resources (both human and equipment) - expertise, expensive equipment and software. From the International Atomic Energy Agency's (IAEA) Directory for Radiotherapy Centres (DIRAC) [2], as of March, 2020, 28 (52%) of Africa's 54 countries had access to some form of external beam radiotherapy, 21 (39%) had brachytherapy capacity, and no country had a capacity that matched the estimated treatment need. Urgent initiatives/collaborations in the setting-up of RT facilities, human capacity building and management are needed to change Africa's worrying trajectory in providing quality comprehensive cancer care to patients in the next decade comparative to same quality of care by the best hospitals in the U.S.A., Europe, and Asia.

According to the International Atomic Energy Agency's (IAEA) publication [3], radiotherapy facilities should acquire sufficient experience in 3D conformal radiotherapy (3D-CRT) before adopting advanced techniques like intensity-modulated radiotherapy (IMRT) or volumetric modulated arc therapy (VMAT). While IMRT and VMAT are widely used in North America, Western Europe, and leading cancer centers globally, many African radiotherapy facilities remain reliant on 3D-CRT. Even new facilities often begin with 3D-CRT. Although advancing radiotherapy techniques should be a gradual process, it is essential for Africa to develop capacities to adopt advanced radiotherapy as a standard for cancer care, aligning with global best practices.

II. MATERIALS AND METHOD

The Republic of Togo; located in West Africa is bordered by Benin, Burkina Faso, and Ghana. The current population is estimated to be 9,614,855 as of December 2024, based on Worldometer projections of the latest United Nations (UN) data [4]. Lomé, the capital city, is situated in the southwest of the country and is the largest city with a vibrant sea port. According to World Bank data [5], Togo recorded an annual percentage growth rate of Gross Domestic Product (GDP) of 6.40 % in the year 2023. A technical document from the World Health Organisation (WHO) "Cancer Togo 2020 Country Profile" [6] outlined the health system capacity and workforce locally available for cancer management - Screening, Diagnosis and Treatment in the country. Below are two main key tables from this document (Table 1 and Table 2).

Table 1 Togo's cancer healthcare system capacity according to the 2020 WHO technical document [6]

Cancer system capacity	As at the year	Status
Availability of population-based cancer registry (PBCR)	2019	Registration activities
Quality of mortality registration	2007-2016	No coverage
No. of external beam radiotherapy (photon, electron)[a]	2019	0.0
No. of mammographs [a]	2020	19.0
No. of CT scanners [a]	2020	16.9
No. of MRI scanners [a]	2020	2.1
No. of PET of PET-CT scanners [a]	2020	0.0

[a] per 10,000 cancer patients

Table 2 Togo's cancer human resource capacity according to the 2020 WHO technical document [6]

Cancer workforce capacity	As at the year	Status
Availability staff in Ministry of Health who dedicates significant proportion of their time to cancer	2019	Yes
No. of radiation oncologist [a]	2019	n/a
No. of medical physicist [a]	2019	n/a
No. of surgeons [a]	2014	42.1
No. of radiologist [a]	2019	n/a
No. of nuclear medicine physician [a]	2019	0.0
No. of medical & pathology lab scientists [a]	2015	857.7

[a] *per 10,000 cancer patients*

III. RESULTS AND DISCUSSION

The international partners contributed technical expertise, encompassing facility design, equipment installation, and software implementation, as well as continuous clinical and operational support. Prior to clinical takeoff, the local team were offered requisite training and upgrades where necessary. Meanwhile, the local partners have forged alliances with the local university and prominent healthcare institutions to offer theoretical, practical training opportunities for students and professionals as a form of adequate local human resource capability building.

Notably, the Centre International de Cancerologie de Lomé (CICL) in Togo boasts a workforce comprised entirely of West African professionals, including radiation and medical oncologists, medical physicist, radiation therapists, biomedical engineer, oncology nurses and medical secretaries. From January 2021 to December 2024, the center had treated 906 cancer patients across various age range successfully, administering only advanced (VMAT) treatments as captured in Figure 1.

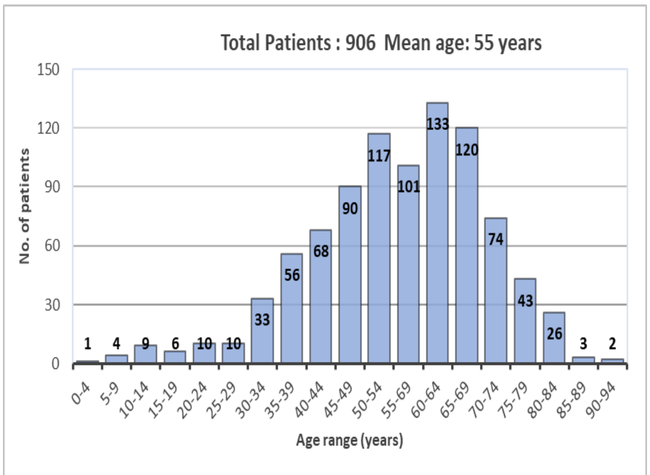
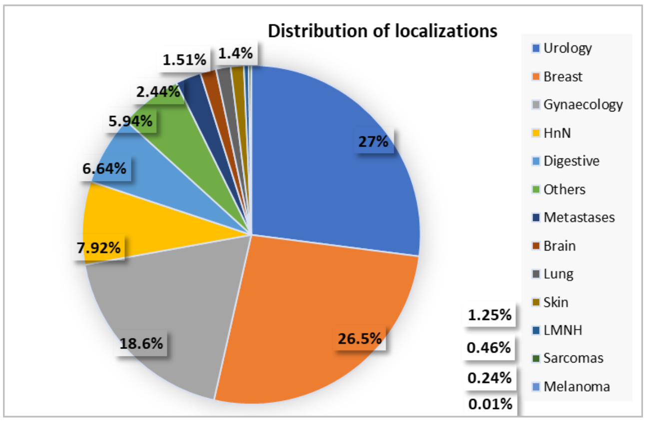


Fig. 1 Total number of cancer patients per age ranges treated with VMAT

The mean age was 55 years with the highest number of patients falling within the 60 – 64 years age range. The pathology distribution of all cancer treated within the same time period are presented in Figure 2 with urological cancers (including prostate cancer, renal/kidney cancers, bladder cancer, testicular and penile cancers) been the most treated cancer cases followed by breast cancer.



NB: HnN=Head and Neck, LMNH=Non-Hodgkin's lymphoma

Fig. 2 Pathological distribution of cancer cases treated with VMAT

IV. CONCLUSIONS

Such efficient collaborative strategies do not only help build human resource capacity for Africa but build competent and confidence workforce capable of delivering same high-quality care as in major international RT centers. Togo, a country with no RT facility and experience has gone from zero external beam treatment capability in 2020 to fully VMAT treatment. This oncology solution is proving to be very successful and hope such model can be replicated to other parts of the African continent. In 2023, a similar local-international partnership was replicated in Blantyre in Malawi (International Blantyre Cancer Center) to birth the country's first radiotherapy facility offering advanced cancer treatments.

Critical to the success of building local capacity is for African countries with rich expertise to help train other African countries through a deliberate national-national, public-private or local-foreign collaborations supported by governments, professional bodies and other key stakeholders. With the right collaborations, advanced treatment techniques should be the standard treatment modality for care all radiotherapy facilities in Africa within the next decade. Staff from CICL have offered clinical training to radiation therapy staff from newly established RT facilities in Nigeria and Malawi. These partnerships have also impacted positively on expanding cancer care in these countries by offering technical and human resource support to its governments (Togo and Malawi) in the setting up of a second radiotherapy facility.

ACKNOWLEDGMENTS

Special appreciation to the local and foreign CICL partners for making this VMAT facility possible for the people of Togo and many within the West African sub-region in tackling the increasing burden of cancer.

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EDUCATIONAL TOPICS

THE NEED OF EDUCATIONAL MATERIALS AND TEXTBOOKS FOR THE PROFESSIONAL GROWTH - A RETROSPECTIVE VIEW AND DISCUSSION

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Abstract— **Educational materials and textbooks are the backbone of all University courses, producing young colleagues for the need of global healthcare. The paper presents a retrospective view of the educational materials and textbooks published in the past 30 years and relates these to the double growth of the profession in this period. In the discussion the paper raises the question of the need to give more prominent place to textbook publishing, alongside research paper citation, in the staff assessment practices. This would encourage the publishing of more books and educational materials, what will further boost education in order to produce the high number of medical physicists needed by 2035.**

I. INTRODUCTION

The growth of medical physicists in the world is strongly supported by IOMP and its Regional Organisations (RO) - Federations in all continents. This is directly linked with the number of University courses in medical physics. The analysis of the professional growth in the period 1965 – 2015 [1], shows that while the first decades (1965-1975, 1975-1985, 1985-1995) have an almost equal global growth of medical physicists of the order of 2000 new professionals per decade, the next two decades (1995-2005 and 2005-2015) have double growth per decade (approximately 4000 per decade and 8000 per decade, respectively). The analysis relates this to the accent given to medical physics education and the introduction of free materials for the students and young professionals during these decades. The statistics for the current decade (2015-2025) have not been made yet, but it is expected the growth to be of the order of 7-8000 per decade. The maintenance of this professional growth is directly linked with the availability of materials and textbooks, supporting education. This paper aims to show specific activities associated with the development of educational materials and textbooks.

II. THE NEW EDUCATIONAL E-MATERIALS (E-BOOKS, DATABASES AND WEBSITES)

The use of e-materials and e-learning in the profession was very strong in the period 1995-2015. On one side most specialists in medical physics have very good IT knowledge. On the other side the 1990s were the time when Internet entered human life and steadily established itself as a platform for exchange of information. On this background the pioneer project EMERALD took the aim of developing new electronic educational materials (e-materials), to be used in medical physics training [2].

These materials were supported by specific educational image databases (IDB). The number of images was initially 1400 and grew to 3000. This was the largest collection of educational images in the profession. The 5 IDBs were engraved on separate CD-ROMs. The first CD-ROM was also one of the first in the world CD-ROMs with ISBN number (as paper books). It is not a coincidence that the first in the world 3 CD-ROMs with ISBN number are in the field of medicine, where images are essential for the education [2]:

-Atlas of Pathology: Urological Pathology CD-ROM, **published on 30 Dec 1997**, Springer-Verlag, ISBN 3540146571

-EMERALD Image Database, Training Courses in Medical Radiation Physics CD-ROM, **published on 19 February 1998**, King's College London, ISBN 1870722035

-Developmental Psychology Image Database CD-ROM, **published on 30 April 1998**, McGraw-Hill, ISBN 0072896914

The rapid development of Internet allowed for placing the content of the CD-ROMs on educational websites and also to be freely available to all in the profession. Thus, the first educational website in the profession was created and launched in November 1999. This was developed by the team of project EMERALD, under the name EMERALD – INTERNET ISSUE (EMERLAD II). This web site (now **www.emerald2.eu**) became rapidly very popular - with thousands of users per month from its first months to now [2, 3]. The 3000+ images (plus text and a Manual) found a stable place in the educational activities in the profession and continued to be used for Power Point presentations. Also, a number of these were used as samples for creating new educational images (in different modern scenarios).

Almost in parallel in 2000 was launched another educational website - The Sprawls Resources, based on the excellent textbooks of Prof. Perry Sprawls, USA. This web site (now **www.sprawls.org**) includes full e-books and text with hundreds of diagrams plus other educational images. It also has thousands of users per month [2, 4].

Both websites continue to be used globally, especially by lecturers and students from LMI countries. Several Questionnaires of attendees to the ICTP International College on Medical Physics (ICMP) in Trieste, stated clearly the high importance given to these and other educational web sites for the educational process in LMI countries [5, 6].

Around the end of 2002 another set of CDs with teaching materials appeared – issued by the International Atomic Energy Agency (IAEA). These included ready lecturing materials (Power Point slides as ready lectures). These three CDs were distributed free and were of great help to the medical physics community. These excellent materials also included a Manual and Multiple-Choice Questions [2].

After a couple of years IAEA developed a special website aimed at the education of medical physicists and medical staff using radiation, but also educating the public - **www.iaea.org/resources/rpop**. This educational website rapidly grew with constant updates and upgrades. It includes many educational materials on Radiation Protection and quickly established itself as the most visited web site in the profession.

The set of free educational images, discussed so far, is now complemented by free animated images and other visual aids, developed free by many colleagues – e.g. from the University of Colorado, USA.

The Questionnaires at the ICTP-ICMP showed that over 80% of all attendees use the above educational websites and over 50% use e-learning. Many of those colleagues developed new University courses and websites in their own countries. Each attendee of the ICMP after 2002 received a full set of all teaching materials and slides related to Medical Imaging Physics. These, plus the above websites, deliver important information for the educational process in LMI countries.

Around 2006 was launched another excellent educational set of online materials- **www.aapm.org/education/VL** - the Virtual Library of the American Association of Physicists in Medicine (AAPM). This is a very useful educational tool, including videos of many open lectures presented at the AAPM meetings. Soon after the launch the website was opened for free use by all colleagues from LMI countries [7].

The current statistics (2024) of the Medical Physics educational programmes (mainly at MSc-level) show that currently there are 388 such programmes in the world. This is about 10 times more compared with the decade before 1995. What is very important – now many of these programmes are in LMI countries, where such programmes were almost non-existent before 1995 [8]. This exceptional progress is based on several factors, the most important being:

-The accent on medical physics education, supported by IOMP and all its ROs (through various course, seminars, workshops and educational event, satellite to various Conferences and Congresses);

-The support of IAEA (and the ICTP-ICMP) for opening of educational courses in LMI countries and providing them with educational materials;

-The above-mentioned websites with educational materials.

All these materials appeared priceless during the time of the pandemic, supported also by various materials and books explaining the process of including teaching materials in the educational e-learning programmes and building educational modules [9]. Also, at that time rapid progress was made by the IOMP School educational webinars.

Additionally, to the web-based educational materials, the educational process needs textbooks, as these provide not only specific information and images, but also an educational frame, very important for the gradual build-up of knowledge in the students.

III. THE TEXTBOOKS

Textbooks are essential for education in any profession. One of the most important initial textbooks in medical physics is the classical "The Physics of Radiology" by Harold Johns and John Cunningham. The book, initially published in 1953, continues to be used in its 5th edition (updated by a number of eminent colleagues - Eva Bezak, Alun Beddoe, Loredana Marcu, Martin Ebert, Roger Price).

We cannot list all important textbooks used in the profession, but after the World Congress in 1982, IOMP and IFMBE formed a book *Series in Medical Physics and Biomedical Engineering* with the Publisher CRC Press (Taylor and Francis) [10]. This very important Series continues now 40 years with 105 textbooks (+booksets). The first textbook in the Series (from 1985) is: *Fundamentals of Radiation Dosimetry, Second Edition* by J G Greening, 1985. The third book in the Series was published in 1993: *The Physics of Three-Dimensional Radiation Therapy: Conformal Radiotherapy, Radiosurgery and Treatment Planning*, by S Webb. This book introduced the specific red colour Series banner on its cover. A full list of all books in the Series is presented at an ANNEX here.

After 1997 the Series became more active. The Series Editors at that time were R F Mould (UK), C G Orton (USA), J A E Spaan (The Netherlands) and J G Webster (USA). This intensification of the Series continued in 2010 with new Series Editors: Kwan-Hoong Ng (Malysia), Russell Ritenour (USA), Slavik Tabakov (UK) and John G. Webster (USA). After 2017 the first three Editors remained (John Webster retired from the Series) and most of the textbooks were in the field of Medical Physics. The latter team of Editors is associated with about 75% of all books in the Series.

During 2017 the CRC-IOMP Series formed a sub-series *Focus Series in Medical Physics and Biomedical Engineering* , aimed at small focused hot-topic textbooks with quick publication. Its Editors were selected as Tae Suk Suh (S Korea) and Magdalena Stoeva (Bulgaria). In 2019 IOMP added some changes in the structure of the IOMP-CRC Series Editorial Board, including the Chair of the Publication Committee (currently Francis Hasford, Ghana).

The Editors of the IOMP-CRC *Series in Medical Physics and Biomedical Engineering* are formally linked to the IOMP Publication Committee. Their work is on voluntary basis, related mainly to commissioning and first assessment of new textbook proposals. The following process is with the Publisher CRC Press (Taylor and Francis). The main CRC Editors during the period after 2010 were Franceska McGowan, Rebecca Davies, Kirsten Barr and Danny Kielty. Recently the Series is also associated with Routledge – another Publisher member of the Taylor and Francis Group.

The Taylor and Francis Group is one of the four largest Publishers in the fields of Science, Technology, Engineering and Mathematics (STEM). Part of the Contract with IOMP includes 30% discount of the books to IOMP members and 30 free books, to be donated to LMI countries. The free books from the CRC-IOMP Series entered in many libraries in the LMI countries (an activity also related with the AAPM-IOMP Library Programme). This difference between the CRC-IOMP Series and other potential Publishers is important for the growth of the profession.

Another very important publisher of textbooks for the profession is the IAEA. Its specific Textbooks *A Handbook for Teachers and Students* (in various fields of medical physics) cover the most important educational materials in the profession [11]. The books are again a free contribution of many eminent specialists, developed under the guidance and support of the IAEA. These free textbooks (often distributed as e-books) form the backbone of many educational modules from the MSc programmes worldwide. Their content is complemented by other free IAEA Guides, which further deliver practical aspects to the academic content. These Guides are again developed on voluntary basis by eminent specialists within the frame of specific IAEA projects, associated with medical physics.

A specific book to be mentioned is the Encyclopedia of Medical Physics. A project was developed over 5 years with over 150 contributors from 50 countries. The Encyclopedia is very useful for educational programmes, as it is aimed at Master-level colleagues and students. Its second edition (published in 2022) includes 3300 cross-referenced full entries related to medical physics and associated technologies [12]. The materials are supported by over 1300 figures and diagrams. The Encyclopaedia also includes over 600 synonyms, abbreviations and other linked entries. The materials of the Encyclopaedia are available as free resource at **www.emitel2.eu** . The website links the Encyclopaedia entries with a Scientific Dictionary of Medical Physics Terms, cross translating terms in 32 languages. Both resources use an original specially built website [13].

In 2013 IOMP launched the Journal Medical Physics International (MPI) with the main aim to support educational and professional activities in medical physics. Statistic shows that the papers related to education (incl. Review papers) have around 10,000 downloads each [14].

The MPI Journal was made deliberately as an open access Journal **www.mpijournal.org** , delivering this information free to all medical physicists, and also publishing information about their educational materials and activities.

In order to further distribute information about these very important educational resources IOMP and its ROs provide lists of resources on their websites. As an example, such is the new European EFOMP e-learning platform e-LEMENT (e-Learning for Education in MEdical physics and New Technologies), available at: **https://e-lement.efomp.org/** [15]

IV. DISCUSSION

It is well known that educational materials and textbooks are the backbone of any educational programmes and professional development. With the increased need of medical physics specialists for global healthcare, it is clear that the number of such publications should increase. However, this is not an easy task.

Usually, it takes a lot of experience and at least one or two years to write a textbook on any subject. At the same time writing a standard research paper is often related to one-two months work. Having in mind that a number of universities and other institutions in the world place the accent of their staff assessment on the paper citation indexing, textbook writing naturally is given less priority by a number of specialists. There are some paradoxes – e.g. including the value of a textbook (in staff assessment) as almost equal to a small paper assessing this very textbook.

Similar problem is that textbooks are rarely included in the List of reference materials to a paper. Large Review papers, describing the development and application of a specific method or equipment, normally cite the relevant textbooks in the specific field. However, other papers on the subject cite the Refence paper, and not the related books. Also, some websites with e-materials are often not cited.

The predominant use of citation indexes for staff assessment does not favor the development of specialists from smaller (usually LMI) countries. Now most Journals with high citation indexes require payment for publishing a paper. This is often impossible for colleagues from LMI countries. Thus, their assessment in global terms falls back, despite the fact that they could be promising specialists.

Similarly, specialists in smaller professions (such as medical physics or biomedical engineering) have naturally smaller number of citations, compared with other larger groups of specialists (e.g. radiologists and other medical specialists). Also, specialists working in a niche field will have less citation, compared with specialists working in large fields.

The research papers are extremely important for any profession, but staff assessment would need to be updated to include also the efforts and high value of textbook publishing. We can hardly expect the existing staff assessment practices to be updated overnight, but if this question is often discussed, some progress in the field can be made. Meanwhile large professional organisations, such as IOMP and its Regional Organisations, will need to encourage their members to contribute more actively to the writing of textbook and other educational materials.

V. CONCLUSION

The production of more content for the students will be one of the most important activities supporting the necessary significant growth of the profession by 2035 (aiming to reach approximately 60,000 medical physicists globally) [1, 16]. Publishing of textbooks has its own frame, not only in the IOMP-CRC Series, but with various Publishers, and only needs encouragement of authors. However, the production of e-books, websites and other materials is related to specific educational projects. The experience from the period 1995-2015 showed how the high impact of these e-materials influenced professional growth [1]. The same is needed for the new coming decade 2025-2035 and IOMP could have a leading role in the encouragement of colleagues to initiate such new projects.

