DEVELOPING KNOWLEDGE ON PRACTICES FOR IMAGING IN RADIOTHERAPY THROUGH ICRP MENTORSHIP PROGRAMME

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Abstract– **Task Groups of the International Commission on Radiological Protection (ICRP) publish reports giving recommendations and guidance on the safe use of ionising radiation in a variety of applications. For the preparation of reports background material and information on current radiological practices need to be gathered from around the world. Sometimes the feasibility of new techniques for use in different locations may need to be investigated. ICRP launched a mentorship programme to enable early career radiation scientists to participate in this preparatory work and broaden their experience in radiological protection. Task Group 116, which is concerned with imaging in radiotherapy, assembled a group of mentees from 22 countries throughout the world. The mentees have participated in a variety of projects involving surveys of current practices, literature searches and reviews, experimental measurements to investigate dosimetry techniques, computer modelling and data analysis. Many young enthusiastic medical physicists eager to participate in improvement projects are often working at hospitals in countries where medical physics is still at an early stage of development and so have more limited professional support. The mentorship programme provides research opportunities with scientific backup through virtual meetings at which mentees can discuss findings from their projects with more experienced scientists and researchers. This enables them to obtain advice on the analysis of results, highlight issues that arise and air new ideas and suggestions. This paper describes the evolution of work by the mentee network linked to TG116. Initiatives of this type can promote the involvement of early career medical physicists in implementing medical developments with support from virtual forums, demonstrating the value of the scientific approach of medical physicists in healthcare.**

Keywords— **Mentorship, ICRP, cone beam computed tomography, imaging, radiotherapy**

I. INTRODUCTION

The International Commission on Radiological Protection (ICRP) has the mission to provide recommendations and guidance on radiological protection based on an understanding of the science of radiation exposures and effects, and value judgements taking account of societal expectations, ethics, and experience. Reports are prepared by Task Groups (TGs) set up to address specific topics and often require a significant amount of background investigation into the current state of knowledge and radiological practices around the world. In 2019, ICRP launched a mentorship programme to assist TGs in carrying out the background work required when getting ready to assemble a report. The programme provides opportunities for emerging radiation scientists worldwide to broaden their experience in the field of radiological protection through participation in the work of ICRP TGs and also provides mentees with an opportunity to gain insight into ICRP processes. In this way the programme can help to strengthen expertise in radiological protection, a need identified in the ICRP Vancouver Call for Action [1] supported by 19 other international organizations [2]. Moreover, the programme is able to attract and involve early-career medical physicists from a wide geographic range, many of whom have limited contact with radiation scientists in their own country, especially in Asia, Africa, and South America where numbers practicing in some scientific professions are limited. The wide geographic distribution of mentees enriches the work of the TGs and assists in ensuring the relevance of recommendations in a global setting. The link with ICRP is helpful in encouraging support from employers and national organizations, as well as providing a way for ICRP experts to assist with initiation and follow-up of the introduction of recommendations. The programme can provide early-career scientists with an opportunity to carry out investigations, which can then be discussed with experienced scientists and researchers in a virtual forum to assist in interpreting results and identifying problems. After a brief overview of the mentorship programme, this paper describes the development of a project linked to a TG in imaging in radiotherapy involving a survey of practices, followed by development of an experimental technique, and finally a survey of patient imaging doses.

II. THE ICRP MENTORSHIP PROGRAMME

The mentorship programme is designed to offer applicants with appropriate backgrounds and experience from any educational, governmental, private or other organization a part-time voluntary position as a mentee. There are no fees and the mentee's home organization bears all costs associated with the mentorship, but the programme provides an opportunity to work as part of an international team broadening their experience in the field while contributing to the background knowledge necessary for writing the reports. Mentees are assigned a specific role, task, or project that is defined in advance, but this can be developed during the mentorship period with the agreement of mentor and mentee, as knowledge of the topic evolves and needs of the TG change. Examples of typical projects that have been undertaken by medical physicists are:

- Carrying out background literature searches and reviews
- Making measurements such as on medical equipment performance or dose levels.
- Carrying out computer calculations or simulations.
- Participating in the organisation of surveys, data collection, and analysis.

Mentorship positions are advertised on the ICRP website (https://www.icrp.org/page.asp?id=465) and persons interested must submit an application, setting out their expertise and explaining why they are interested in the specific project. They must also include a letter of support from their employing organization. The assignment is for a pre-set initial period, typically one year but can be renewed as the project develops. Selection of mentees is based on expertise of the applicant as well as consideration of diversity and regional representation. The mentor is normally a member of the TG and is responsible for providing guidance and support to the mentee. At the end of the mentorship period, the mentor and mentee each submit a brief confidential report about their experiences and these are being used to gradually improve the mentorship programme. Renewal of the mentorship for a further period depends on requirements of the TG and will take account of the mentee's performance.