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ANNEX: TEXTBOOKS IN THE IOMP-CRC SERIES 1985-2025

-Proton Therapy Physics, 3rd Edition
2025 Forthcoming, Edited By Harald Paganetti
-Essentials of Functional MRI: Basic Concepts to Advanced Applications, 2nd Edition
2024, Patrick W. Stroman
-Biomedical Photonics for Diabetes Research
2024, Edited by Andrey Dunaev, Valery Tuchin
-Image-guided Focused Ultrasound Therapy: Physics and Clinical Applications
2024, Edited By Feng Wu, Gail ter Haar, Ian Rivens
-Clinical Insights for Image-Guided Radiotherapy: Prostate
2024, Mike Kirby, Kerrie-Anne Calder
-Calculating X-ray Tube Spectra: Analytical and Monte Carlo Approaches
2024, Gavin Poludniowski, Artur Omar, Pedro Andreo
-Handbook of Nuclear Medicine and Molecular Imaging for Physicists: Instrumentation and Imaging Procedures, Volume I
2024, Edited By Michael Ljungberg
-Handbook of Nuclear Medicine and Molecular Imaging for Physicists: Modelling, Dosimetry and Radiation Protection, Volume II
2024, Michael Ljungberg
-Handbook of Nuclear Medicine and Molecular Imaging for Physicists: Radiopharmaceuticals and Clinical Applications, Volume III
2024, Michael Ljungberg
-Handbook of Nuclear Medicine and Molecular Imaging for Physicists - Three Volume Set
2024, Edited By Michael Ljungberg
-Introduction to Medical Physics
2024, Edited By Stephen Keevil, Renato Padovani, Slavik Tabakov, Tony Greener, Cornelius Lewis
-Radiotheranostics - A Primer for Medical Physicists I: Physics, Chemistry, Biology and Clinical Applications
2024, Edited By Cari Borrás, Michael G. Stabin
-Practical Biomedical Signal Analysis Using MATLAB® 2nd Edition
2024, Katarzyna J. Blinowska, Jarosław Żygierewicz
-Monte Carlo in Heavy Charged Particle Therapy: New Challenges in Ion Therapy
2024, Edited By Pablo Cirrone, Giada Petringa
-Spectral Multi-Detector Computed Tomography (sMDCT): Data Acquisition, Image Formation, Quality Assessment and Contrast Enhancement
2023, Xiangyang Tang
-Clinical Nuclear Medicine Physics with MATLAB®: A Problem-Solving Approach
2023, Edited By Maria Lyra Georgosopoulou

-Auto-Segmentation for Radiation Oncology: State of the Art
2023, Edited By Jinzhong Yang, Gregory C. Sharp, Mark J. Gooding
-Electrical Impedance Tomography: Methods, History and Applications, 2nd Edition
2023, Edited By Andy Adler, David Holder
-Problems and Solutions in Medical Physics - Three Volume Set
2022, By Kwan-Hoong Ng, Robin Hill, Alan Perkins, Jeannie Hsiu Ding Wong, Geoffrey Clarke, Chai Hong Yeong, Ngie Min Ung
-Problems and Solutions in Medical Physics: Radiotherapy Physics
2022, Kwan-Hoong Ng, Robin Hill, Ngie Min Ung
-Diagnostic Radiology Physics with MATLAB®: A Problem-Solving Approach
2022, Edited By Johan Helmenkamp, Robert Bujila, Gavin Poludniowski
-A Practical Approach to Medical Image Processing
2020, Elizabeth Berry
-Contemporary IMRT: Developing Physics and Clinical Implementation
2020, S. Webb
-Proton Therapy Physics, Second Edition
2020, Edited By Harald Paganetti
-e-Learning in Medical Physics and Engineering: Building Educational Modules with Moodle
2020, Vassilka Tabakova
-Minimally Invasive Medical Technology
2020, Edited By John G. Webster
-The Physical Measurement of Bone
2020, Edited By C.M. Langton, C.F. Njeh
-Achieving Quality in Brachytherapy
2019, B.R. Thomadsen
-Diagnostic Endoscopy
2019, Edited By Haishan Zeng
-Quantifying Morphology and Physiology of the Human Body Using MRI
2019, Edited By L. Tugan Muftuler
-Handbook of Photonics for Biomedical Science
2019, Edited By Valery V. Tuchin
-Correction Techniques in Emission Tomography
2019, Edited By Mohammad Dawood, Xiaoyi Jiang, Klaus Schäfers
-Intelligent and Adaptive Systems in Medicine
2019, Edited By Olivier C. L. Haas, Keith J. Burnham
-Radiosensitizers and Radiochemotherapy in the Treatment of Cancer
2019, Shirley Lehnert
-Ultrasound in Medicine 1st Edition
2019, Edited By Francis A. Duck, A.C Baker, H.C Starritt
-Modelling Radiotherapy Side Effects: Practical Applications for Planning Optimisation
2019, Tiziana Rancati, Claudio Fiorino
- On-Treatment Verification Imaging: A Study Guide for IGRT
2019, Mike Kirby, Kerrie-Anne Calder
- Advanced Radiation Protection Dosimetry
2019, Editors: Shaheen Dewji, Nolan E. Hertel
- The Physics of CT Dosimetry: CTDI and Beyond
2019, Robert L. Dixon
- Problems and Solutions in Medical Physics: Nuclear Medicine Physics
2019, Kwan Hoong Ng, Chai Hong Yeong, Alan Christopher Perkins
- Introduction to Megavoltage X-Ray Dose Computation Algorithms
2019, Editor: Jerry Battista
-Ethics for Radiation Protection in Medicine
2018, Jim Malone, Friedo Zölzer, Gaston Meskens, Christina Skourou
- Proton Therapy Physics, Second Edition
2018, Editor: Harald Paganetti
- Mixed and Augmented Reality in Medicine
2018, Editors: Terry M. Peters, Cristian A. Linte, Ziv Yaniv, Jacqueline Williams
- Clinical Radiotherapy Physics with MATLAB: A Problem-Solving Approach
2018, Pavel Dvorak
- Advanced and Emerging Technologies in Radiation Oncology Physics
2018, Editors: Siyong Kim, John W. Wong
-Advances in Particle Therapy: A Multidisciplinary Approach
2018, Editors: Manjit Dosanjh, Jacques Bernier
- Radiotherapy and Clinical Radiobiology of Head and Neck Cancer
2018, Loredana G. Marcu, Iuliana Toma-Dasu, Alexandru Dasu, Claes Mercke
- Problems and Solutions in Medical Physics: Diagnostic Imaging Physics
2018, Kwan Hoong Ng, Jeannie Hsiu Ding Wong, Geoffrey D. Clarke
- A Guide to Outcome Modeling In Radiotherapy and Oncology: Listening to the Data
2018, Editor: Issam El Naqa
-Quantitative MRI of the Brain: Principles of Physical Measurement, Second edition
2018, Editor: Mara Cercignani, Nicholas G. Dowell, Paul S. Tofts
-Handbook of X-ray Imaging: Physics and Technology
2018, Editor: Paolo Russo
-Advanced MR Neuroimaging: From Theory to Clinical Practice
2017, Ioannis Tsougos
-A Brief Survey of Quantitative EEG
2017, Kaushik Majumdar
-Emerging Technologies in Brachytherapy
2017, Editors: William Y. Song, Kari Tanderup, Bradley Pieters
-Environmental Radioactivity and Emergency Preparedness
2016, Mats Isaksson, Christopher L. Raaf
-Gamma Cameras for Interventional and Intraoperative Imaging
2016, Editors: Alan C. Perkins, John E. Lees
-Fundamental Mathematics and Physics of Medical Imaging
2016, Jack Lancaster, Bruce Hasegawa
-The Practice of Internal Dosimetry in Nuclear Medicine
2016, Michael G. Stabin
-Radiation Protection in Medical Imaging and Radiation Oncology
2015, Editors: Richard J. Vetter, Magdalena S. Stoeva
-Graphics Processing Unit-Based High Performance Computing in Radiation Therapy
2015, Editors: Xun Jia, Steve B. Jiang
-Statistical Computing in Nuclear Imaging
-2014, Arkadiusz Sitek
-Radiosensitizers and Radiochemotherapy in the Treatment of Cancer
2014, Shirley Lehnert
-The Physiological Measurement Handbook
2014, Editor: John G. Webster
-Diagnostic Endoscopy
2013, Editor: Haishan Zeng
-Medical Equipment Management
2013, Keith Willson, Keith Ison, Slavik Tabakov

-Targeted Muscle Reinnervation: A Neural Interface for Artificial Limbs
2013, Editors: Todd A. Kuiken, Aimee E. Schultz Feuser, Ann K. Barlow
-Quantifying Morphology and Physiology of the Human Body Using MRI
2013, Editor: L. Tugan Muftuler
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2008, Editor: Valery V. Tuchin
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ACCREDITATION OF MEDICAL EDUCATION PROGRAMS, RESIDENCY PROGRAMS AND CPD ACCREDITATION OF EDUCATIONAL ACTIVITIES - IOMP INITIATIVES

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Abstract — **Harmonization, standardization, and accreditation are essential processes for ensuring the quality and consistency of medical physics education. This article explores the importance of harmonization, standardization, and accreditation in medical physics education, detailing their benefits, challenges, IOMP initiatives and implementation strategies. The IOMP is instrumental in developing and updating educational standards and guidelines which ensure that educational programs provide comprehensive and up-to-date training. The article highlights ongoing Medical Physics education programmes; importance of harmonization, standardization and accreditation in medical physics education; challenges in implementing harmonization, standardization and accreditation; status of medical physics profession; IOMP initiatives for improving medical physics education; and activities of the IOMP accreditation board.**

Keywords— **harmonization, standardization, accreditation.**

I. INTRODUCTION

Medical physics is a dynamic field that bridges the gap between physics and medicine, playing a critical role in the diagnosis and treatment of diseases through advanced imaging and radiation therapy. The continuous advancement in medical technologies and practices necessitates that medical physics education remains current and of high quality.

As the field evolves, the need for harmonization, standardization, and accreditation of medical physics education becomes increasingly vital. These processes ensure that medical physics programs provide consistent, high-quality education that meets global standards and prepares graduates to meet the demands of the profession. Harmonized educational standards enable medical physics professionals to work and be recognized internationally and crucial in a world where healthcare professionals often cross borders to provide expertise and services.

Harmonization ensures that all educational programs meet a minimum standard of quality. This consistency is critical for maintaining the integrity and reputation of the medical physics profession. When educational standards are harmonized, it is easier for institutions to collaborate on research, training programs, and professional development initiatives. This article explores the importance of harmonization, standardization, and accreditation in medical physics education, detailing their benefits, challenges, IOMP initiatives and implementation strategies.

II. ROLE OF PROFESSIONAL ORGANISATIONS IN SHAPING THE PROFESSIONAL CURRICULUM

Professional organizations such as International Organization for Medical Physics (IOMP), the American Association of Physicists in Medicine (AAPM), regional organisations of IOMP and many others play a central role in setting educational standards. In addition to professional organisations, organisations such as International Atomic Energy Agency [IAEA], Abdul Salam International Center for Theoretical Physics [ICTP], World Health Organisation [WHO], Commission on Accreditation of Medical Physics Education [CAMPEP], American Board of radiology [ABR] provide guidelines, accreditation, certification, and continuing education opportunities that shape the curriculum and ensure that programs meet high standards.

Professional organizations are instrumental in developing and updating educational standards and guidelines. These standards ensure that educational programs provide comprehensive and up-to-date training. For example, IOMP Policy Statement No. 2 ‘Basic requirements for education and training of medical physicists’ and the IAEA Publication- Training Course Series No. 56 [Rev. 1] which is endorsed by the IOMP) incorporates the IOMP Model Curriculum provides necessary information for starting Medical Physics educational programmes.

According to the IAEA Human Health Series (HHS 25), the structure of medical physics education and training should be:

- *A university degree in physics, engineering, or equivalent physical science.*
- *Appropriate academic qualifications in medical physics (or equivalent) at the postgraduate level.*
- *At <u>least two years</u> (full time equivalent) structured clinical in-service training undertaken in a hospital*

The holder of a university degree in medical physics without the required hospital training cannot be considered Clinically Qualified Medical Physicist (CQMP). Further this education and training should be recognized by a national accreditation body.

However, for Latin America and Africa region, to facilitate and cope up with the grave shortage of CQMP in the region one-year full time structured clinical residency is enough to be considered CQMP.

For the Africa region, the document - African Regional Cooperative Agreement for Research, Development and

Training Related to Nuclear Science and Technology (AFRA) academic and clinical training programmes and portfolios for the regional training in medical physics - Minimum Requirements for Medical Physics Education in AFRA Member States are used, whiles for the Latin America region the document - Guías de Formación Académica y Entrenamiento Clínico para Físicos Médicos en América Latina - ALFIM- IAEA [Academic Education and Clinical Training Guides for Medical Physicists in Latin America is available and followed.

III. ONGOING MEDICAL PHYSICS EDUCATION PROGRAMMES

To cope with the growing demand of medical physicists, many Institutes/Universities have started medical education programs across the globe. The Education and Training Committee [ETC] of IOMP has compiled the data on medical physics education programs around the world and at present more than 390 Medical Physics undergraduate / postgraduate and research programmes are available with the distribution in various regions as follows:

- *ALFIM [Latin America] - 46 programmes i.e. 0.076 programs/million population*
- MEFOMP [Middle east] - 21 *programmes i.e.* 0.08 programs/million population
- AFOMP [Asia Oceania] - 119 *programmes i.e.* 0.03 programs/million population
- USA - 42 *programmes i.e.* 0.127 programs/million population
- EFOMP [Europe] -105 *programmes i.e.* 0.141 programs/million population
- FAMPO [Africa] – 37 *programmes i.e.* 0.026 programs/million population
- CANADA – 18 *programmes i.e.* 0.49 programs/million population

The details are available at https://www.iomp.org/education-training-resources/

Further we find a huge diversity and therefore the task of harmonization of Medical Physics education and profession is quite challenging because of heterogeneity in terms of socioeconomic and educational standards. Further there is a big gap in availability of CQMP in various regions and, therefore a great potential to ramp up the structured education and training of medical physicists to cope with the growing need of not only today but also of future.

IV. THE IMPORTANCE OF HARMONIZATION IN MEDICAL PHYSICS EDUCATION

Harmonization refers to the process of aligning educational standards and practices across different institutions, regions and globally. In the context of medical physics education, harmonization is essential for ensuring that all students receive a comparable level of education, regardless of where they study.

a) Global Mobility and Recognition

Harmonized educational standards enable medical physics professionals to work and be recognized internationally. This global mobility is crucial in a world where healthcare professionals often cross borders to provide expertise and services.

b) Quality Assurance

Harmonization ensures that all educational programs meet a minimum standard of quality. This consistency is critical for maintaining the integrity and reputation of the medical physics profession.

c) Facilitating Collaboration

When educational standards are harmonized, it is easier for institutions, professional organisations and regulatory authorities to collaborate on research, training programs, and professional development initiatives. This collaboration can lead to significant advancements in the field and the sharing of best practices for benefit of society.

V. THE IMPORTANCE OF STANDARDIZATION IN MEDICAL PHYSICS EDUCATION

Standardization involves establishing and enforcing consistent educational criteria and practices across medical physics programs. This process is fundamental to ensuring that all students receive the same foundational knowledge and skills irrespective of the nation, state or region.

a) Curriculum Development

Standardization helps in developing a core curriculum that all medical physics programs must follow. This ensures that essential topics and competencies are covered uniformly across programs.

b) Benchmarking and Assessment

Standardized criteria allow for the benchmarking of educational programs and the assessment of their effectiveness. This process helps in identifying areas for improvement and ensuring that programs continuously meet high standards.

c) Certainty for Employers

Employers can be confident that graduates from standardized programs possess the necessary skills and knowledge to perform effectively. This certainty is crucial for maintaining high standards of patient care and safety.

VI. THE IMPORTANCE OF ACCREDITATION IN MEDICAL PHYSICS EDUCATION

Accreditation of medical physics education programs plays a pivotal role in maintaining and enhancing the quality and relevance of these programs. Accreditation is a process by which educational programs undergo rigorous evaluation to ensure that they meet predetermined standards of quality and effectiveness. These standards cover various aspects, including curriculum design, faculty qualifications, clinical training, and resources, ensuring a comprehensive and well-rounded educational experience. There are many stakeholders and beneficiaries of accreditation. Accreditation serves as an assurance of quality for students, educators, and the broader healthcare community. Prospective students can confidently choose accredited programs, knowing that they meet health industry-recognized standards. Employers, in turn, can trust that graduates from accredited programs are well-prepared and possess the necessary competencies for their roles as medical physicists. The presence of **accreditation adds validity to the profession's claims to quality, increasing consumer confidence at all levels.** Therefore, accreditation of medical physics education programs is essential for ensuring high-quality, standardized, and globally recognized training for future professionals. Despite challenges, the advantages far outweigh the drawbacks, making accreditation a cornerstone for advancing the field of medical physics.

VII. ADVANTAGES OF ACCREDITATION OF EDUCATIONAL PROGRAMMES

a) Ensuring Educational Quality

Accreditation ensures that educational programs adhere to rigorous standards of quality. Accredited programs undergo regular evaluations to maintain their status, ensuring continuous improvement and adherence to best practices.

b) Student Confidence

Students enrolled in accredited programs can be confident that they are receiving a high-quality education that will be recognized by employers and professional bodies. This confidence is crucial for attracting and retaining talented students.

c) Professional Certification

Accreditation is often a prerequisite for professional certification. Graduates from accredited programs are typically eligible to sit for certification exams, which are essential for professional practice in many regions.

VIII. CHALLENGES IN IMPLEMENTING HARMONIZATION, STANDARDIZATION AND ACCREDITATION

There is a huge disparity in economic, social, educational standards across the globe. Some countries and regions are highly developed and has high standards of education as well healthcare system and therefore it is quite difficult and challenging to achieve perfect harmonization, however efforts are put to have a minimum standard and uniformity. In this direction IOMP and IAEA are working in collaboration and have brought out many guidelines for harmonization, standardizing and accreditation of medical physics education.

a) Diverse Educational Systems

Different regions and countries have diverse educational systems, making it challenging to implement uniform standards. Overcoming these differences requires significant coordination and cooperation among various stakeholders.

b) Resource Limitations

Implementing and maintaining harmonization, standardization, and accreditation processes can be resource intensive. Institutions may face challenges in allocating the necessary resources for these activities.

c) Resistance to Change

Institutions and individuals may resist changes to established practices and curricula. Overcoming this resistance requires effective communication and demonstrating the benefits of these processes.

IX. STRATEGIES FOR EFFECTIVE IMPLEMENTATION

a) Stakeholder Collaboration

Collaboration among professional organizations, academic institutions, healthcare facilities, and regulatory bodies is essential for effective implementation. Stakeholders must work together to develop and enforce standards that meet the needs of the profession.

b) Regular Review and Updates

Educational standards and accreditation criteria should be regularly reviewed and updated to reflect advancements in the field and emerging best practices. This ensures that programs remain relevant and effective.

c) Capacity Building

Efforts should be made to build the capacity of institutions to implement and maintain harmonization, standardization, and accreditation processes. This includes providing training, resources, and support to educators and administrators.

d) Global Initiatives

Global initiatives, such as those led by the International Organization for Medical Physics (IOMP) and the International Atomic Energy Agency (IAEA), can play a crucial role in promoting harmonization and standardization. These initiatives can provide guidelines, resources, and support to institutions worldwide. The IAEA has been instrumental in supporting medical physics education in developing countries through its Human Health Division. By providing educational resources, training programs, and fellowships, the IAEA helps to raise the standards of medical physics education globally.

X. STATUS OF THE MEDICAL PHYSICS PROFESSION GLOBALLY

The status of medical physicists varies significantly across regions, influenced by local healthcare systems and regulatory frameworks.

A) High-Income Countries (HICs):

- **Recognition**: Medical physicists are well-established as integral members of healthcare teams in regions like North America, Europe, and Australia.
- **Regulation**: Many countries require certification by professional bodies, such as the American Board of Radiology (ABR) or EFOMP.
- **Challenges**: Despite high recognition, there is a growing demand for medical physicists due to advancements in technologies like proton therapy and AI-based systems.

B) Low- and Middle-Income Countries (LMICs):

- **Recognition**: In many LMICs, medical physics is still an emerging profession, with limited understanding of its role in healthcare.
- **Regulation**: Few countries have established certification or licensure requirements.
- **Challenges**: Lack of accredited education and training programs; Inadequate resources for clinical practice; Brain drain, with trained professionals migrating to high-income countries.

XI. IOMP INITIATIVES FOR IMPROVING MEDICAL PHYSICS EDUCATION

Establishing Global Education Standards

One of the IOMP's primary missions is to harmonize medical physics education globally, ensuring consistent training standards.

- **Educational Modules**: The IOMP has developed a series of educational materials, including textbooks, online resources, and structured training programs, to support medical physics education worldwide.
- **Core Curriculum**: The IOMP has published guidelines on the essential components of medical physics education, encompassing topics like radiation safety, imaging physics, and treatment planning.
- **IOMP School**: A virtual platform offering webinars, online courses, and certification programs.
- **Collaborations**: Partnerships with organizations like IAEA, WHO to develop documents, training materials.

XII. IOMP ACCREDITATION BOARD

IOMP Accreditation Board [AB] has been set up in 2016 to ensure that accredited medical physics programs satisfy the highest standards established by IOMP. The IOMP accreditation board accredits medical physics degree/Post graduate programs, residency programmes, medical physics education and training institutions/centers and education and training events.

Until November 2024, IOMP AB has accredited 7 masters' in medical physics education programmes, 05 Medical Physics residency programmes and 23 CPD accreditation of educational/training programmes. As a case study, accreditation of Master's in Medical Physics [MSc-MP] program from National University of Colombia, Bogota, Colombia accomplished in September 2024 and IOMP accreditation awarded for 5 years from 1 November 2024 is discussed herewith.

IOMP Accreditation was received from course coordinator on 05 May 2024. The Chair of IOMP Accreditation Board assessed the documents submitted, provided preliminary feedback, and requested additional information. As per the accreditation manual, Chair of AB constituted the assessment team [AT]. The AT sought relevant information, detailed clarifications and documents from course coordinator. Finally, an accreditation visit to the program was arranged during 18-20 September 2024 to verify the facilities, the submitted documents, interaction with students, alumni, faculty, supervisors and feedback documents.

The IOMP On-Site AT was satisfied with the structure, quality and performance of the program. The program meets all the criteria recommended by the IOMP for a high-quality postgraduate medical physics education program. Upon endorsement of report, AB recommended for IOMP accreditation of the Master of Medical Physics (MSc-Medical Physics) program offered by the National University of Colombia, Bogota for 5 years which was approved by IOMP ExCom. Chairman of the AB issued the accreditation certificate for the program.

XIII. DETAILS ABOUT THE PROGRAM

The Master of Medical Physics (MSc- Medical Physics) program offered by the National University of Colombia, Bogota was founded in 2006. It is the first postgraduate medical physics education program in Colombia to cater to need of medical physicists for the country.

Another private university has started the Postgraduate medical physics program recently, second program in Colombia. The program closely follows the academic syllabus and curriculum recommended by IAEA [TCS 56 (Rev)].

The program admits 12 students annually and nowadays has 22 active MP master's students. The selection process consists of a knowledge test (40%), a curriculum vitae (30%), and an individual interview (30%). The program has graduated a total of 119 MP students since 2006, where 94% are working as medical physicists in healthcare institutions, 3.4% in companies and government, and the rest in companies created by former graduates. The master's activities are divided into coursework and clinical practice. Coursework is primarily conducted in the University Bogotá campus.

Clinical practices are carried out in 9 hospital institutions located in Bogotá (Instituto Nacional de Cancerología, Fundación Santa Fé, Radioterapia Oncologia Marly, Fundación Clinica Shaio, Hospital Universitário Nacional de Colombia), Cali (Fundación Valle del Lili and Hospital Universitário del Valle Evaristo García), Medellín (Hospital Pablo Toben Uribe), and Neiva (Hospital Hernando Moncaelano Perdomo).

The maximum Grade Point Average (GPA) is 5.0, and the passing GPA is 3.0 or above.

Further it is important to note that the Master Medical Physics program at National University of Colombia has received high-quality accreditation from the Ministry of National Education on August 30th, 2024 (Resolution n^{o} 013943).

Some of important benefits of IOMP accreditation are:

- Reputation of accredited programs and courses which will result in more demand for these education and training activities
- Provision of an international dimension to an education event that will attract participants from other countries
- Evidence of highest teaching standards and best preparation of medical physicists for the work environment
- Publication of accredited programs and courses on the IOMP website

Further details about IOMP accreditation program, manual, application forms, list of accredited programmes and related information are available at https://www.iomp.org/accreditation/

XIV. PHOTOS OF ACCREDITATION BOARD ACTIVITIES

Fig. 1: Meeting with Vice President of Aacdemic Affairs [Vice Chancellor], Deans of faculties, Coordinator and course director

Fig. 2: Visit to Medical Physics Demonstartion labs

Fig. 3: Visit to National Cancer institute, Bogota

XV. CONCLUSION

Harmonization, standardization, and accreditation are essential processes for ensuring the quality and consistency of medical physics education. These processes provide numerous benefits, including improved educational outcomes, enhanced professional practice, and global consistency. While there are challenges to implementation, effective strategies and collaboration among stakeholders can overcome these obstacles. As the field of medical physics continues to evolve, the importance of these processes will only increase, ensuring that educational programs remain relevant and capable of preparing professionals to meet the demands of modern healthcare. Accreditation is not a one-time achievement but an ongoing commitment to continuous improvement. Accredited programs are expected to engage in self-assessment, regular evaluations, and updates to stay contemporary with evolving educational practices, emerging technologies, and advancements in the field. This commitment ensures that graduates are equipped with the latest knowledge and skills relevant to contemporary healthcare needs.

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THE PROFESSIONAL MASTER'S DEGREE PROGRAM ON MEDICAL PHYSICS IN BRAZIL - A NOVEL EXPERIENCE

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Abstract— **It is indeed highly commendable the efforts made by national and international organization such as, IOMP, IAEA and WHO to provide recommendations regarding the curriculum of the Medical Physics educational program. However, the particularities and the needs of each country and the financial opportunities that arise make it very difficult to follow precisely those guidelines. This program was created to attend a critical demand generated by a massive Linac acquisition program made by the Ministry of Health to fill part of the existing lack of radiation oncology centres in Brazil. The content and number of hours of the course have followed very closely the international recommendations and specifically the requirements established by the Brazilian Society of Medical Physics to prepare the emerging students to be eligible for Board Certification, a process that exists since 1979. As result, the Universidade do Estado do Rio de Janeiro (UERJ) and the Cancer Foundation (CF) decided to create a professional Master's degree in Medical Physics, a novel experience, to adequately train physicists to be prepared to work as a professional in radiation oncology centres. The result was excellent, all 22 students were able to complete successfully all the requirements and now they all are working in the field.**

Keywords— **Brazil, Master's degree, Medical Physics.**

I. INTRODUCTION

The present population in Brazil is about 220 million people, distributed unevenly in a continental area. The number of new cancer cases in the present year estimated by the National Cancer Institute (NCI) is of about 600,000 disregarding the non-melanoma skin cases. As a result, 60% will need radiation therapy at some point of their treatment.

There are 265 cancer centres with 320 machines, mostly linear accelerators, and a few Cobalt units, though a significant portion of machines are lacking the most recent technology to allow intensity modulated radiotherapy (IMRT) and hypofractionation treatment schemes.

This small number of machines results in about 40,000 people without access to this treatment option as reported in the study of the stereotactic body radiotherapy (SBRT).

In 2012, The Ministry of Health decided to launch the National Expansion Plan in Radiotherapy which included the acquisition of 100 linear accelerators to be installed in different regions of the country in new centres or replacing old machines or enhancing the capabilities of some regional centres.

Now, more than half have been being installed and are functioning and installation is in progress for the other half but with some delay due to the need for having extensive building construction, especially in the new sites.

As expected, a demand for instance of qualified medical physicists for this program was higher than what the established training centres were able to provide.

The Cancer Foundation, in association with the State University of Rio de Janeiro, and funded by the Ministry of Health decided to offer an extensive training program of 1,200 hours for training new radiation technologists, several up-dated short courses for the medical physicists, radiation oncologists, nurses working in radiation therapy and to create a Professional Master's Degree Program in Medical Physics.

The main objective of this paper in to describe and share the experience with the design, implementation and the results of the Professional Master's Degree Program in Medical Physics, designed in a moment where there was an expectation of a shortage of 100 medical physicists in the country – number that will not be fulfilled by the existing program.

Since 1979 in Brazil, for medical physicists to become responsible for activities in radiation oncology centres, they must be Board certified by the Brazilian Association of Medical Physics or have an equivalent certification recognized by the Licensing Authority. In both cases, several hours of clinical training under the supervision of a Board-Certified Medical Physicist is required to be eligible for the Board Examination or to be recognized as such.

At present, there are several BSc. in Medical Physics programs which function as an introduction into Medical Physics. There are several academic oriented Master and D.Sc. programs in Medical Physics which are more research oriented with insufficient clinical experience, and several residency programs, mostly clinically oriented with unsatisfactory academic content.

II. PROJECT DESIGN

This project was designed as a final goal to train medical physics students or to allow working medical physicists to upgrade their expertise specifically in radiation oncology.

The main motivation to create the Professional Master's Degree in Medical Physics was to offer a training program that would harmonize both aspects, the academic and the clinical training. The program was designed and conducted in seven complementary modules, totalling 91 weeks with 60 hrs/weeks.

The first module began with 611 hours of intensive solid academic content, including practical classes providing sufficient information to allow the students to follow the coming activities on the designated cancer centres where the clinical training took place (Figure 1). A treatment planning system (TPS) CAT-3D with a non-clinical license was installed on each computer and a set of typical clinical cases were used for their initial training.

Figure 1a: Exercise on how to make moulds and masks

Figure 1b: The TPS being used under proper supervision

The following modules started with a minicourse of 40 hours and then 8 weeks of clinical training. During each phase of the clinical training, they were free to follow the routine defined by the preceptor and in addition the central coordination requested to concentrate and fully register the treatment planning and QA locally used for some of the most prevalent types of tumours such as prostate, breast, lung, colon rectum, lymphoma, head and neck cases.

After each clinical training module, all students came back to the Cancer Foundation headquarters and the first week was dedicated to the individual presentation of at least one case planned and treated in each place where there was exchange of different experiences and approaches by each student.

During the following week, all students participated in a hands-on 40-hour theory and experimental exercise in one of the minicourses below:

- The IAEA TRS 398 Dosimetry Code of Practice
- Machine commissioning
- Data acquisition, modelling and TPS validation
- Quality assurance of IMRT and VMAT
- Dosimetry of small fields

The number of hours of the six modules amounts to 611 hours of theory and 4,739 hours of clinical work, 5 specific mini courses of 40 hours each.

The short courses were also open to 20 medical physicists already working in public radiation oncology centres. After each module, a written examination was applied covering topics previously planned for each module.

The final stage (two weeks) of the program was dedicated for each student to present before a committee their mini projects developed under the supervision of local preceptors.

The number of hours (5,350 hours) is considered sufficient for the students to be eligible for the Board examination by Brazilian Association of Medical Physics (ABFM) and/or professionally be accredited and recognized by the Licensing authority, the Brazilian Nuclear Energy Commission (CNEN). Figure 2 is an overview of the course structure.

To undertake such a project, the Cancer Foundation (CF) in collaboration with the State University of Rio de Janeiro involving several regional radiation oncology centres submitted a Grant Request to the Ministry of Health, which was approved within the framework of the PRONON, which allows the CF to gather financial support from several companies.

Staff involved:

Eight Ph.D., four MSc., one PMO, one M.Sc. in education, twenty-five invited lecturers, five staff clerical workers, two TI and twenty-two preceptors all Board certified in Medical Physics.

Financial Aspects:

During the course duration of 24 months a fellowship was provided, the transportation costs and as well as a token grant to each institution to cover the costs incurred by the students. The training grant also covered the administrative costs and a token fee for each invited speaker.

The Students Selection Procedures:

- Priority was given to the new sites designated by the Ministry of Health project
- Letter of recommendations from Radio Oncologist and Medical Physicist
- Analysis of the curriculum vitae
- Online interview by Skype carried out before 3 staff members
- Medical record
- English proficiency (reading & understanding)
- Institutional indication of their desire to hire the student upon return.

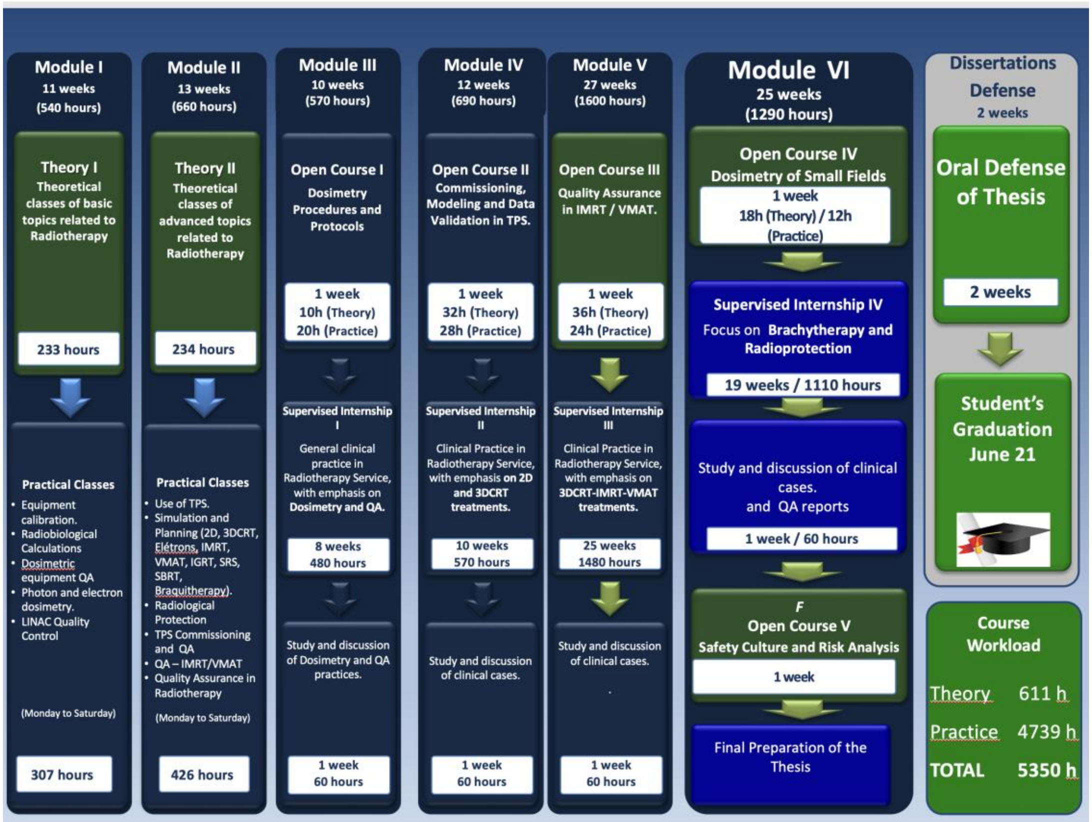

Figure 2. An overview of the course structure

In the selection process, 27 students were initially selected out of 32 applicants to finally result in 22 students from 12 different states (Figure 3).

Figure 3. Students initially selected into the program

III. METHODOLOGY

To manage so many areas involved in the project, a software named Tandle (Teach and Learn) was developed to manage all areas of the project.

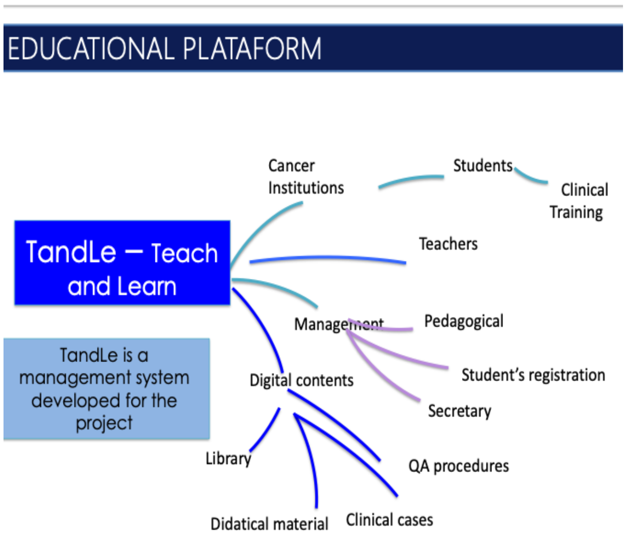

Figure 4. A broad view of the education platform developed to manage the project

Each student received a laptop with an individual password to access the Tandle since all activities described below were registered online.

The Tandle was then used to:

- register the student's grades.
- record all lectures with open access after they were delivered during the duration of the project.
- access the bibliography.
- register the results of the experimental lab reports as well as the ones developed during the clinical training.
- maintain contact with the preceptors and follow the ongoing performance of the student.
- register the selected clinical cases developed in each clinical training.
- register all administrative procedures.

All the didactic materials were made available to the students.

The Clinical Training Sites and the Research Project

Several clinical sites were approached and invited to be part of the project and at the end 22 were selected. The criteria to select the clinical training sites were based on the availability of modern treatment equipment, including at least one 6 MV Linac with three-dimensional (3D) and IMRT treatments, active brachytherapy with high dose rate (HDR) ^{192}Ir, radiosurgery procedures and the availability of computed tomography (CT) and magnetic resonance imaging (MRI), though in some cases positron emission tomography (PET-CT) was also available. It was required to provide a set of dosimetry systems sufficient to allow high-quality quality assurance (QA) and quality control (QC) procedures according to published recommendations.

The experience of the preceptors and the willingness of each centre to welcome the students and as well to supervise the research project was a strong point for the final consideration used in the process.

Figure 5. The participating institutions were selected from different states in Brazil except one which was in Cordoba-Argentina

IV. DISCUSSION:

The classes and the practical disciplines of modules I and II have proved to be sufficient to qualify the student to move forward to the supervised clinical training.

The clinical training was successfully conducted under the supervision of a Board qualified physicist, following the requirements of the Brazilian Medical Physics Society.

The number of hours in each module was carefully planned and executed in harmony with the pre-requisites to apply for the Board Certification by the Brazilian Society of Medical Physics and the Licensing Authority (CNEN).

In each module, a main theme of increasing complexity was proposed as a guide to the preceptor to cover all aspects and to make the monthly reports of the students' progress very objective.

This methodology has proven to be efficient in following the students' performance and their ability to face the subsequent module.

The research project developed by each student during the clinical training and presented before a Board was also a requirement to obtain the degree.

V. CONCLUSIONS:

As a result, 22 students have successfully completed the program, 20 are working as medical physicists in radiotherapy centres and two are working as product specialist for Varian and PTW.

It was clearly demonstrated and proven that when a well-designed project and the resources are available with the promptly accepted participation of several colleagues and renowned institutions the result is worth the efforts.

The MSc. program is carried on, now covering also the diagnostic radiology area.

VI. ACKNOWLEDGMENTS

It is necessary to register our recognition to the amazing efforts made by the whole staff directly involved in the project, the institutions that have agreed to provide the clinical training, the professional societies involved (SBRT and CONTER), the fantastic work done by the preceptors, the speakers, the grant donors, the manufactures, the support of the National Cancer Institute (INCa) and CNEN.

Last, but not least, special thanks to the Directors of the Cancer Foundation, Dr. Marcos Moraes and Dr. Luis Maltoni, and the whole staff of the Foundation for their dedication and continuous support to the project and for their efforts to search for donors under the PRONON's rules.

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EDUCATION AND TRAINING IN MEDICAL PHYSICS IN ARGENTINA: THE ROLE OF ARGENTINE SOCIETY ON MEDICAL PHYSICS (SAFIM)

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Abstract—**The Argentine Society of Medical Physics (SAFIM) was founded in 1988 and has since then been involved in the organization of courses, congresses, seminars and workshop and facilitated the participation of its members in scientific meetings. This article presents the role of the Society in the education and training of medical physicists in Argentina. It also highlights the Society's role in the celebration of the International Day of Medical Physics (ICMP)**

Keywords— **Medical Physics, Education and Training, Argentina, SAFIM.**

I. INTRODUCTION

The Argentine Society of Medical Physics (SAFIM) was founded in 1988 on the occasion of the International Workshop on Medical Physics and the IV International Course in Medical Physics. This course, organized by the International Center for Theoretical Physics – Trieste - Italy (ICTP) and Comisión Nacional de Energía Atómica - Argentina (CNEA), included the participation of prestigious professors like Pedro Andreo, Pierre Dutreix and Andree Dutreix, among others. Since then, SAFIM was involved in the organization of courses, congresses, seminars and workshop and facilitated, as far as possible, the participation of its members in Scientific Meetings. Just to mention a few relevant events, the organization of the 12th Argentine Congress on Medical Physics, Buenos Aires, 2014; 13th Argentine Congress on Medical Physics, Carlos Paz, Córdoba, 2016; and the 14th Argentine Congress on Medical Physics, Bariloche, 2024 (Figure 1).

In 2023 (Organized by SAFIM Education and Training Commission) two dosimetric intercomparison workshops for well chambers were held in Rosario and Córdoba, with the participation of physicists from the Regional Reference Center with Secondary Standards for Dosimetry (CRRD) and from different institutions, both public and private. These events gave the physicists of the participating institutions the possibility of calibrating well chambers with the option of obtaining the respective certificate issued by the CRRD, satisfying a specific need of the partners.

Webinars on specific topics were held in 2023, such as "Quality Control in Mammography" and "Application of the New IAEA Code of Practice for Calibration of Well Chambers" and a Workshop on "Internal Dosimetry in Metabolic Therapies".

As a registered, publisher SAFIM issued a Clinical Training Program for Physicists Specializing in Nuclear Medicine (Figure 2) [1]. The publication of similar programs in Radiotherapy and Radiology is a project for the upcoming year.

In October 2024, the 14th Argentine Congress of Medical Physics, organized by SAFIM, was held in the city of San Carlos de Bariloche. The congress (Figure 3) brought together 212 attendees from different parts of the world, who participated in two days of talks led by international, national and student lecturers. The presentation of more than 150 scientific papers and a full day dedicated to practical courses designed to strengthen clinical and technical skills:

- Course "DCAT Technique for Lung and Liver SBRT: Optimization and Quality Control with Elekta One Planning and ThinkQA" Sponsor: ELEKTA
- Theoretical-Practical Workshop "Mastering Brainlab Tools: Elements and ExacTrac DynamiC" Sponsor: Brainlab
- Practical Workshop "Quality Control in Mammography – Simple and automated. IAEA ATIA Program"
- Clinical Experience for PSQA of SRS/SBRT using CMOS Technology Detector
- Automation & Scripting Course Sponsor: Varian
- End-to-End Testing for Commissioning and Quality Control in SRS/SRT Sponsor: PTW

The abstracts of the papers and the complete version of a special selection of papers are planned to be published subsequently.

II. ACTIVITIES ON INTERNATIONAL DAY OF MEDICAL PHYSICS 2024

On November 4 – 7, SAFIM hosted Medical Physics Week, a virtual event that included 10 selected talks on key topics such as radiotherapy, nuclear medicine, diagnostic imaging, radiation protection and education. These presentations, originally held within the framework of the 14th Argentine Congress of Medical Physics, were transmitted online to reach those colleagues and students who could not join in-person. The result was extraordinary: more than 250 attendees from more than 20 countries throughout the region participated in this space for exchange and learning. The presentations are available – in Spanish – on the Youtube channel of SAFIM https://www.youtube.com/@SAFIM-You-Tube

Figure 1: 14th Argentine Congress on Medical Physics Bariloche 2024

Figure 2: Published book on Nuclear Medicine

Figure 3: Scenes from the Argentine congress held in 2014

III. EDUCATION AND TRAINING PROGRAMS

There are several undergraduate degree specializations, masters' degrees and residency programmes in Argentina, in accordance with the provisions of the regulations to work as Clinical Medical Physicists. These training programs include students and professionals from several various Latin American countries.

List of medical physics education and training programs in Argentina are:

- M.Sc. in Medical Physics: 1. Instituto Balseiro (Bariloche) and Universidad Nacional de Cuyo y FUESMEN (Mendoza). 2. Universidad de Buenos Aires. Facultad de Ciencias Exactas y Naturales. Departamento de Física
- Postgraduate Specialist in Physics of Nuclear Medicine: Universidad Nacional General San Martín (UNSAM) Escuela de Ciencia y Tecnología
- Postgraduate Specialis in Physics of Radiotherapy: Universidad Nacional General San Martín (UNSAM) Instituto Dan Beninson

- Medical Physics Engineering,: Universidad Favaloro Facultad de Ingeniería y Ciencias Exactas y Naturales
- BSc. Medical Physics: 1. Universidad Nacional General San Martín (UNSAM) Escuela de Ciencia y Tecnología; 2. Universidad Nacional de la Plata Facultad de Ciencias Exactas
- Residence/Fellow in Clinical Practice for Physics in Radiotherapy and Nuclear Medicine: 1. Instituto Oncológico Ángel H Roffo – Facultad de Medicina Universidad de Buenos Aires. 2. Fundación Médica de Río Negro y Neuquén (FUNMED)

These programs are recognized by the Nuclear Regulatory Authority (ARN) as "specialized education" to grant licenses to work as a Medical Physicist in the areas of their competence (Radiotherapy and Nuclear Medicine). After completing this specialized education, applicants must carry out supervised internships in healthcare institutions.

The continuous advancement of health-related technologies, particularly those involving the use of ionizing radiation, demands highly trained professionals equipped with the necessary tools to address current challenges. This makes it necessary to update training programs based on an optimized relationship between educational and healthcare institutions.

This topic was discussed in depth during the 14th Argentine Congress of Medical Physics and triggered several lines of work and discussion at SAFIM.

By way of example, the general aspects of one of these programs (Training and Education Program for Clinical Medical Physicists According to IAEA/IOMP/ALFIM Guidelines) are summarized [2].

To comprehensively comply with regional and international recommendations and the current legal requirements of our country, this paper presents the Structured Program for Supervised Clinical Training (PEECS), developed by the INTECNUS Foundation in collaboration with the Balseiro Institute (IB - UNCu) and the National Atomic Energy Commission (CNEA), with university accreditation. This program is also based on the concept of Entrustable Professional Activities (EPAs), following the recommendations of the Ministry of Health for evaluating clinical competencies for healthcare professionals.

The program includes a two-year Clinical Medical Physics Specialization (with a focus on Radiotherapy or Nuclear Medicine and Radio-diagnostics, as applicable) and two one-year Clinical Medical Physics Diplomas (one in Radiotherapy and another in Nuclear Medicine), integrated into a Clinical Medical Physics Residency conducted at the INTECNUS Foundation. Both the Specialization and Diploma programs are university-accredited, and their curricula align with the guidelines established by IAEA, IOMP, and ALFIM for training clinically qualified medical physicists.

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PROFESSIONAL ISSUES

A SURVEY ON RADIATION PROTECTION AWARENESS ABOUT THE RADIATION HAZARDS AND SAFE PRACTICE AMONGST THE NURSING FACULTY AND STAFF IN RAJASTHAN, INDIA

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Abstract— **The application of ionizing radiation in medicine has immensely revolutionized healthcare. However, the knowledge of radiation protection is of utter importance for those involved or assisting in medical radiological procedures in order to ensure patient and staff safety. The present study attempted to assess knowledge of radiation protection among nursing faculty and practicing nurses. A questionnaire based online survey was performed among nursing faculty and staff in the state of Rajasthan of India. Total 88 nursing faculty and practicing nurses completed the online radiation protection survey google form. Fifty percent of the participants in the survey were relatively young and were in the age group 28 - 37 years. Majority of responses were received from males (N = 58, 66%). The outcome of present work revealed that the knowledge of radiation protection is very limited among nursing faculty and practicing nurses in Rajasthan state, India and needs appropriate corrective measures. The Government, regulatory bodies, nursing associations and institutes should take effective measures to bridge the gap that exists in radiation protection education among faculty and practicing nurses in India.**

Keywords— **Radiation Protection, Nurses, Awareness, Survey.**

I. INTRODUCTION

The use of ionizing radiation is rapidly increasing in healthcare sector for diagnosis and treatment of various diseases [1]. Furthermore, the use of radiation in paediatric imaging saves many young lives by early appropriate diagnosis and treatment [2]. However, ionizing radiation is hazardous and has potential to cause harm to staff as well as patient if not used judiciously and appropriately. Therefore, underlying radiation protection and safety measures are a great concern for patients and occupational staff during medical radiological examinations and treatment [3].

The current approach to radiation protection is widely accepted globally based on advice from International Commission on Radiological Protection (ICRP) based on three fundamental principles of justification, optimization and dose limitation [4, 5]. Many healthcare workers presume conformity with these basic principles is sufficient, however, this is not always so and current framework does not address many dilemmas that may arise in clinical use of ionizing radiation in medicine [6]. Moreover, inappropriate use of medical radiological technologies by unskilled health professionals can result in potential health hazards for patients as well as staff [7].

Insufficient knowledge level on the use of medical ionizing radiation and radiation protection may induce radiophobia that can lead to compromised patient care and safety [8-10]. Practicing nurses can perform a variety of work during medical radiological procedures. Several studies have reported that practicing nurses lack knowledge of radiation health hazards and various methods of radiation protection [11, 12]. Few attempts have also been made to provide fundamentals of radiation protection, especially for nurses [13]. Notably, the competency of nurses during radiological procedures is not studied well nor do formal guidelines/curriculum of radiation protection training for them exist in this part of the country.

The present study was aimed to explore the radiation protection knowledge among nursing faculty and practicing nurses in Rajasthan state of India. In our study, the target population is nursing faculty and practicing nurses who are working as teaching faculty in nursing colleges and nursing staff practicing in hospitals, clinics and other healthcare sectors in Rajasthan state.

In India, practicing nursing staff are exposed to medical radiation in routine who are working in operating theatres, radiology, Cathlab, interventional radiology, nuclear medicine and radiation oncology practices and assisting in radiological procedures. The purpose of present work was to identify the key areas of radiation protection where in nursing faculty and practicing nurses can be educated by recommending the additional modules of radiation hazards and safety for nurses in the nursing curriculum.

II. MATERIALS AND METHODS

An online cross-sectional survey questionnaire was prepared following universally employed guidelines for conducting online cross-sectional surveys using google form. This was an electronic survey prepared in English language. The questionnaire consists of two parts. In the first part, personal and demographic details were included such as name, email ID, age, gender, institute, work experience, education level, type of employment etc. The details of personal and demographic responses are shown in Table 1. In addition, the radiation protection knowledge was tested using 40 multiple choice questions (MCQ) in part two. The survey was conducted among nursing faculty and practicing nurses from Rajasthan.

Table 1: Questionnaire details of survey for participant's personal and demographic information

Parameters	Details
Name Email ID	
Age (in years)	18-27 28-37 38-47 48-60 Over 60
Gender	Male Female
Institute	
Work experience (in years)	0-4 5-9 10-14 15-20 Over 20
Education in Nursing	Diploma Undergraduate Postgraduate Higher degree
Type of Employment/job	Private Public Others (Please specify)
Working unit	Teaching faculty Operating theatre Medical ward Emergency ward Cath lab Radiology department Radiation Oncology department Nuclear Medicine department
Are you taught/ gained knowledge about Radiation Protection during your study?	Yes/ No
Are you involved in teaching students?	Yes/ No
If you are involved in teaching, how many years of teaching experience?	______
If you are involved in teaching, are you teaching Radiation Protection to your students?	Yes No Leave empty
Any other comment/ suggestion(s)	

The questionnaire was distributed to various nursing colleges and hospitals for voluntary participation for receiving responses from 1 July 2024 - 31 August 2024. The questionnaire was provided to nursing faculty and practicing nurses for easy access using a google form link shared on email and WhatsApp. The participants were invited to complete self-reported questionnaire. The response of participants was anonymous and followed adherence to standards of good research practice for publication. Confidentiality of the records were maintained. Analysis of data was performed using Excel (MS Office 365). After collecting all of the data, it was checked for any missing or duplicate entry of data. All the categorical data were mentioned as numbers and percentage.

III. RESULTS AND DISCUSSION

Total 88 responses have been received through online radiation protection survey google form. Nearly half of the responders (N = 44, 50%) were relatively young in the age group of 28-37 years. A complete gist of demographic details of participants is provided in Table 2.

Table 2: Demographic details of nurses (N=88) participated in the study

Parameters	Number (%)
Age (in years)	18-27: 18 (20.5%) 28-37: 44 (50%) 38-47: 20 (22.7%) 48-60 :3 (3.4%) Over 60: 3 (3.4%)
Gender	Male: 58 (66%)
Work experience (in years)	0-4: 27 (30.7%) 5-9: 19 (21.6%) 10-14: 22 (25%) 15-20: 12 (13.6%) Over 20: 8 (9.1%)
Education in Nursing	Diploma :3 (3.4%) Undergraduate: 29 (33%) Postgraduate: 43 (49%) Higher degree: 13 (14.8%)
Type of Employment/job	Private: 74 (84%)
Working unit	Teaching faculty: 75 (85.2%) Operating theatre :5 (5.7%) Medical ward: 3 (3.4%) Emergency ward: 2 (2.3%) Cath lab: 0 (0%) Radiology department: 2 (2.3%) Radiation Oncology department: 2 (2.3%) Nuclear Medicine Department: 0 (0%)
Are you taught/ gained knowledge about Radiation Protection during your study?	Yes: 77 (87.5%)
If you are involved in teaching, are you teaching Radiation Protection to your students?	Yes: 50 (66.7%)

As suggestion, responders have appreciated the efforts for conducting the online survey and they have stressed on mandating the radiation protection teaching to students. Few nurses were interested in knowing more about radiation protection for teaching to students.

Interestingly, there were no participants who were practicing in Cath lab and Nuclear Medicine. Likewise, only two participants each were involved in the voluntary online survey from Radiology and Radiation Oncology Departments. Therefore, the outcome of our survey has a great significance since most of the participants (N = 75, 85%) belong to teaching faculty in nursing colleges and they were involved in the teaching of nursing students. Hence, the results of the present survey were skewed towards responses reported from nursing teaching faculty. The findings of present work generalizable to the population of nursing teaching faculty in the state.

In our work, it was noticed while analyzing the data that only 23 out of 40 questions have been answered correctly by the participating nurses with a response rate of more than 50%. In other words, forty-three percent (N = 17, 43%) of the questions were answered wrongly by participants with a low correct response rate i.e. below 50%. This fact provided empirical evidence and strongly suggests that the knowledge of radiation protection is very limited among the study participants, especially in the group of nursing teaching faculty. All the forty multiple choice questions related to radiation protection were summarized with correct response rate in Table 3.

Investigation of responses received from the participants by MCQs revealed vital information regarding the online survey. For instance, question 15 was reported with a 41% correct response rate only. In contrast, question 3 was reported with a 69% correct response rate. This fact showed that participants have average knowledge in basic radiation physics.

Similarly, a mixed response was received from the questions prepared in the domain of basic principles of radiation protection. Question 20 was reported with a 60% response rate. However, questions such as 21 and 23 were reported with 40% of correct response rate only. Broadly, the participants showed average knowledge of basic principles of radiation protection.

Furthermore, the questions such as number 6, 7, 9, 24, 25, 26, 32 and 36 were related to the use of ionizing radiation and radiation protection application in hospital setting. These eight questions were observed with correct response rate below 40% only. In this line, during the survey, the question "What is the factor affecting patient radiation doses?" was reported with the lowest correct response rate of 9% only. Hence, the findings suggest that the participants showed below average knowledge in radiation usage and application of radiation protection principles at workplace during occupational exposure. The possible explanation for this observation can be because of large number of responded nurses were teaching faculty who were not regularly involved with the use of radiation at clinics.

Additionally, the questions such as "Which of the following is considered as most sensitive tissue to radiation?" and "Which of the following is the correct increasing order of sensitivity to radiation?" were related with basic radiobiology. These two questions were reported with the lowest correct response rate, around 10% only. For these reasons, the performance of participants showed poor in the context of basic radiobiology.

Table 3: Findings of forty multiple choice questions* related to radiation protection is presented with correct answer and response rate responded by nurses (N = 88)

Question	Correct answer	Number (response rate)
1. What are the types of radiation?	All the Above	76 (86%)
2. The removal of one or more electrons from Atom is known as:	Ionization	67 (76%)
3. Which of the following is a non-ionizing radiation:	All the above	61 (69%)
4. Which of the following is a correct pair of ionising radiation:	X-rays & Gamma rays	68 (77%)
5. Where is ionizing radiation in healthcare used?	All the above	67 (76%)
6. What is the most commonly used Radioisotope in Nuclear Medicine?	Technicium-99m	35 (40%)
7. What is the most commonly used Radioisotope in Tele-gamma machines of Radiation Oncology?	Cobalt-60	33 (38%)
8. Which one is the Competent Authority for issuing licenses for Radiation equipment in India?	Atomic Energy Regulatory Board (AERB)	57 (65%)
9. Which of the following is correct pair of imaging modality, do not use ionizing radiation?	MRI & Ultrasound	35 (40%)
10. Which types of cells is most sensitive to radiation?	White blood cells	55 (63%)
11. Which of the following is considered as most sensitive tissue to radiation?	Breast	10 (11%)
12. Which of the following is the correct increasing order of sensitivity to radiation?	Adult, Old People, Pregnant Women, Child	6 (7%)
13. Which of the following period of pregnancy is the most sensitive to radiation?	Organogenesis and early foetal period	59 (67%)
14. Which phase of pregnancy is the most sensitive to radiation?	8 to 25 weeks	28 (32%)
15. What is the radiation Absorbed Dose?	Energy imparted per unit Mass	36 (41%)
16. What is the S.I. unit of Radiation Absorbed Dose?	J/Kg	64 (73%)
17. What is the unit of Radiation Absorbed Dose?	Gray (Gy)	49 (56%)
18. No dose of radiation is safe dose:	True	56 (64%)
19. What is the full form of ALARA?	As low as Reasonably achievable	56 (64%)

20. The lesser the time spent near a radioactive source or an X-ray tube:	Less radiation dose will be received	53 (60%)
21. When the distance from the source of radiation is doubled, the amount of radiation received will be	Reduce by 1/4	35 (40%)
22. Limiting radiation dose to patient will help to limit dose to staff:	True	57 (65%)
23. TLD badge is a Radiation Protection device.	False	35 (40%)
24. TLD badge should be worn above the lead apron during medical radiological procedures.	No	23 (26%)
25. In case a lead apron is being used, where should the TLD badge be placed?	Below the lead apron	32 (36%)
26. TLD badge should be worn by a:	Nurse regularly assisting fluoroscopic guided procedures	22 (25%)
27. The main source of radiation for the staff in a fluoroscopy room is the patient:	True	61 (69%)
28. Scatter Radiation Dose is directly proportional to:	Both of the above	48 (55%)
29. Tube under couch position reduces, in general, high radiation dose rates to the specialist's eye lens	True	60 (68%)
30. As patient size increases:	All the above	57 (65%)
31. What is the factor affecting patient radiation doses?	Relative Patient entrance Dose	8 (9%)
32. What are the protection tools from ionising Radiation?	Thyroid Collar	14 (16%)
33. Cataract can occur because of ionising Radiation?	True	65 (74%)
34. Ceiling suspended movable lead glass is generally used in:	Interventional Radiology	49 (56%)
35. Which of the following radiation protection device are used in Cath lab?	All the above	60 (68%)
36. Which of the following is the correct increasing order of energy of radiation used for medical radiological procedure?	Mammography, Chest X-ray, CT scan	25 (28%)
37. What is the annual radiation dose limit for the radiation worker?	20 mSv	42 (48%)
38. What is the permitted minimum age limit of the radiation worker for occupational exposure?	18 years	39 (44%)
39. What is the most appropriate location of diagnostic X-ray machine installation?	Low occupancy areas	58 (66%)
40. What is the most appropriate scenario from radiation protection point of view, during Chest X-ray of adult?	Check for nobody staying inside X-ray room except patient with door closed before imaging	52 (59%)

In present work, most of our responders were relatively young in the age group of 28-37 years of age who holds postgraduate degree educational level and working as a teaching faculty in nursing education. Contrary to the fact, the present study reported lack of radiation protection knowledge amongst nurses. Henceforth, it is important to make aware and train the nursing faculty in radiation hazards and philosophy of radiation protection so that the knowledge is appropriately transferred to nursing students and then they can apply this knowledge and skill in practice.

Similar to our study, 44 intensive care nurses from same hospital in Iran were studied for the knowledge of radiation safety and their behaviour towards portable radiological examinations. They have reported that nurses lack knowledge of radiation protection and recommended in-service training programmes [12].

In another study reported from Malaysia, a cross-sectional survey among 395 nurses conducted on usage of radiation and radiation protection knowledge. They have shown that nurses have sufficient radiation protection knowledge but lack in knowledge of radiation physics and radiation usage principles. They also stressed strengthening the training of nurses involved or assisting in medical radiation environment [11].

In a study carried out by Rowantree et al. on radiation safety knowledge of orthopaedic surgeon's during fluoroscopy environment reported low level of knowledge of ALARA principle and lack in formal radiation safety training. Formal and continuous radiation safety training is advised to prevent the long-term effects of ionizing radiation during fluoroscopy procedures [14].

In a policy perspective for nurses reported by Wang et al., advocated to implement a policy mandating annual radiation protection training for nurses assisting in medical radiological examinations [8].

From the present study, it is clear that a gap exists in radiation protection knowledge among nursing faculty and practicing nurses. Further, the study findings suggest that the lack of radiation protection knowledge can be attributed to absence of provisions for periodic radiation protection training programmes during employment after completion of formal education. Typically, the development of curricula of radiation protection and its inclusion in nursing education is not sufficient. This is just the first and immediate action to address the issue. Next, a robust periodic radiation protection education programmes in the form of online modules or training at institutes is required to fulfil the patient safety goals comprehensively in the context of radiation protection globally. In summary, commutative attempts are needed on priority from government, regulatory body, nursing associations, nursing education institutes, healthcare institutes to address this gap in a holistic manner.

IV. CONCLUSIONS

The present study evaluated the radiation protection awareness amongst nursing faculty and practicing nurses. The outcomes of present study showed that nurses are well qualified, however, knowledge of radiation protection is very limited. This may seriously impact patient care and occupational safety. Periodic radiation protection training programmes are key to enhancing knowledge of radiation protection in this ever growing and technologically advanced field of ionizing radiation in medicine.

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NAVIGATING RADIOLOGICAL CHALLENGES IN NIGERIA: A COMPREHENSIVE REVIEW

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Abstract— **Radiology in Nigeria faces formidable challenges, including limited resources, inadequate infrastructure, and a scarcity of skilled personnel. This article reviews these challenges, highlighting their impact on healthcare outcomes and the urgent need for intervention. By presenting case studies, statistics, and analysis, the review emphasizes the critical nature of these issues while proposing solutions. Collaboration among stakeholders is essential to improving radiological services and healthcare delivery. Addressing these challenges is vital to ensuring better healthcare outcomes for Nigerians.**

Keywords— **Radiology, Healthcare, Infrastructure, Solutions, Collaboration.**

I. INTRODUCTION

Radiology is integral to modern healthcare, enabling precise diagnoses and effective treatments across medical disciplines. However, Nigeria faces significant challenges in radiology, including limited resources, inadequate infrastructure, and a shortage of skilled personnel. These challenges are especially acute in rural areas, where the healthcare system struggles to meet the population's needs. For instance, Nigeria, with a population exceeding 200 million, has only 0.4 radiologists, 0.2 radiographers, and 0.1 medical physicists per 100,000 people. This is far below global averages of 10 radiologists, 5 radiographers, and 2 medical physicists per 100,000 population (Table 1) [1, 2]. A comparative analysis of radiological indicators reveals glaring disparities in access to infrastructure, personnel, and training between Nigeria and other regions [3]. These shortages directly affect patient care, often resulting in delayed diagnoses and worsened health outcomes.

For example, a 45-year-old woman with suspected pulmonary tuberculosis may experience delayed diagnosis due to the absence of functional X-ray machines, exacerbating her condition. Addressing these issues is critical for ensuring equitable access to quality radiological services. This review examines the root causes of these challenges and proposes practical solutions. It emphasizes the importance of collaborative efforts among radiologists, radiographers, medical physicists, and other healthcare professionals to improve radiology in Nigeria.

II. CHALLENGES IN MEDICAL PHYSICS AND RADIOLOGY

Shortage of Medical Physicists

Medical physicists are vital for ensuring the safe and effective use of radiation in imaging and therapy. They handle quality assurance, equipment calibration, radiation safety, and patient dosimetry. However, Nigeria faces a severe shortage of qualified medical physicists due to limited training programs. Many aspiring professionals seek education abroad, resulting in brain drain and further compounding the shortage. Government recognition of medical physicists remains inadequate, leading to inconsistencies in standards across healthcare facilities [4]. Moreover, infrastructure in radiology departments is often insufficient, with outdated imaging equipment and a lack of tools for radiation safety and dosimetry. Additionally, medical physicists are not remunerated adequately, resulting in low job satisfaction and motivation [5, 6, 7, 8]. A study published in the Journal of Radiological Protection found that many radiology facilities in Nigeria lack adequate quality assurance programs and adherence to radiation safety practices [9].

Case Study

A survey conducted in a Nigerian hospital highlighted key challenges faced by medical physicists, including inadequate training opportunities and minimal government support. The majority of respondents cited these barriers as significant obstacles to professional growth. Addressing these issues through government intervention is crucial for enhancing the contributions of medical physicists to healthcare delivery [10].

Impact on Healthcare Delivery

The lack of adequate radiological services has far-reaching consequences for Nigeria's healthcare system. Delayed diagnoses increase the likelihood of disease progression, leading to higher treatment costs and poorer patient outcomes. This situation disproportionately affects rural areas, where access to radiological services is severely limited [11]. For example, a child with symptoms of appendicitis may face life-threatening complications due to the unavailability of ultrasound imaging in rural clinics. These delays not only endanger lives but also place immense pressure on tertiary healthcare centers, which are already overburdened.

Table1: Comparative analysis of radiological services in Nigeria compared to other regions

Indicator	**Nigeria**	**Africa**	**Asia**	**North America**	**South America**	**Europe**
Radiologists per 100,000 population	0.4	1-2	3-5	10-20	5-10	10-20
Medical Physicists per 100,000 population	0.1	0.2-0.3	0.5-1	1-2	0.5-1	1-2
Access to Radiological Services	<20%	30-40%	50-60%	80-90%	60-70%	90-95%
Infrastructure and Equipment	70%	50-60%	60-70%	80-90%	70-80%	90-95%
Skilled Personnel	<20%	30-40%	50-60%	80-90%	60-70%	90-95%
Quality Assurance and Radiation Safety	Low	Moderate	Moderate	High	Moderate	High
Training and Continuing Education	<30%	40-50%	60-70%	80-90%	70-80%	90-95%

III. PROPOSED SOLUTIONS

Capacity Building

Addressing the shortage of skilled personnel requires the establishment of training programs for radiologists, radiographers, and medical physicists [12]. Scholarships and incentives can encourage young professionals to pursue careers in medical physics and radiology within Nigeria. Ensure that training programs are tailored to the specific needs of the Nigerian healthcare system and are aligned with international best practices [13]. Ghana has partnered with international organizations like the International Atomic Energy Agency (IAEA) to train radiographers and medical physicists, improving the availability of skilled personnel [14]. Germany has a well-established system of continuous education for radiologists and radiographers, ensuring that healthcare professionals are up to date with the latest developments in the field [15]. Learn from successful quality assurance programs in other countries to inform the design and implementation of similar programs in Nigeria [16]. Egypt has implemented a comprehensive quality assurance program for radiology services, including regular inspections and audits to ensure compliance with safety standards [17]. Canada has developed stringent radiation safety regulations and guidelines, which are regularly updated based on scientific evidence and best practices [18].

Government Support

The government must prioritize investments in radiology by upgrading infrastructure, providing modern equipment, and enforcing standards for radiation safety. Establishing regulatory frameworks will ensure consistency in practices across healthcare facilities. It is imperative to advocate for sustainable government support and policy reforms that prioritize radiology, including the establishment of a regulatory council for medical physics, to ensure comprehensive oversight of all aspects of radiological services [19, 20]. NSIA-LUTH collaboration, which has demonstrated the feasibility of long-term infrastructure investments in healthcare. The South African government has made significant investments in upgrading and expanding radiology infrastructure, particularly in rural areas, through initiatives like the National Health Insurance (NHI) program. The UK's National Health Service (NHS) has implemented a modernization program for radiology services, including the introduction of digital imaging systems and the refurbishment of existing facilities [21]. Rwanda serves as a prime example of successful policy reforms in prioritizing radiology in healthcare. The country has established a national radiology program and integrated radiology services into primary healthcare, leading to improved access and quality of care [22]. Norway has also demonstrated the importance of a national strategy for radiology services, including funding for infrastructure, training, and quality assurance programs, ensuring sustainable support for radiology practice [23].

Collaborative Efforts

Collaboration among stakeholders is essential to addressing these challenges. Partnerships between government agencies, healthcare institutions, and international organizations can facilitate resource sharing and knowledge transfer. Partner with local influencers, community leaders, and healthcare professionals to disseminate information effectively. Monitor the impact of the campaign through surveys, focus groups, and media analytics [24]. Kenya has conducted public awareness campaigns on the importance of early detection through radiology screenings, particularly for diseases like cancer [25]. The American College of Radiology (ACR) has launched educational campaigns to raise awareness about radiation safety and the benefits of radiology services [26].

IV. CONCLUSION

Radiology in Nigeria faces critical challenges that undermine healthcare delivery and patient outcomes. Addressing these issues requires a multi-faceted approach involving capacity building, government support, and stakeholder collaboration. Recognizing the vital role of medical physicists and providing them with the necessary resources will be pivotal in improving radiological services. By tackling these challenges head-on, Nigeria can pave the way for equitable access to quality healthcare, ensuring better health outcomes for all. Specifically, the article calls upon the Nigerian government to take concrete steps, such as passing the Medical Physics Regulatory Council Bill 2023, and urges the National Assembly to prioritize this critical legislation. This bill would establish a regulatory body to oversee and regulate the practice of medical physics in Nigeria, ensuring high standards of practice and patient safety.

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INVITED PAPERS

MEDICAL PHYSICS AND CLINICAL TRIALS

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Abstract— **This paper underscores the vital, yet often under-recognized, role of medical physicists in clinical trials, particularly in radiation oncology and imaging. Medical physicists contribute significantly across all stages of clinical trials, from trial design and protocol development to quality assurance, data analysis, and outcome assessment. Their expertise is integral in managing high-cost, high-technology interventions, ensuring the precise application of advanced medical technologies, and addressing critical safety and dosimetric concerns. In radiation oncology, medical physicists ensure the accuracy of treatment delivery, especially in trials involving advanced techniques like Intensity Modulated Radiation Therapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT), which pose complex challenges in radiation distribution and patient safety. Medical physicists play a crucial role in pre-clinical research, particularly in the development of small animal irradiation platforms used to test new therapies that complement radiation treatment. These platforms are vital for obtaining regulatory approval for clinical trials involving human subjects. The paper also emphasizes the importance of medical imaging in radiation oncology clinical trials, which aids in target delineation, treatment monitoring, and compliance assessment, ultimately ensuring the integrity of trial results.**

The complexity of medical imaging technologies makes it difficult to assess and improve their clinical efficacy. Clinical imaging trials are often impractical due to ethical and logistical challenges. Virtual clinical trials (VCTs), which simulate patients and imaging systems, offer an alternative. VCTs have advanced significantly, with key components such as computational phantoms, simulators, and interpretation models, applied across various imaging techniques. As the demand for high-quality clinical trials increases, it is a priority for the international medical physics community to better recognize the pioneers who have contributed significantly in clinical trials.

Keywords— **clinical trials, radiation oncology, medical imaging, medical physicist, modelling**

I. INTRODUCTION

Medical physics practice is diverse and covers many domains in medicine. The conduct of clinical trials is a very important area of medicine that influences medical practice around the world. Clinical trials especially randomised controlled ones provide some of the highest quality evidence that evolves how patients with specific disease profiles are managed. There are some extremely high cost/high technology interventions that industry makes available to the healthcare market, and proving the benefits and deciding which patients are likely to see improved outcomes is a critical step in providing cost effective medical care where resources can be scarce. Some of the interventions involve technology that necessitates medical physics expertise to understand how it can be used and what the limitations and safety concerns are such that trial design and conduct would be impossible without such expertise. Medical physicist involvement with clinical trials is often overlooked and therefore under-recognised. To the knowledge of the authors there are no awards available to medical physicists specifically from medical physics only organisations that recognise excellence in work that supports clinical trials. An excellent editorial by physicist Tomas Kron from 2013 nicely summarises the extent of medical physicist's roles in clinical trials [1].

II. ROLE OF MEDICAL PHYSICISTS IN CLINICAL TRIALS

There are many activities related to clinical trials that provide opportunities for medical physicist involvement. These range from trial conception, pilot studies to prove practicability of trial methodology, protocol development, statistical power calculations to determine subject accrual targets, components of research ethics board submissions, quality assurance requirements to ensure trial conduct consistency, investigator and institutional credentialing, real-time review of adherence of investigators to trial protocol requirements, data analysis to develop conclusions of the trial and publication of results in the literature.

Ensuring consistency and adherence to clinical trial protocols is key to any trial that is seeking to show whether a significant difference exists between a standard arm of treatment and a new experimental arm [2, 3]. This paper will focus mostly on examples from radiation oncology, but medical physics input in clinical trials generally comes from medical physicists employed in radiation oncology, nuclear medicine, magnetic resonance imaging, diagnostic imaging, academics, and industry.

III. RADIOTHERAPY CLINICAL TRIALS SUPPORT AND EXAMPLES OF MEDICAL PHYSICIST CONTRIBUTIONS

Clinical trials involving radiation therapy (phase I, II or II) are relatively common and may be international or national multi-centre studies as well as single institution investigator-initiated trials. Some trials involving new technology, for example, Intensity Modulated Radiation Therapy (IMRT) or Volumetric Modulated Arc therapy (VMAT) where the trial objective is to evaluate the highly conformal dose distribution intervention against a 3-dimensional conformal technique, can be difficult to perform. This is because prior to consent to the study patients have to understand that they could receive a treatment that will naturally cause radiation to be delivered to much larger organ volumes. These kinds of challenges to health technology assessment were highlighted in a publication by medical physicist Søren Bentzen in 2008 [4]. Bentzen also has made fundamental contributions in the literature that helped to improve quality and integrity of randomised clinical trials [5, 6, 7, 8].

Fundamental to the success of clinical trials where the primary intervention involves radiotherapy is the accuracy of the delivered ionising radiation dose. There have been many physics led initiatives over the years that provide analysis and infrastructure to assess dosimetric accuracy across many institutions that may be geographically distributed locally, nationally and internationally. 30 years of experience of this in the United Kingdom was published by several medical physicists in 2015 [9] and followed the initial work by medical physicists David Thwaites et. al. [10]. The review article [9] offers an historical chronology of dosimetry audits by various groups around the world. The International Atomic Energy Agency (IAEA) in 1966 started a mail-in thermoluminescent dosimetry (TLD) service to assess the accuracy of dose delivered globally for Cobalt-60 treatment machines. The work was led by medical physicists Svensson et. al. [11] and in 1968 the group was joined by the World Health Organisation and that program still operates today.

In Europe, some of the earliest dosimetry audit and quality assurance work was pioneered by medical physicist Andrée Dutreix [12, 13] and led to the establishment in 1998 of the European Society for Radiotherapy and Oncology (ESTRO) Quality Assurance Network for radiotherapy (EQUAL). Medical physicist Stefano Gianolini was involved in developing the software package known as Visualization and Organization of Data for Cancer Analysis (VODCA) that allows data to be collected from multiple clinical trial sites treatment planning computers and centrally analyzed for quality assurance purposes. The European Organisation for Research and\Treatment of Cancer (EORTC) have implemented VODCA to support RT quality assurance involving several trials.

Medical physicists in the USA have also made significant contributions in several areas that have led to world class support for conducting high quality radiotherapy clinical trials. One of the notable pioneers was Robert Shalek, Chair of the Physics Department at MD Anderson Cancer Centre. In 1968, following a successful funding proposal to the National Cancer Institute (NCI), he established the Radiological Physics Centre (RPC) that was responsible for monitoring radiation treatment facilities involved in NCI clinical trials [14]. This legacy endures today (RPC is now known as the Imaging and Radiation Oncology Core—Houston [IROC-H]) with mail-in dose monitoring, postal phantom services to credential centres to participate in advanced technology clinical trials and carrying out site visits. In addition, data exchange platforms that can receive RT planning data for clinical trials quality assurance were developed by physicists James Purdy [15], Joseph Deasy [16] and Jatinder Palta and James Dempsey [17].

In Australia, medical physicist Martin Ebert was responsible for developing a software platform called SWAN [18]. This software allows upload and review of complex radiation treatment planning data for patients participating in multi-centre clinical trials. It facilitates rigorous quality assurance review of treatment plans thus minimising the likelihood of protocol deviations that could affect outcomes and hence trial results. This software is widely used to support quality assurance efforts in clinical trials conducted by the Trans-Tasman Radiation Oncology Group (https://trog.com.au/). Of note in Australasia in 1996 there was an early multi-centre phantom assessment of expected and measured doses in mantle radiotherapy treatments for Hodgkin's lymphoma that was spearheaded by three medical physicists (Amies, Rose and Metcalfe) and a radiation oncologist colleague (Barton) [19]. In 2000 medical physicist and co-author of this paper (WB) and radiation oncologist colleagues published a study involving 10 Australian radiation oncology centres treating an anthropomorphic phantom with two different breast sizes and looking at the variation in planned versus delivered dose at multiple points [20]. In 2002, a further study led by Kron used an anthropomorphic phantom at 18 Australian and New Zealand radiation treatment centres assessing clinical trials dosimetry of tonsil and prostate [21].

Another area of activity that medical physicists have contributed to is the development of radiation therapy treatment platforms that allow precision irradiation of small animals. These systems are vital to enable pre-clinical work that is often necessary to get regulatory approval to open clinical trials involving human subjects. Such trials can involve testing efficacy of new generations of drugs that can be used to compliment traditional radiation therapy and show promise of improving treatment outcomes. Irradiation platform development examples involving medical physicists were led by John Wong [22], David Jaffray [23] and Strahinja Stojadinovic [24]. Some of these systems are now commercially available and widely employed in pre-clinical studies.

IV. VIRTUAL CLINICAL TRIALS IN MEDICAL IMAGING

The importance of imaging in radiation oncology clinical trials is fundamental from being able to delineate targets and normal tissue structures before the treatment of trial subjects to monitoring treatment beam placement during the treatment and after treatment for outcome assessment [25]. Moreover, assessing compliance to clinical trial protocols using imaging as a tool has shown compromises to clinical trials outcomes and a significant example of this is highlighted in the paper by peters from 2010 [3].

The increasing complexity and variety of medical imaging technologies have surpassed the ability to effectively assess and improve their clinical applications. This presents a growing challenge for both researchers and clinical practitioners. Ideally, these evaluations would take place through clinical imaging trials, but such studies are often impractical due to ethical concerns, high experimental costs, time constraints, or lack of definitive reference data.

Virtual clinical trials (VCTs), also known as *in silico* imaging trials, provide an alternative by simulating patients, imaging systems, and interpreters to assess imaging technologies in a virtual environment. The field of VCTs has made significant advancements over recent decades. A recent review paper discusses the common components of VCTs, including computational phantoms, imaging simulators, and interpretation models, while also highlighting their applications in various imaging techniques [26].

Some Common Methodologies in Virtual Clinical Trials

1. Computational Modelling and Simulation: VCT rely on the usage of computational models of human anatomy, physiology and pathology. These models apply techniques such as finite element analysis (FEA), Monte Carlo simulations to simulate the dynamic nature of human health and the effects of medical interventions. They are used in the assessment of dose distribution and protocol optimisation. Thus, researchers can simulate various clinical conditions and treatment protocols, providing valuable insights into the effectiveness of imaging systems.

2. Digital Phantoms and Virtual Patients: Digital phantoms are utilised for simulating medical imaging protocols. These phantoms can represent various tissue types, pathological conditions and patient demographics, enabling highly accurate simulation of imaging modalities such as CT, MRI and ultrasound. Virtual patients are more sophisticated, computing-intensive models that incorporate both anatomical and physiological information, enabling the simulation of disease progression, treatment responses, dosimetry studies and image acquisition protocols.

3. Radiomics and Data Analytics: Radiomics plays a central role in VCT. By applying M and DL techniques to radiomic data, researchers can develop predictive models for diagnosis, prognosis and response to therapy. Virtual trials can integrate radiomic features with patient models to evaluate the performance of imaging systems in real-world clinical scenarios.

4. ML and AI Integration: ML and AI are incorporated into VCTs to analyse large datasets, optimise imaging protocols and predict clinical outcomes. AI models can potentially help to identify patterns within virtual patient data, refine imaging protocols and even predict outcomes. In virtual trials, AI systems can assist in the evaluation of imaging modalities and protocols in enhancing both accuracy and efficiency.

V. IMAGING VCT APPLICATIONS

Abadi et al [26] published an excellent review on “Virtual clinical trials in medical imaging”. We present a few selected examples here.

Breast Imaging

One of the earliest applications of VCTs was in breast imaging for investigations of image quality, dosimetry, optimization, and technology evaluation. [27]

In another example, VCTs were used in the optimum projection to evaluate the smallest detectable diameter of various lesions, showing that digital breast tomosynthesis (DBT) is superior to digital mammography (DM) for masses detection.

CT Imaging

VCTs can simulate dose studies using computational phantoms and Monte Carlo-based CT simulators. These studies enable assessment of organ doses for various imaging protocols.

Zhang et al. [28] investigated uncertainties in organ dose estimations across different computational phantoms, revealing that variations in organ location and anatomy can lead to significant differences in dose estimates

Another study by Sahbaee et al. [29] assessed the effect of iodinated contrast agents on organ dosimetry in CT. The results showed that the presence of iodine increased the dose, highlighting the need to balance image quality with patient dose when optimizing contrast-enhanced CT protocols.

VI. CONCLUSIONS

Medical physicists play a vital yet often under-recognized role in clinical trials, particularly in radiation oncology and medical imaging. Their expertise is crucial in trial design, quality assurance, and data analysis, ensuring the accuracy and safety of interventions. Through their contributions, they help improve the reliability of trial outcomes and advance patient care. As the demand for high-quality clinical trials increases, it is a priority for the international medical physics community to better recognize the pioneers who have contributed significantly in clinical trials.

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A COMPREHENSIVE STUDY OF THE FACTORS THAT INFLUENCE THE GAMMA PASSING RATES IN IMRT PLAN SPECIFIC QUALITY ASSURANCE

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Abstract— **This study aims to evaluate various parameters which affect the gamma passing rate (GPR) in IMRT Quality Assurance. A correlation between the modulation factor in the treatment planning, various treatment sites in planning, gamma analysis criteria such as low dose threshold value (LDT) and various normalization methods were analyzed against gamma passing rate. The study included 108 patients who were treated in Elekta Versa HD. The treatment plan was exported to imatrixx phantom and the fluence was calculated. The calculated fluence was compared against delivered fluence and Gamma analysis was performed. There is a negative correlation found between delivered MU and GPR. The Brain, Head and Neck have relatively lower passing rate than Pelvis and Thorax. When the low dose threshold value is increased from 5 to 10%, the global normalization method shows a decrease in gamma passing, whereas the local normalization method shows the contrary results. The Monitor Unit has to be controlled in treatment planning as this will improve Gamma Passing Rate. The Brain and Head and Neck are having lowest passing rate since these sites have OAR closer to the PTV. The Global Normalization method has better passing rate than local as it hides the error in low dose area. Irrespective of LDT value applied, the Gamma passing rate is above 95 % in Global Normalization method whereas Selection of LDT is crucial in Local Normalization method as the passing rate goes as low as 90% when the LDT is 5%.**

Keywords— **Intensity Modulated Radiation Therapy, Gamma Passing Rate, Normalization method, Low Dose Threshold.**

I. INTRODUCTION

Intensity modulated radiation therapy (IMRT) can deliver highly conformal prescription doses to target volumes while minimizing doses to organs at risk (OAR) in proximity to the target volumes, which enables high local control as well as reduction of complications related to radiotherapy [1]. In IMRT the modulated beams are produced using complex motion of Multi Leaf Collimator. As the dose gradient in IMRT is sharp and also the Monitor Unit delivered is very high than conventional treatment like 3DCRT, the discordance between the planned and delivered dose could cause critical clinical malpractices. Therefore, pre-treatment plan-specific quality assurance (QA) for IMRT and Volumetric Modulated Arc Therapy (VMAT) plans are highly recommended in the clinic as a verification procedure of the treatment plan before patient treatment [1]**.** 2D gamma evaluation is generally performed in the clinic which compares the planned and delivered dose distribution. A composite analysis developed by Harms et al [2] called gamma index which combines both the dose difference and distance to agreement in low dose and high dose gradient respectively. This gamma index can be affected by both the precision of the TPS calculation and the precision of treatment delivery [3]. In TPS calculation the plan complexity is measured in terms of MU and there are various parameters used in the analysis of Gamma index which affects Gamma passing rate. Task group (TG) generated by the American Association of Physicist in Medicine recommends global normalization with acceptance criteria of 3% of dose difference, 3mm distance to agreement (DTA). In addition to this low dose threshold is applied to remove the background noise (possible measurements due to the effects of radiation scattering). AAPM TG-119 instructs facilities to use a 10 % of Low Dose Threshold value or Region of Interest determined by jaw setting [4]. According to a survey [5], 70 % of clinics use a low dose threshold of 0-10 %. But there is no clinical data to quantitatively demonstrate the impact of Low Dose Threshold. This study aims to study various parameters which are used in the analysis that affects the Gamma Pass Rate (GPR) and thus be able to apply it by establishing norms and criteria for evaluating the gamma index for the future. In addition to this, a correlation between GPR and the treatment site was also studied.

II. METHODOLOGY

This study included 108 cases from the Brain, Head, Neck, Thorax, and Pelvic regions. These patients were planned dynamic IMRT in Monaco TPS (v. 5.11.03) and were generated using 6MV beam. The Equivalent Uniform Dose (EUD) based optimization was used in the Planning system. The calculation algorithm used in TPS was Monte Carlo. The calculation grid size was 0.3 cm, and statistical uncertainty was 1% set in the calculation parameters. Plans were evaluated using Quantitative Analyses of Normal Tissue Effects in the Clinic (QUANTEC) criteria.

Treatment plans were transferred and calculated on 2-D array system (IBA Dosimetry, Germany). This array has 1020 vented parallel ion chamber which can measure an active area of 24.4 × 24.4 cm^2 and the detector spacing of the array is 7.62 mm. This array was scanned with 5 cm build-up and 5 cm back scatter material (Fig-1). The build-up phantom material is PMMA and of density 1.16 g/cc. The density of phantom was forced in TPS, and the plan was calculated for QA on phantom. The output calibration was routinely performed every quarter to account for the output deviation of the machine. There are studies which prove there is no statistically significant difference in the gamma analysis between zero and non-zero treatment angles [6]. Hence the various gantry angles of IMRT plan were collapsed to zero angle during QA calculation. The coronal plane dose distribution exported to my QA software (v. 2017-002(2.9.23.0)) for measured and calculated dose comparison (Fig-2) The plans were delivered in Elekta Versa HD (Stockholm, Sweden) LINAC.

Gamma Passing Rate was analyzed for 3% dose difference and 3mmDistance to agreement criteria. This is the evaluation criteria originally recommended by Low et al [2]. The plans were analyzed using global normalization and low dose threshold set was 5%. The plans which had 90% pass percentage were accepted.

The relationship between various treatment site, MU, Modulation Factor which are decided in the TPS are analyzed against the GPR. The relationship between analyzing parameters such as Normalization method and Low dose threshold which are used in Gamma analysis are also analyzed against the GPR.

The average gamma passing rate found for all the patients was 97.11±2.36. There were 7 plans which did not pass with the 3%, 3mm criteria. The detector array setup was reverified and analyzed using different passing criteria. But these were excluded from the study. The Fig-3 given below shows distribution of Gamma Passing Rate of all 108 plans.

Figure 1: IMRT QA setup

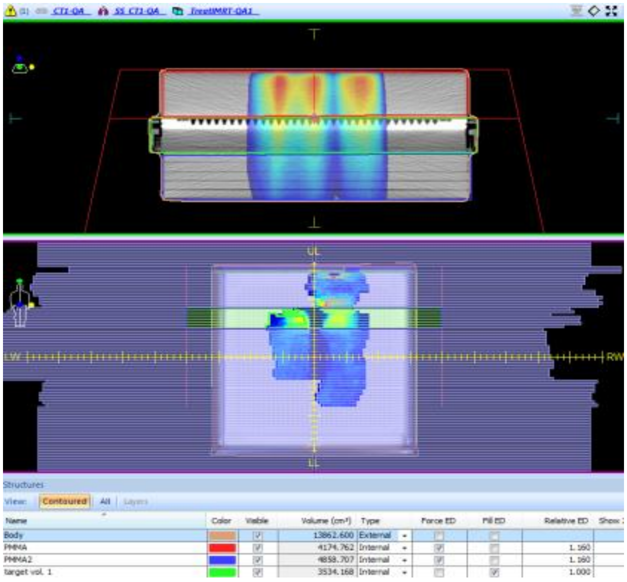

Figure 2: Dose delivery on imatrixx phantom in TPS

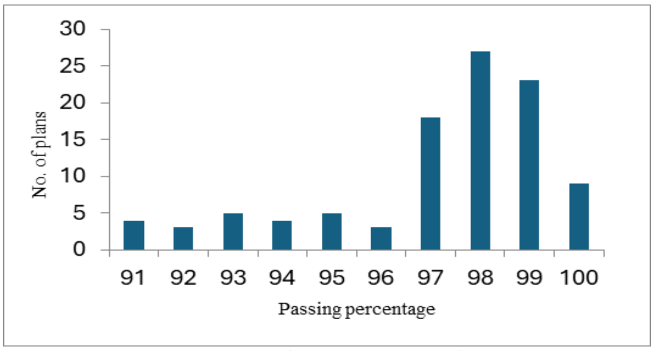

Figure 3: Distribution of gamma pass rate of 108 patients

III. RESULTS

Relationship between total MU, Treatment Site and Gamma Passing Rate:

A total of 20 brain, 24 pelvis, 25 thorax and 39 head and neck cases were included in the study. The bar graph below shows the Gamma passing rate of various treatment sites (Fig-4)

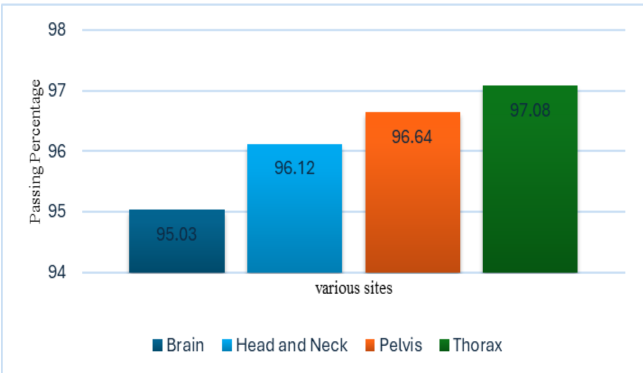

Figure 4: GPR of various Sites

In the modulated treatment like IMRT there are various parameters such as MU, Complex shaped segments, small apertures and a large number of segments affect the matching between planned and delivered dose distribution to the patient [7]. Among them Monitor Units delivered alone is taken to evaluate the plan complexity of IMRT plans. SPSS software was used to find the correlation between total MU and Gamma Passing Rate. A weak negative correlation was found between MU and Gamma Passing Rate. Spearsman correlation coefficient found to be -0.05172. Fig 5 shows the correlation found between MU and GPR.

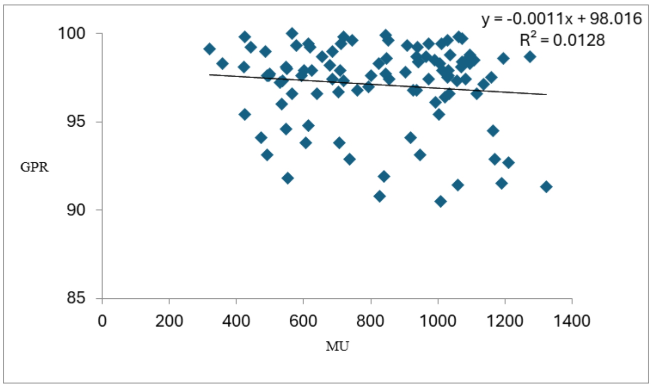

Figure 5: MU vs GPR

Confidence Limit:

There are always differences between measurement and calculation. This could be because of limited resolution of the QA device, limitation in the accuracy of dose calculation, limitation in the dose delivery system. TG-119 proposed a way to quantify the degree of agreement between measurement and calculation.

CL= (100 – mean) + 1.96σ ……………..(1)

Where mean is the average of GPR and σ is the standard deviation.

Detectability Threshold:

DT = 100 – CL …………………………(2)

As per TG-119 protocol the CL of overall 108 patients were analyzed and the CL found was 4.6 and Detectability Threshold (DT) calculated was 95.4.

Normalization method:

The data was analyzed using Global normalization method by changing the low dose threshold value from 5 % to 10 %. When the low dose threshold value increases from 5% to 10 % the gamma passing percentage decreases from 96.3 to 95.6% for the 3%, 3 mm. With stricter evaluation criteria like 2 %, 2 mm also the pattern observed remains same. The Gamma Passing Rate decreases from 93.5 to 92.5% (Figure 6).

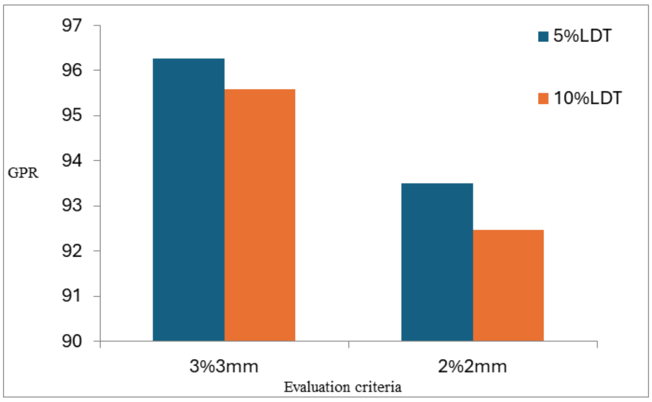

Figure 6: Global Gamma Index

Local Normalization: When Local Normalization was applied using 3%, 3mm passing criteria, GPR increased from 90.2 to 91.6% when Low Dose Threshold increased from 5 to 10 %. The pattern of increase in GPR remains same even with the stringent evaluation criteria such as 2%, 2mm. With the tighter evaluation criteria, the GPR increases from 87.5 to 88.6% (Figure 7).

Table 1: Comparison between Global and Local Normalization

Analysis Criteria	Low Dose Threshold	Local Gamma Index		Global Gamma Index	
		Mean	SD	Mean	SD
3%, 3mm	5%	90.19	5.89	96.26	4.19
	10%	91.61	6.29	95.59	4.87
2%, 2mm	5%	87.49	6.37	93.49	5.39
	10%	88.63	6.90	92.46	6.29

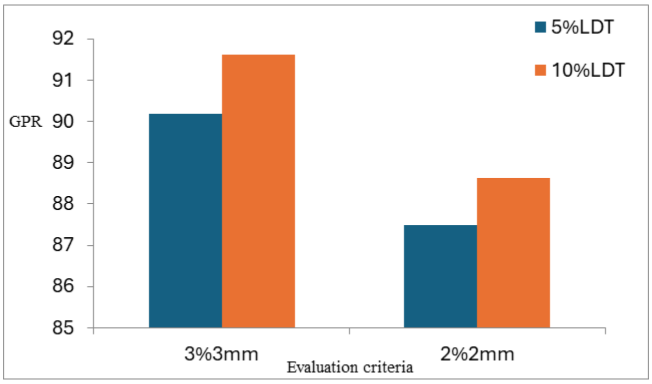

Figure 7: Local Gamma Index

Comparison Between the Global and Local Normalization for Various Threshold Values and Evaluation Criteria:

Similarly, 6.1% difference is seen between Global and Local gamma index for 3%, 3mm criteria at Low dose threshold of 5%. For 10% of Low dose threshold there is 4% of gamma index difference seen between Local and Global index.

Using the 2%, 2mm criteria, the percentage difference observed was 6% between global and local gamma index with 5% Low Dose Threshold. With 10 % threshold 4% difference was found between global and local normalization.

Irrespective of the dose evaluation criteria, the percentage of difference observed between global and local normalization remains same and local gamma index shows decrease in the GPR than Global gamma index for various Low dose threshold values.

Table-1 Shows the comparison between the Global and Local Normalization for various threshold values and evaluation criteria.

IV. DISCUSSION

Correlation Between Treatment Site and Gamma Passing Rate:

In this study lowest gamma passing rate was found in brain and Head and Neck cases of 95.03 and 96.12 % respectively. The reason could be that the highest modulation was done in these cases as these sites involve the major critical organs such as Optic structures, Brain Stem and Spinal Cord. These results are comparable to the results obtained by Shizhang Wu [7] where chest and abdomen have highest passing rate and head and neck have the least passing rate.

Correlation Between MU and Gamma Passing Rate:

The quantity of MU delivered is an indicator of treatment efficiency. The higher the total MU, lower the treatment efficiency. Hence, the total MU in treatment plans optimization to be controlled. The passing rate improves by this and also the treatment efficiency.

Confidence Limits:

When the large number of data points are to be evaluated, an additional quantity of Confidence Limit is introduced by Venselaar (2001) [8] which combines the systematic and random deviations. The confidence limit is based on the average difference between measurements and calculations for a number of data points in a comparable situation, and the standard deviation (SD) of the average of the differences. The confidence limit is then defined as the sum of the average deviation and 1.5 SD. The factor 1.5 was based on experience and a useful choice in clinical practice. A multiplicative factor of 1.96 instead of 1.5 proposed by Palta et al [4] for having 5% of the individual points exceeding the tolerance level.

As per TG-119 the CL was found and it was 4.6 and Detectability Threshold (DT) calculated (100-CL) was 95.4. These values show that the overall the IMRT QA results are stable and of statistical significance.

Various Normalization Methods:

Global normalization applied to the maximal value of the calculated dose distribution. In contrast the local normalization applied to the currently evaluated pixel. Both the local and global γ have advantages and disadvantages. The local tends to highlight failures in regions of high dose gradient, and in the global, these failures are less evident but show the errors within the high dose regions within the dose distributions.

Nelms et al [9] also mentioned as Global normalization focuses only on the maximum dose, it hides the error in the low dose region and leads to insensitivity in gamma analysis especially in the 3%, 3mm passing criteria. But irrespective of the low dose threshold value in global normalization with 3%,3mm criteria, the passing rate is above 95%. Hence, we conclude that the low dose threshold has less impact in global normalization method.

In contrast to the global normalization, in local normalization with increase in the low dose threshold the gamma passing rate increases. Among the low dose threshold studied 5 and 10 %, the 5% has gamma passing rate 90.19% for 3%, 3mm criteria.

Generally, a low dose value falls on the periphery of target or penumbra regions. However, if low dose falls on the Organ at Risk it could cause fatal consequence. Moreover, the low dose has the risk of causing secondary cancer especially in pediatric cases. Hence Low doses should be evaluated strictly and delivered. The impact of low dose threshold is high in local gamma analysis. Applying 5 % low dose threshold value in the gamma passing rate is as low as 90 %. Thus, applying various threshold values in local gamma analysis would be a helpful approach to evaluate the gamma passing rate.

V. CONCLUSION

We tried to evaluate various parameters of treatment planning and gamma evaluation which affects the Gamma Passing Rate. As far as Monitor Unit (MU) is concerned, a negative correlation is found between the MU and Gamma Passing Rate which shows the MU should be controlled in the planning system to have better Gamma Passing Rate. By this not only the passing rate increases but also the treatment efficiency improves which has clinical relevance.

We also tried to find the correlation between various treatment sites and gamma passing rate. The lowest passing rate was seen in Brain and Head and neck. This could be because the study selected were all close to the Organ at Risk like Brain Stem, Optic chiasma in brain and Spinal Cord in Head and Neck which are highly constrained.

We conclude that in Global normalization method, the gamma passing rate is above 95% irrespective of low dose threshold value using 3%,3mm criteria whereas in Local normalization method, the gamma passing rate is only 90% when the low dose threshold value is 5%. Hence it is recommended that adequate selection of low dose threshold value in local gamma analysis is required as it affects the gamma passing rate.

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COMPARISON OF DOSE MEASUREMENTS USING IONIZATION CHAMBER AND POINT DOSE FROM THE TREATMENT PLANNING SYSTEM AS A STRATEGY FOR THE LIMITED-RESOURCE CENTRES IN PATIENT-SPECIFIC QUALITY ASSURANCE

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Abstract— **When a verification plan is created, it generates a Monitor Unit (MU) which delivers a single fraction. The two-dimensional/three-dimensional (2-D/3-D) array detectors are suitable for performing Intensity Modulated Radiation Therapy (IMRT) / Volumetric Modulated Arc Therapy (VMAT) for Patient-Specific Quality Assurance (PSQA) as they check the fluence of entire fields. However, ionization chambers can play a significant role in the measurement of the point doses and absolute doses. The objective of this study was to compare the Dose measurement using an ionization chamber versus the Point dose in the treatment plan for Patient-Specific Delivery Quality Assurance in a Hypo-fractionated (HF) regimen.**

The mini-phantom made up of Perspex filled with water, marked with small pieces of the lead wire at the center and lateral sides were scanned with an ionization chamber placed inside of the hole at the mini-phantom. The scanned image was exported into the treatment planning system. The verification plans were mapped to the mini phantom that has been computed tomography (CT) scanned. The dose was measured at 100 cm Source-Axis Distance (SAD), at 5 cm depth. The sensitive volume of the chamber was marked and point dose measurements from the TPS were collected. The IMRT-HF plans of 33 patients were prepared after acquiring the CT dataset of each patient and their contours drawn. The verification plan was created using point dose measurements from the treatment plan. The point dose at the ionization chamber was measured based on the calculation of the TPS Analytical Anisotropic Algorithm (AAA). The measurement of the absolute dose of each patient was verified using an ionization chamber. The point dose measurements from the TPS were compared to the measurements of the absolute dose.

Median doses for measured dose by ionization chamber and TPS Point doses were 3.986±0.22Gy and 3.888±0.22Gy respectively. The minimum and maximum doses were (3.56 ±0.22Gy, 4.43±0.22 Gy) and (3.42± 0.22Gy, 4.32±0.22Gy) for measured and TPS point doses respectively. The mean doses measured by the ion chamber at 5cm depth and the point dose from the TPS were (3.9854 ±0.216) Gy and (3.8858± 0.229) Gy. The agreement in 90% of the measured dose and TPS point doses are in agreement within ±5% as recommended by the International Commission on Radiation Units and Measurements.

The agreement of the measured dose and point doses to within ±3 % suggests that the LMIC may utilize an ionization chamber for verification of the IMRT/VMAT plans.

Keywords— **Dose, treatment planning system, patient-specific quality assurance.**

I. INTRODUCTION

It has been found that in Low-Middle Income Countries (LMIC) such as Sub-Saharan Africa, there are limited resources for the treatment of cancer despite a gradual increase in new cases (Ngwa et al. 2020). It was suggested that the treatment decisions should consider increasing patient access to the treatment in the few radiotherapy equipment areas that are currently available (Ngwa et al. 2020). The novel solution proposed to use a hypofractionation regimen instead of conventional treatment (Ngwa et al. 2020) allows more patients to be treated at a given center. However, a hypofractionation regimen needs advanced radiotherapy planning such as Intensity Modulated Radiation Therapy (IMRT)/ Volumetric Modulated Arc Therapy (VMAT) which can allow dose escalation and reduce toxicity to the normal tissue (Zelefsky et al. 2000). It has been reported that the scarcity of 2D or 3D array detectors for patient delivery quality Assurance of IMRT/VMAT as among the challenges in the implementation of hypofractionation (Olatunji et al. 2023) in the HypoAfrica clinical trial. Patient-Specific Quality Assurance(PSQA) is a cornerstone in the radiotherapy workflow especially when advanced techniques are involved (Stambaugh and Ezzell 2018). It helps to discover any discrepancies between the radiation dose that is calculated by the algorithm of Treatment Planning Systems (TPS) and the dose that is delivered by the radiotherapy machine (Moran et al. 2011). This step is important to ensure the safety and accuracy of radiotherapy delivery (Moran et al. 2011). Therefore, the study aimed to show a possible strategy for PSQA in a limited resource setting such hypofractionation regimens could be safely implemented using IMRT/VMAT: Measuring the absolute dose using a mini phantom and ionization chamber compared with the point dose calculated by the Algorithm of the TPS.

The objective of this study is to compare Point Dose measurement using an ionization chamber versus Point dose in the treatment Plan as a part of Patient-Specific Delivery Quality Assurance.

II. METHODOLOGY

The mini phantom marked with small pieces of lead wire at the center and lateral sides were scanned with a slice thickness of 5mm embedded with an ionization chamber placed in the central slot provided in the mini phantom as shown in Figure 1(a). The scanned image was imported into the treatment planning system. The verification plans were mapped to the mini phantom that has been computed tomography (CT) scanned. The dose was measured at a distance of 100 cm from the Source to Axis Distance (SAD), at 5 cm depth. The sensitive volume of the ion chamber was marked and point dose measurements from the TPS were collected. The IMRT-HF plans of 32 patients were prepared after acquiring the CT dataset of each patient with the required contours. The verification plans were created using point dose measurements from the treatment plan. The verification plans were attached to the mini phantom. The point dose at the ionization chamber was measured based on the dose to the calculation of the TPS algorithm as shown in Figure 1. Then the measurement of the absolute dose of each patient was verified using a cylindrical ionization chamber placed at 5 cm depth, Source-Surface Distance of 95 cm. Then the doses predicted by the TPS at the center of the ionization chamber were compared to the absolute dose measurements by the ion chamber. All treatment plans were delivered with the gantry at zero degrees. The reference point of the ion chamber was at the central axis of the beam and 5 cm depth. The ionization chamber was connected to the Electrometer and the correction of Temperature and Pressure was performed. The fundamental equation of absolute dose measurement from IAEA -TRS 398 (Oguchi 2012)was used.

$$D_{w,Q(Zref)} = M_Q K_{TP} N_{DWQ} K_{QQ_o} \;\ldots\ldots 1$$

whereby $D_{w,Q(Zref)}$ is the reading of dose at a reference depth z_{ref}, M_Q is the amount of charges collected by the Electrometer from the ionization chamber positioned at Z_{ref}, K_{TP} Correction for influence quantities, Temperature, and Pressure. N_{DWQ} is calibration factor in terms of absorbed dose to water for a dosimeter at a reference beam quality Q. K_{QQ_o} Is a chamber-specific factor that corrects for the difference between the reference beam quality Q_o and the actual quality being used Q. When verification plans are created for either to be mapped by the Portal Dosimetry or the phantom, it uses a dose of a single fraction (3.10 Gy) with their corresponding Monitor Unit per each field. The dose measured using an ionization chamber is the dose expected to be uniformly distributed in the entire active volume of the ion chamber.

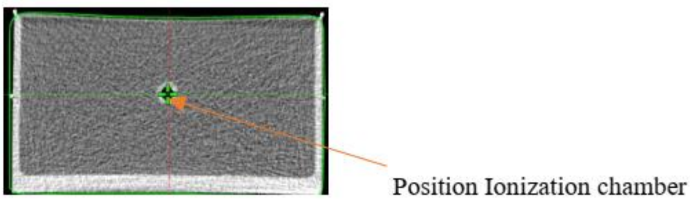

Figure1(a): The image of the mini phantom scanned before creation of verification plan

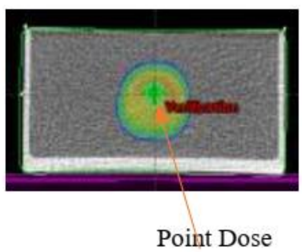

Figure 1(b): The image of the Mini-Phantom scanned Point of after creation of the verification plan

III. RESULTS

The boxplot (Figure 3) below summarizes the results of the study, the median doses for measured dose by ionization chamber and Point dose from the TPS were 3.986±0.22Gy and 3.888±0.22Gy. The minimum and maximum doses of measured and point doses from the TPS were (3.56 ±0.22Gy, 4.43±0.22 Gy) and (3.42± 0.22Gy, 4.32±0.22Gy) respectively. The average doses measured by the ion chamber at 5cm dept and the point dose from the TPS were (3.9854 ±0.216) Gy and (3.8858± 0.229) Gy respectively. Figure 4 shows the percentage deviation between measurement and prediction for all patients. Blue and orange trend lines show good agreement between the measured dose and the predicted TPS point dose. Figure 5(a) shows the relation between the Monitor Unit versus point dose and measured dose by ion chamber. The Figure 5(b) boxplot of the Monitor Unit used for verification of the plans.

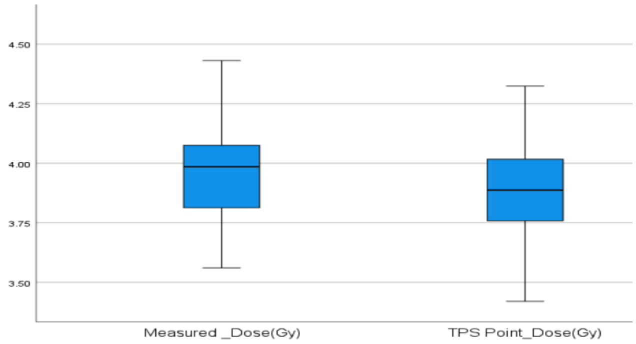

Figure 3. The boxplot of the dose Measured Ionization chamber and the TPS point dose

Table 1: Statistical information of the measurement

Parameter	Measured Dose (Gy)	TPS Point Dose (Gy)
Mean	3.9854	3.8858
Median	3.9856	3.8875
Mode	3.56	3.42
STD	0.21605	0.22936
Variance	0.047	0.053
Minimum	3.56	3.42
Maximum	4.43	4.32

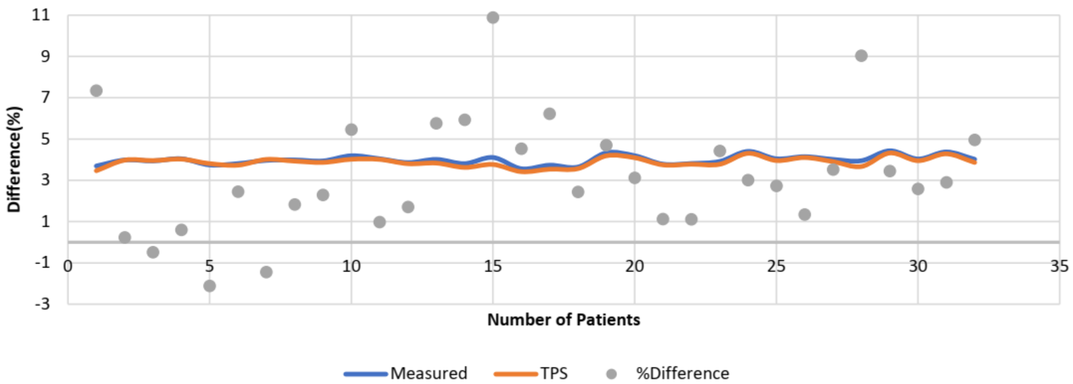

Figure 4: Agreement of the dose measured by an ionization chamber and TPS

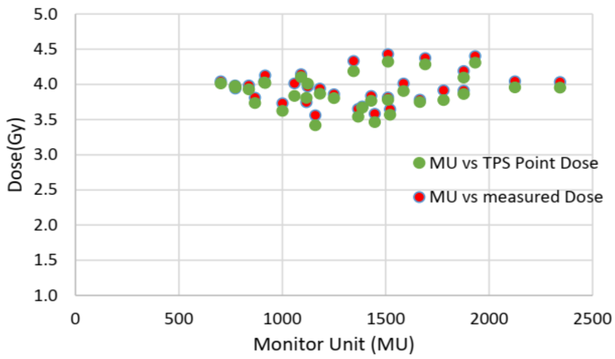

Figure 5(a): Relation between Monitor Unit and dose measured by ion chamber and point dose measurement

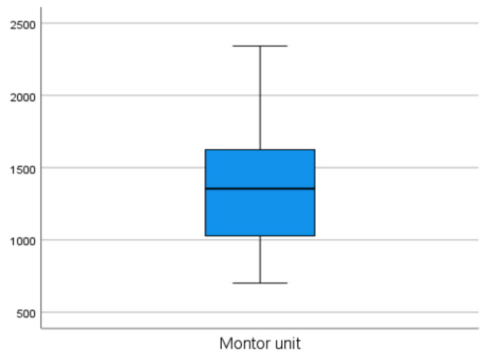

Figure 5(b): Shows the boxplot of the Monitor Unit used for verifaication of the plans

IV. DISCUSSION:

The dose measured by the ion chamber is not exactly a point dose as it is an averaged dose over several points within the chamber's active volume. 90% of the measured dose and TPS point dose are in agreement within ±5% as recommended by the International Commission on Radiation Units and Measurements. The 10% were not in agreement within ±5% may have contributed to the high-dose gradient around the point of dose verification. Therefore, lack of exact point dose in the TPS the average dose of several points around the verification point could be considered in the point dose measurement. Also, uncertainty in measuring temperature and pressure for correction of mass of air in the ionization chamber may contribute to 10% of the outliers in the selected sample. Since there is good agreement between the measurements performed by the ionization chamber and the ones calculated by the TPS algorithm, this method could be used for patient-specific Quality Assurance.

V. CONCLUSION

When a verification plan is created it generates MU which delivers a single fraction. The 2D/3D array detectors are suitable for performing IMRT/VMAT PSQA as they check the fluence of entire fields. However, the ionization chambers can play a significant role in the measurement of the point doses and absolute doses. The agreement of the measured dose and point doses suggests that the Low-Middle Income Countries (LMIC) may utilize an ionization chamber for verification of the IMRT/VMAT plans. Understanding the outliers could make this technique usable for future use in patient-specific QA in LMIC.

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HOW TO

CLINICAL INDICATIONS FOR DIAGNOSTIC REFERENCE LEVEL IN COMPUTED TOMOGRAPHY PROCEDURES

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Abstract— **Diagnostic reference level (DRL) is the investigation level used for optimization of protection in the medical exposure of patients. The DRL quantity is the value commonly and easily measured or determined radiation metric that assesses the amount of ionizing radiation used to perform a medical imaging task. The purpose of this study is to establish the local clinical indication based Diagnostic Reference Levels (LcDRLs) for the Computed Tomography (CT) procedures. Twelve CT procedures for 50 adult patients per procedure were acquired by 5 CT scanners. Both male and female patients age were 18 years old and over with the body weight ranged from 45 to 75 kg or the body mass index (BMI) ranged from 19 to 29 kg.m^{-2}. The twelve clinical indications selected were: 1. Head-trauma, stroke, infarction; 2. Head - tumor, infection, metastasis; 3. Sinus- sinusitis and polyps; 4. Cervical spine-trauma, herniation, degenerative disease; 5. Chest – unclear chest symptom; 6. Chest - follow up-metastasis, staging, tumor evaluation, dyspnea; 7. Chest -metastasis, staging, tumor evaluation, dyspnea, unclear symptom, first exam; 8. Chest CTPA - thrombus detection; 9. Chest HRCT – interstitial lung disease, bronchiectasis; 10. Cardiac – detection of calcified plaques and coronary vessels, calcium score non-contrast acquisitions; 11. Abdomen–detection, follow up of hepatocellular carcinoma, cholangio-carcinoma; 12. Abdomen/pelvis – detection of stone. The radiation metric, volume computed tomography dose index ($CTDI_{vol}$), dose–length product (DLP), total DLP, and scan length are recorded. The LcDRLs is set at the median values of the distribution of the data and 75th percentile of the distribution of the median quantity for national clinical indication diagnostic reference levels, NcDRLs. If the regional cDRLs are available, they should be set as the median values of the NDRLs values for the countries in the region. The LcDRLs of the CT procedures were established and compared to the NDRLs, and the gold standard of RDRLs, European Study on Clinical Diagnostic Reference Levels for X-ray Medical Imaging (EUCLID).**

Keywords— **clinical indications DRL, median, third quartile, optimization, CT procedures**

I. INTRODUCTION

Use of Computed Tomography (CT) scans has increased significantly due to their speed and accuracy in diagnosis, crucial for timely patient treatment [1-9]. However, the cost-effectiveness and appropriateness of the radiation exposure associated with CT scans, which tends to be higher than conventional X-ray examinations are questionable. Reports also highlight potential risks and hazards associated with the cumulative radiation exposure from all medical imaging procedures, which induce to cancer development in patients [10-15].

In the past, each medical institution has emphasized the importance of providing radiation doses with CT scans by setting dose levels according to anatomical-based diagnostic reference levels (DRLs), without considering individual patient conditions [16-20]. However, nowadays, several institutions recognize the significance of tailoring radiation doses according to specific clinical indications [21-24]. This approach leads to better outcomes for patients, as it ensures appropriate radiation doses while maintaining diagnostic efficacy. For instance, the urinary tract stones may necessitate focusing on specific disease areas that do not require higher radiation doses for accurate diagnosis. However, with advancements in technology and more sophisticated equipment, it is feasible to reduce radiation doses and compensate for examinations in certain disease areas, thus lowering patients' radiation exposure risk. It is worth noting that besides considering anatomical-based DRLs, determining radiation doses tailored to specific disease areas can maximize patient benefits and appropriateness of care.

DRLs are originally defined [18] for an anatomical location, with lacking information on the clinical indication and on the procedure. Such the information strengthens the significance of DRLs, as they correspond to a better specified setting and would ultimately provide a stronger tool for optimization and comparisons between centers or countries. Therefore, the definition of clinical indication-based diagnostic reference levels, cDRLs, should be a combination of disease and symptoms, anatomical location and of the used technique. The concept is applicable for CT examinations in Thailand. Twelve clinical indications were proposed according to the concepts. Identified parameters including the number of phases, scan and reconstruction techniques, protocol details, reference phantom size etc. were reported. The facility with radiation dose monitoring software collect the data of $CTDI_{vol}$, DLP per phase, total DLP and the scan length in order to establish cDRLs for those clinical indications. Patient size is selected from the body weight, 45-75 kg, or BMI, 19-29 kg.m^{-2} that is the standard size for Thai people. Optimization should be performed after the radiation dose reduction and the image quality assessment. The second clinical indication DRLs after the anatomical DRLs should be obtained and led to the establishment of the LcDRLs in Thailand.

II. MATERIALS AND METHODS

Study design and setting

The analytical, observational, retrospective study is conducted at Department of Radiology, King Chulalongkorn Memorial Hospital. The Institutional Review Board, Faculty of Medicine Chulalongkorn University approved the IRB No. 0891/65 COA No.0247/2023 title "Local and Clinical DRLs of Computed Tomography procedures at King Chulalongkorn Memorial Hospital". The data were included for diagnostic CT examinations from five CT scanners of adult patients aged 18 years and older between January 1, 2021 and December 31, 2022. The body sizes ranged from 45 to 75 kilograms (60±15 kg) or body mass index (BMI) 19-29 kg.m^{-2}. The examinations for research, surgical or interventional procedures, the hybrid systems i.e. PET/CT, SPECT/CT and for radiation oncology guidance were excluded.

Data from fifty adult patients were collected for each CT protocol. Total number of patients were 600. The radiation metric of volumetric computed tomography dose index, CTDIvol, in the unit of mGy, dose length product, DLP per phase (mGy.cm), total DLP (mGy.cm), and the scan length (cm) are collected to estimate the local cDRLs using the radiation dose monitoring software, Radimetrics™ Enterprise Platform (Bayer HealthCare, Whippany, NJ, USA) installed in 2017, current version 3.4.2. The anatomical-clinical indication based protocols are shown in Table 1.

Table 1 Twelve anatomical-clinical indication protocols with/without contrast and number of phases

Anatomy	NC/C	Clinical Indication	Phases
1. HEAD	NC	Trauma, Stroke, Infarction	1
2. HEAD	NC+C	Tumor, Infection, Metastasis	2
3. SINUS	NC	Sinusitis and polyps (Screening)	1
4. CERVICAL SPINE	NC	Trauma, herniation, degenerative disease	1
5. CHEST	NC	Unclear chest symptoms	1
6. CHEST	+C	Metastasis, tumor evaluation, Dyspnea, Unclear symptom) F/U	1
7. CHEST	NC+C	Metastasis, Staging, tumor evaluation, Dyspnea, Unclear chest symptom, 1st Exam	2
8. CHEST CTPA	+C	Thrombus detection	1
9. CHEST HRCT	NC	Interstitial lung disease, bronchiectasis	max 3
10. CARDIAC	NC	Detect calcified plaques and coronary vessels (Calcium score)	1
11. ABDOMEN	NC+C	Detection, F/U of HCC, Cholangio Carcinoma	max 4
12. ABDOMEN/ PELVIS	NC	Detection of stones	1

The national diagnostic reference levels, NDRLs Thailand, in diagnostic imaging-anatomical based, was established in 2021 by the Department of Medical Science, Ministry of Public Health, Thailand. The NDRLs of CT procedures –anatomical based, 75th percentile of CTDIvol and DLP is shown in table 2. In 2023, the updated NDRLs Thailand of CT procedures is shown in table 3.

Table 2 National Diagnostic Reference Level of CT procedures, 75th percentiles of CTDIvol and DLP, established in 2021 in Thailand

CT Procedures	CTDIvol (mGy)	DLP (mGy.cm)
Brain without contrast media	62	1028
Brain with contrast media	52	935
Chest without contrast media	18	417
Chest with contrast media	18	665
Whole abdomen without contrast media	18	717
Whole abdomen with contrast media	20	717

Table 3 National Diagnostic Reference Level of CT procedures, 75th percentiles of CTDIvol and DLP, established in 2023 in Thailand.

CT Procedures	CTDIvol (mGy)	DLP (mGy.cm)
Chest and whole abdomen, venous phase *	14.4	1001
Pulmonary artery (CTPA), arterial phase	12.7	495
Angiography of the whole aorta, arterial phase	12.2	860
Angiography of the thoracic aorta, arterial phase	12.2	490
Angiography of the abdominal aorta, arterial phase	13.8	667
Angiography for stroke fast track, arterial phase	26.2	1095
Urinary stone, non-contrast phase *RCRT	13.6	625
Angiography of coronary artery, arterial phase - Prospective gating	18.7	233
- Retrospective gating	60.2	976
Coronary artery, calcium scoring	6.2	85
Neck, venous phase	16.1	504
Upper abdomen, venous phase	34.3	548

III. RESULTS

In order to establish the local clinical indication diagnostic reference level, LcDRLs, the radiation metric data is statistical analyzed to obtain the 50th percentile (median) of CTDIvol (mGy), DLP (mGy.cm), total DLP (mGy.cm) and scan length (cm) from twelve CT anatomy (clinical indication) protocols with three hundred patient data as shown in Table 4.

Table 4 Establishment of the Local Clinical Indication DRL (KCMH) with 12 CT clinical protocols.

CT procedures: Anatomy (Clinical Indications)		CTDI (mGy)	DLP (mGy.cm)	Total DLP (mGy.cm)	Scan length (cm)
1.	HEAD (Trauma, Stroke, Infarction)	47	1011	1011	22
2.	HEAD (Tumors, Infection, Metastasis)	47	1033	2066	22
3.	SINUS (Sinusitis and polyps)	30	457	457	16
4.	CERVICAL SPINE (Trauma)	18	496	496	27
5.	CHEST (Interstitial Lung disease, Bronchiectasis)	9	373	373	40
6.	CHEST F/U exam (Metastasis, Staging)	9	381	381	41
7.	CHEST (Metastasis, Staging,1st Exam)	9	367	745	40
8.	CHEST (Thrombus detection)	12	389	389	34
9.	CHEST (Interstitial lung disease)			307	
	Axial Inspiration HRCT	1	29	-	30
	Helical Inspiration Chest	7	259	-	40
	Axial Expiration HRCT	0.6	17	-	28
10.	CARDIAC (Calcium score NC)	3	43	43	16
11.	ABDOMEN (Detection, F/U of HCC)	11	333	1325	31
12.	ABDOMEN/ PELVIS (Detection of Stones)	7	359	359	49

IV. DISCUSSION

The European Union, EU, has formally introduced the concept and the mandatory use of DRLs in every Member State since 1997. Most of the existing DRLs (independently of the imaging modality) have been established based on anatomical locations. However, some limitations of this approach were pointed out for computed tomography (CT) as, for the same anatomical location, one could have several clinical indications with consequently different protocols corresponding to different exposure levels. For example, chest CT could correspond to the work-up for pulmonary embolism, lung cancer, or even coronary calcium scoring, each of which requires corresponding image quality parameters and scan length, and hence should have different DRLs [5]. The concept was introduced to Thailand by the International Atomic Energy Agency Expert of the RAS 6088 in 2022. The project title is “Strengthening Education & Clinical Training Programmes for Medical Physicists” The local diagnostic reference level was established at King Chulalongkorn Memorial Hospital in 2023. (Table 4)

The European Study on Clinical Diagnostic Reference Levels for X-ray Medical Imaging, EUCLID, identified ten common clinical indications for undergoing CT protocols [3]. EUCLID category of “stroke” most closely aligns with a routine head CT performed to exclude hemorrhage, so brain perfusion scans and cerebrovascular CT angiograms were excluded.

Table 5 EUCLID: CT DRLs for ten clinical indications investigated in the survey. (2014)

Body region	EUCLID Clinical Indication	CTDIvol EUCLID	DLP (mGy.cm)	Total DLP (mGy.cm)	Scan Length (cm)
Head	Chronic sinusitis	11	188	211	16
	Stroke	48	807	1386	18
Neck	Cervical spine trauma	17	455	495	23
Chest	Coronary calcium scoring	4	72	81	17
	Lung cancer	8	348	628	47
	Pulmonary embolism	9	307	364	35
	Coronary CT angiography	25	415	459	17
Abdomen	Hepatocellular carcinoma	9	354	1273	37
	Colic/abdominal pain	8	436	480	48
	Appendicitis	9	498	874	49

The LcDRLs of King Chulalongkorn Memorial Hospital, KCMH, in table 4 is compared to the NDRL United States [24], which the 75th percentile of the distribution of the median has been used**.** In order to compare to the EU of regional, RcDRLs, the median values of the NDRLs values for the countries in the region has been used. [24]

Table 6 Median doses (50th percentile) for $CTDI_{vol}$ (mGy) and DLP (mGy.cm) in the EU and KCMH and (75th percentile) for United States (US), for $CTDI_{vol}$ (mGy) and DLP (mGy.cm)

Body region	EUCLID category	US	EU	KCMH	US	EU	KCMH
		(75th)	(50th)	(50th)	(75th)	(50th)	(50th)
		$CTDI_{vol}$	$CTDI_{vol}$	$CTDI_{vol}$	DLP	DLP	DLP
Head	Chronic sinusitis	26.9	17.6	30.1	446	265	457
	Stroke	56.2	37.8	46.9	1072	691	1011
Neck	Cervical spine trauma	24.1	11.3	18.1	609	256	496
Chest	Coronary calcium scoring	8.0	1.6	2.7	125	34	43
	Lung cancer	11.9	3.5	9.3	478	130	373
	Pulmonary embolism	14.9	3.7	12.2	594	138	389
	Coronary CT angiography	26.5	5.5	-	914	180	-
Abdomen	Hepatocellular carcinoma	12.5	6.9	10.9	1773	683	1325
	Colic/abdominal pain	12.6	6.9	-	645	325	-
	Appendicitis	14.5	8.9	-	880	433	-

$CTDI_{vol}$ and DLP of KCMH were highest for sinusitis. The rest of KCMH radiation metric were in between EU and US. The discrepancy among both DRL are according to the scan length, number of phase and CT parameters and this study was pilot study without optimization. In order to optimize the CT patient dose, the radiology team should plan to include the image quality to adjust the mentioned parameters to obtain the appropriate image quality with patient dose reduction.

Clinical indication of Diagnostic Reference Level is influenced by several factors such as image quality, scan length/collimation, number of phases/projections/images that affect patient dose. Different image quality is needed for different clinical indications of the same anatomical location. Kidney stone (high-contrast structures) evaluation, using lower radiation doses than appendicitis (low-contrast structures, high image noise).

In addition, the new technologies of CT machine have featured that aid in adjusting protocols to suit clinical conditions. For instance, in some diagnostic procedures, the dual energy technique can be utilized to generate Virtual Non-Contrast images instead of performing a true non-contrast phase. This approach can significantly reduce radiation exposure and enhance contrast enhancement at various energy levels, thus minimizing the need for repeated scans in cases where the scan does not align with the contrast phase or when patients have compromised kidney function and can only tolerate limited contrast injection. Moreover, these technologies can assist in diagnosing underlying conditions.

V. CONCLUSION

The established anatomical based of NDRL Thailand on CT protocols was in 2021 and 2023. The local clinical indication diagnostic reference level of 12 CT procedures has been introduced in 2022 and established in 2023 at King Chulalongkorn Memorial Hospital, Bangkok, Thailand. The median values of $CTDI_{vol}$, DLP per phase, total DLP and the scan length were calculated. Our results showed the highest $CTDI_{vol}$ and DLP for chronic sinusitis. The large number of phases and extensive scan lengths result in high total DLP values, Head 2066 mGy.cm. The comparison of our results to NDRLs US of 75th percentile and EUCLID RDRLs at 50th percentiles of similar categories shows that our results are lower than NDRL US but higher than EU except sinusitis. Three procedures of our results are not available – CTA, colic/abdominal pain and appendicitis. The factors influenced the radiation metric were the scan length, collimation, the number of phases, and CT parameters including the image quality. The optimization of radiation protection is planned for the patient dose reduction by adjustment of the CT protocols, and then revised the LcDRLs. The patient clinical indication is one of the most important factors for the dose optimization in CT procedures. There is a need to develop knowledge, skills and competences of health professionals involved on the use of CT equipment to improve the use of available dose reduction tools. More efforts are needed towards end user training on dose optimization.

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ESTIMATION OF CANCER RISK ASSOCIATED WITH PATIENTS UNDERGOING BRAIN COMPUTED TOMOGRAPHY SCAN IN SOKOTO, NIGERIA

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Abstract— **In this research conducted in Sokoto, the aim was to estimate the cancer risks associated with brain computed tomography (CT) scans and find ways to minimize the negative effects of radiation exposure. The study collected data from 100 adult patients with an average weight of 70 ± 10 kg from two centers. The data collected included exposure factors, CT Dose Index ($CTDI_{vol}$), and Dose Length Product (DLP). The effective doses for both centers were assessed using Imaging Performance and Assessment of CT (imPACT) dosimetry software with the National Radiological Protection Board (NRPB) SR-250 dataset. The results showed that the mean effective dose for Center A was 2.8 mSv for males and 2.6 mSv for females, while for Center B, it was 1.4 mSv for males and 1.5 mSv for females. The mean probability of Lifetime Attributable Risk (LAR) of cancer development was calculated as 1 in 515 for males and 1 in 428 for females in Center A, and 1 in 1127 for males and 1 in 914 for females in Center B. The overall estimated cancer risk for all patients in both centers was 1 in 592. The estimated cancer risks in this study were found to be higher than those reported in national and international studies. Therefore, authors of this study emphasize the need for regular quality assurance assessments of the CT machines used in the two centers in Sokoto to prevent overexposure and minimize radiation-related risks to patients. In conclusion, this study highlights the importance of estimating cancer risks associated with brain CT scans and the need for ongoing monitoring and quality assurance to ensure patient safety and minimize radiation exposure.**

Keywords— **Cancer risk, CT scan, Effective dose, and ImPACT CT.**

I. INTRODUCTION

Cancer is a global health concern, and its incidence has been increasing steadily over the years. Diagnostic imaging techniques, such as computed tomography (CT) scans, play a crucial role in the early detection and diagnosis of various medical conditions. However, the use of ionizing radiation in CT scans has raised concerns about potential health risks, particularly the risk of developing cancer. In Nigeria, like many other developing countries, the availability and utilization of CT scans have significantly increased in recent years. However, limited data and research exist regarding the potential radiation-related risks associated with these procedures. Therefore, it becomes imperative to assess the cancer risk associated with patients undergoing brain CT scans in Sokoto, Nigeria. The primary objective of this study is to estimate the cancer risk attributable to ionizing radiation exposure from brain CT scans in Sokoto. By quantifying the potential risks, medical personnel, policymakers, and patients can make informed decisions regarding the use of CT scans and implement appropriate safety measures to minimize radiation-related health hazards.

To achieve this objective, the study employs a prospective cohort design, utilizing data from a sample of patients who have undergone brain CT scans in Sokoto. The sample includes individuals from various age groups, both genders, and with different medical indications for the scan. Information regarding radiation doses, imaging protocols, and patient demographics are collected from medical records and imaging databases. Radiation risk estimation was based on established radiation dosimetry methods and models, which take into account the specific radiation exposure parameters associated with brain CT scans. The estimated cancer risk is expressed as the excess lifetime cancer risk per unit dose of radiation, and the results compared with established international guidelines and reference values.

It is expected that the findings of this study will provide valuable insights into the potential cancer risks associated with brain CT scans in Sokoto, Nigeria. By understanding the magnitude of these risks, healthcare professionals can optimize radiation doses, develop tailored imaging protocols, and implement effective radiation protection measures to ensure patient safety without compromising diagnostic accuracy. Moreover, this research is envisaged to contribute to the limited body of knowledge concerning radiation risks in Nigeria, serving as a foundation for future studies and aiding in the formulation of evidence-based guidelines and policies. Ultimately, the aim is to strike a balance between the diagnostic benefits of CT scans and the associated cancer risks, fostering a culture of radiation safety in medical imaging practices.

This paper presents an introduction to a study focused on estimating the cancer risk associated with patients undergoing brain CT scans in Sokoto, Nigeria. By addressing the gaps in knowledge regarding radiation-related risks and providing evidence-based insights, this research has the potential to significantly impact healthcare practices, radiation safety guidelines, and ultimately, the overall wellbeing of patients in the region.

II. METHODOLOGY

A prospective quantitative research method was chosen to estimate the cancer risk associated with patients undergoing brain CT scan examinations in Sokoto. There was no adjustment of the data collected from the centers.

A) Method of Data Collection

The data was collected using a well-structured data collection sheet designed for the study and the Ethical clearance with code NHREC/30/012/2019 was obtained from the centers. The following information was recorded:

i) Patients' bio data such as age, gender and weight
ii) Scan parameters such as kV, mA, slice thickness, number of slices and pitch factor
iii) Dose description parameters namely, CTDIvol and DLP.

B) Method of Data Analysis

The data were analyzed using SPSS statistics software for estimating mean, range, standard deviation and 75% percentile data. Dosimetry software such as commercially available ImPACT CT patient dosimetry calculator version (1.0.4.xls) was used to calculate the effective dose and this was used in calculating the cancer risk of an individual patient and risk associated with gender at both centers A and B.

III. RESULTS

The LAR of cancer incidence for brain CT examination was varied depending on age, gender and effective dose for every individual CT examination (Tajudeen *et al.*, 2018). The lifetime attributed risk (LAR) of cancer incidence was estimated for different ages and gender from 0.1 Gy equivalent dose using BEIR VII Report Phase 2 (2006). In each case where data was not available for specific age, the matrix interpolation was performed based on the two nearest tabulated ages. The general expression for calculating the LAR of cancer incidence for brain CT with respect to the patient effective dose in (mSv) is given by the mathematical equation.

$$LAR_{at\ an\ age} = \frac{E\ (mSv)}{D} \times \frac{LAR\ cancer\ incident_{at\ an\ age}}{100{,}000}\ \%$$

Where D is equivalent dose equal to 0.1 Gy, constant for adult from 16-80 years that receive effective dose of 0.1-10 mSv (Tajudeen *et al.*, 2018). The statistical summary of the risk of LAR for both male and female at the study centres is presented in (Table 1) and (Table 2), the mean effective dose and estimated lifetime attribute risk of cancer incidence for both male and female for centres A and B is summarized.

Table 1: Mean, range (min & max) dose E and estimated LAR for male patient

Parameters	No of Patients	E (mSv)	LAR %
Centre A			
Mean± SD	32	2.8±1.1	0.1940±0.08
Range		1.1-5.5	0.03-0.38
Centre B			
Mean± SD	17	1.4±0.5	0.0887±0.34
Range		1.0-2.8	0.03-0.31
Total A+B			
Mean± SD	49	2.3±1.2	0.1589±0.08
Range		1.0-5.5	0.03-0.38

Table 1 presents the statistical summary of lifetime attributable cancer risk for male patient in both centers. Centre A recorded the highest mean attributable risk of cancer with 0.1940% and mean effective dose of 2.8 mSv, while Centre B recorded 0.0887% risk with mean effective dose of 1.4 mSv. The combined result shows that male patients recorded 0.1589% of total attributable cancer risk with mean effective dose of 2.3 mSv.

Table 2: Mean, range (min & max) dose E and estimated LAR for female patient

Parameters	No. of Patient	E (mSv)	LAR %
Centre A			
Mean±SD	28	2.6±1.05	0.2335±0.11
Range		0.9-5.5	07-0.510
Centre B			
Mean±SD	23	1.5±0.5	0.1093±0.09
Range		1.0-2.8	0.03-0.17
Total A+B			
Mean±SD	51	2.1±1.0	0.1761±0.12
Range		0.7-5.5	0.03-0.51

Table 2 shows the female LAR, in which Centre A had a highest risk of cancer incidence of 0.02335% with mean effective dose of 2.6 mSv, and Centre B recorded lowest risk of cancer incidence of 0.1093% and mean effective dose of 1.5 mSv. The combined results show that female patient statistics have 0.1761% attributable cancer risk incidence with mean effective dose of 2.1 mSv.

Table 3: Comparison of estimated mean LAR of cancer due to CT brain scan for male and female in study centers

Centres	Male		Female	
	Mean LAR %		Mean LAR %	
A	1 in 515	0.1940	1 in 428	0.2335
B	1 in 1127	0.0887	1 in 914	0.1093
A+B	1 in 629	0.1589	1 in 567	0.1761

Table 3 shows the comparison of LAR of cancer due to CT brain imaging procedure for male and female patients. The mean value of LAR of cancer for male patient is 1 in 515 and for female patient was 1 in 428 for Centre A while male recorded LAR of cancer 1 in 1127 and 1 in 914 for female in Centre B. The cumulative result shows the males had LAR of 1 in 629 and female had 1 in 567 at the study centres. Smith-Bindman *et al.*, (2009), obtained the estimated LAR of cancer for routine head CT in females to be 1 in 8100 and of males to be 1 in 11080. Shaiful (2018) estimated the LAR for head CT as 1 in 248 for males and 1 in 332 for females. From the results, it could be deduced that cancer risk is relatively higher for patients who underwent CT brain imaging in this study.

IV. DISCUSSION

The estimated LAR of cancer was 0.1940% for males and 0.2335% for females in centre A, and 0.0887% for males and 0.1093% for females in centre B. The total LAR of both centers is 0.1589% for male and 0.1761% for female. The approximate percentage for any person to have a cancer was assessed to be 1 in 515 for male and 1 in 428 for female in centre A, while 1 in 1127 for male and 1 in 914 for female in centre B while the total for all the patients in male and female were 1 in 629 male and 1 in 567 females, respectively. For the entire patient population, it was estimated that 1 in 592 patients received a similar effective dose during examination.

The findings of this study show that the statistical summary reveals the age range 21-30, 31-40 and 41-50 years have higher frequency of CT examination, and this could be attributed to the fact that they have percentage risk of cancer incidence, the age group are agile and engaged in many activities that make them susceptible to accident which subjects them to undergo brain CT examinations.

The LAR of cancer incidence also depends on the individual effective dose received by patients and also on the age. Example, people above 65 years are considered weaker healthwise, and hardly survive fatal accidents, largely because many of them might have other ailments such as hypertension, diabetes, and heart related problem, therefore many of them may not live long enough to experience the effects of cancer radiation after exposure to radiation from CT scans.

V. CONCLUSION

This study provides evidence that radiation exposure from commonly performed CT examinations in Sokoto is relatively higher compared to other studies, contributing to a substantially increased risk of cancer. There is therefore the need to optimize CT procedures from this part of Nigeria to ensure patient safety and protection during scanning.

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BOOK REVIEW

DIGITAL MOLECULAR MAGNETIC RESONANCE IMAGING
By Bamidele O. Awojoyogbe, Michael O. Dada

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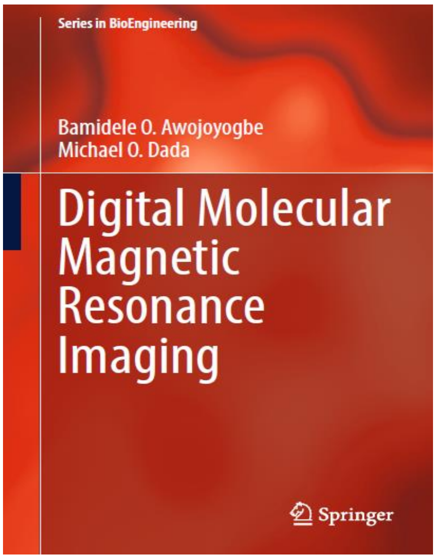
I. BOOK DETAILS

Digital Molecular Magnetic Resonance Imaging
Authors: Bamidele O. Awojoyogbe and Michael O. Dada
Publisher: Springer Nature, Singapore
eBook: 365 pages
ISBN: 978-981-97-6369-6
978-981-97-6370-2 (eBook)



II. REVIEW

Digital Molecular Magnetic Resonance Imaging is an elaborately packaged reference manual for medical physicists, computer scientists, engineers, research scientists, and medical professionals at any level of their respective careers. The choice of topics covered in the content is also well-suited for undergraduate and postgraduate students of these respective fields.

Published as a Series in BioEngineering, the book has fifteen (15) chapters, each of which is independent of the other, presented sequentially to describe the theory of the primary source of signal for magnetic resonance imaging (MRI) and how the nuclear magnetic resonance (NMR) properties of various imaging samples can be manipulated at the molecular level to provide various signal characteristics in MRI for tissue characterization. With a common theme running through all the chapters of the book, each chapter has its own introduction describing the objective, theme and content presented, with in-text citations listed as references at the end of the chapter.

The main themes covered in the book include NMR and MRI theories, NMR signal and image processing techniques, artificial intelligence (AI) and machine learning techniques for digital healthcare, optimization of machine learning algorithms for image classification and diagnosis, application of physics-based knowledge and machine learning in studies of molecular dynamics and tissue characterization toward understanding of origins of disease, development and deployment of computerized platforms to perform various tasks in image processing, and democratization of MRI access through quantum computing. In summary, the book is absolutely an excellent guide for MRI data processing, analysis, classification and by extension development of advanced methods for imaging science applications. The subject matter is well articulated and presented in a comprehensive manner that will keep any MRI enthusiast glued to the text to the very last page.

The following contents in the book are worthy of mention to the prospective reader:

The opening chapter describes the fundamental theories of NMR, spin relaxation, and diffusion relating them to imaging features in MRI. By combining physics-based knowledge with neural networks, methods are suggested and implemented in step-by-step procedures for denoising, feature extraction, and segmentation of MR images. Imaging scientists interested in understanding the use of the image processing pipelines in FSL particularly for functional MRI studies will definitely want to read chapter 1 of this book.

As an important physiological parameter in MRI, the origins of temperature generation and distribution in the body are simulated using physics-informed neural network methods in chapters 2, 7 and 8. This provides the molecular basis for hyperthermia and its influence on quantum mechanical properties of tissue, as demonstrated by thermal diffusivity, conductivity and blood perfusion in the kidney and skin (presented in chapter 8). Biophysicists, mathematicians, and computer scientists will find these three chapters very useful and interesting to read.

Chapter 3 opens the door to a more fascinating mix of mathematics, physics, computing, medicine and imaging sciences. From chapter 4 onward, the reader will find more useful content about development and optimization of various image processing and classification algorithms based on a combined model of physics-based knowledge and artificial intelligence (AI). The authors demonstrate tact in laying excellent foundation for each chapter, highlighting the major research and clinical problem being investigated and solved intelligently (which will amaze the reader) using physics principles implemented through machine learning. Of particular interest is the extension of this combined model in chapter 11 where a scheme for molecular MR fingerprinting of disease to explain the origins of pathology is presented. The challenge of access to big data for model training and simulation is carefully surmounted by the authors by depending on various image data repositories, links to which have been provided in all cases. Thus, the book does not only provide relevant content to teach, inform and guide, it also provides very useful datasets to research scientists in the field of machine learning.

In chapters 5 and 6, the focus turns to telemedicine and personalized healthcare. Using relaxometry data, the utility of machine learning is demonstrated in the design of a web-based service android application as a first-line decision support system for diagnosis of cardiovascular and Alzheimer’s diseases, respectively.

While chapter 9 examines the selection of a high-performing deep learning model for accurate brain tumor classification using brain MR images, chapter 13 implements a refined version of the model tailored for web-based application for brain MRI processing and tumor classification. The work presented provides a ready-to-use platform for clinicians to use as first-line diagnostic tool in brain cancer examination and staging by uploading brain MR images of patients to the platform.

Medical image processing and analysis software generally display images in 2-dimensional views, restricting the flexibility of the user to view images from varied angles at their convenience. Normally, 3-dimensional displays offer more flexibility for image analysis, surgical planning, training, and telemedicine applications. An established framework based on neural radiance fields (NeRFs) for 3-dimensional image reconstruction and rendering is presented succinctly in chapter 10. As a general concluding remark in chapter 14, the potential scope of applications and power of NeRFs in coordinate-based 3-dimensional display of images for enhanced rendering effects are discussed.

While implementing quantum artificial intelligence to demonstrate magnetic resonance imaging at low and high fields in chapter 12, the authors advocate for capacity building and establishment of research laboratories to implement quantum computing in chapter 15, the last chapter. Based on research experiences so far, quantum computing solutions can be leveraged to deploy MRI applications in resource-limited settings as a promising step toward democratization of MRI access. Low-field MRI systems are relatively cheaper to procure and maintain, and are largely built to satisfy the needs of resource-constrained settings. Such MRI systems however have lesser imaging capabilities compared to the commonly installed clinical systems at relatively high field strengths. In practice, the performance of low-field MRI systems can be upgraded through digital quantum computing to solve most of the MRI accessibility issues in resource-limited settings. Practical steps toward achieving this feat are outlined in this last chapter of the book.

These last few concluding paragraphs from the book sum up all it has to offer its prospective readership:

In predictive analytics and deep learning, quantum computing offers the potential to process vast datasets far more efficiently. This efficiency could significantly advance AI’s ability to predict outcomes from large and complex data sets, such as personalized medicine.

In summary, the proposed laboratory for research and capacity building in ***Digital Molecular Magnetic Resonance Imaging*** *will be a digitally generated magnetic resonance signal using the fundamental Bloch NMR flow model equation, Physics-informed Neural Networks (PNN) and Artificial Intelligence to design and deploy magnetic resonance systems with the capacity to work in a digital manner with features of low cost, high performance and accuracy.*

As we peer into this quantum horizon in MRI, a new initiative involving International Society for Magnetic Resonance in Medicine (ISMRM), World Molecular Imaging Society (WMIS), top related research institutes and companies should be motivated to establish Quantum MRI computing laboratories in strategic regions to democratize access to quantum computing that may be able to tackle some of the most pressing global challenges in modern medicine bridging physics and digital health.

In conclusion, the book is a good source of information to readers from a wide range of disciplines beyond physics in medicine focusing on the topic of MRI. It is highly recommended for any reader desiring to explore varied methods of data analysis leveraging automated or computerized models at high speed and accuracy in results.

III. REFERENCE

B.O. Awojoyogbe, M.O. Dada. Digital Molecular Magnetic Resonance Imaging. Springer Nature, 2024. Singapore Pte Ltd. https://doi.org/10.1007/978-981-97-6370-2

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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.

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

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Page Layout: 2 columns layout.

Alignment: Justified.

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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.

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

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

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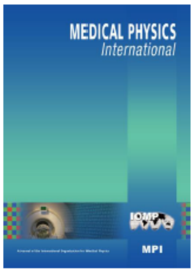

Fig. 1 Medical Physics International Journal

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

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

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

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