III. THE USAGE OF IMAGING IN RADIATION THERAPY

A. Improvements in radiotherapy treatments

Improvements in the capability of linear accelerators to conform radiotherapy treatments to tumour targets have created a need for additional imaging at the time treatments are delivered to achieve the necessary accuracy. The use of image guidance has increased substantially in the last decade and the delivery of more focused radiation treatments has led to better patient outcomes [3] and is regarded as essential for some treatments [4]. ICRP, aware of the increased use of image guidance, set up TG 116 to prepare recommendations and guidance on the radiological protection aspects of imaging in radiotherapy in 2018. The aim is to prepare a report giving an overview of the use of imaging in radiotherapy and provide guidance on optimization of radiological protection aspects related to imaging practices. Most imaging is undertaken with kV X-ray imaging systems incorporated into linear accelerator radiation treatment machines that can be used in a stationary position for plain radiographic images or with the imaging system rotated around the patient for cone beam computed tomography (CBCT). Imaging may be carried out at every fraction for many treatments and the increased use of x-ray imaging exposes normal tissues in the region surrounding a tumour to more radiation. As a result, there are risks, firstly that doses to organs lying near the boundary of the planned target volume may rise above respective tolerance doses [5], and secondly that second primary cancers may be initiated in tissues within the larger volumes surrounding the targets included in images [6]. There is evidence of an association between malignancy in children having CT scans at organ dose levels below 100 mGy [7].

B. A survey of the use of imaging in radiotherapy

The TG decided to advertise positions for mentees for two tasks 1) to carry out a literature survey of imaging practices in radiotherapy and 2) to undertake Monte Carlo simulations to evaluate dose levels from CBCT imaging systems. The call for mentees yielded ten applicants from a broad range of countries with low-, medium-, and high-income levels distributed across six continents. Most of the applicants had medical physics experience, although few had relevant computing experience or access to computing facilities that would enable them to carry out Monte Carlo simulations and several applicants were from countries that did not have well-developed medical physics communities. Since development of knowledge and skills, especially among early career medical physicists in countries such as those from which applications had been received, was a key objective of the mentorship programme, TG members were reluctant to reject these applicants. When reviewing the literature available on image guidance in radiotherapy, it had become apparent that the radiotherapy centres covered were almost exclusively in more developed nations and the TG members realized that it would be useful to have more information about imaging practices in radiotherapy for countries such as those from which mentee applications had been received. Therefore, a new project was set up for the mentee applicants to survey imaging practices in radiotherapy in their own countries. The aim was that each would participate by carrying out a survey of practices in as many radiotherapy centres as they were able to persuade to participate. Periodic virtual meetings were arranged to provide information and discuss results. These were irregular in the early stage but have now settled down at a frequency of about every two months.

The survey would be conducted online, and a questionnaire was developed with the Survey Monkey ® platform by a sub-group of medical physicists within the TG. The TG was ambitious about the amount of information that could be gathered since there would be a mentee with local knowledge and contacts based in each country. The survey comprised a mixture of numerical questions about radiotherapy treatment and imaging equipment and practices, and free text fields for comments on reasons for choices, modifications made to protocols, and the use of national or international guidance documents. The finalized questionnaire contained 130 separate items on practices in each centre and some of these aspects are summarized in Table 1.

The nine mentees appointed contacted groups of radiotherapy centres within their countries and asked each centre to identify a representative to take responsibility for completion of the survey questionnaire. This was done largely through the mentees' contacts, but in higher-income countries, the national medical physics societies helped by providing contacts. Participation in the survey was organized in two parts. Mentees were provided with a link to send to the representatives at each centre, through which they could register and opt into the survey. The initial contact link explained the purpose of the survey, sought agreement that the centres were willing to participate, and collected the representative's email addresses to which links to the full survey were sent. Since the survey was relatively long, the individual links were left open, so that representatives could complete the various sections over several sessions.

The mentees liaised with the different centres, following up on any questions and providing clarification of the requirements. Since only countries with a mentee participated, the survey could only give a snapshot of practices, but it enabled a substantial amount of information to be gathered. The survey was left open for 3½ months, between August and November 2020, and as the deadline approached mentees reminded centres with incomplete submissions and encouraged them to finish the questionnaire. A total of 143 centres registered an initial interest, and 100 completed the full questionnaire in nine countries. Each mentee was responsible for collating the data for their country in an Excel spreadsheet, investigating unexpected responses, and calculating percentages of centres with specific types of facility or carrying out particular practices. Results from the survey were collected centrally and analyzed. Results were discussed with the mentees in several ZOOM meetings and have been reported in the literature [8].

Table 1. Information requested in the questionnaire completed by radiotherapy centres

Pages	Information requested	No. of questions
1-3	General facility information • Facility and local contact details • Type of facility: Public / Private / Academic • Number of patients treated per month • Percentage of treatments using image guidance • Availability of imaging physicists for consultation	22
4	Imaging equipment used for planning • CT Systems (Makes and number) • Other imaging modalities (Types and number)	9
5	Treatment machines and associated imaging facilities • No. of linear accelerators (Makes and dates of commissioning) • No. of Cobalt-60 treatment units • No. of linacs with kV imaging capabilities	8
6	Types of imaging used during treatment • Types of imaging procedures used • Types used for paediatric treatments	18
7-12	Imaging during six specific types of treatment • Imaging modalities used • Frequency of imaging for radical treatments	30
13-16	Optimization undertaken for different X-ray imaging modalities • Use of protocols as supplied by the manufacturer • Adaptation of protocols for individual patients • Recording of dose quantities for individual patients	29
17	Additional information • Types of QC performed on imaging systems • Frequencies for performing QC	14
	Total	130

The survey showed that radiotherapy centres in all countries employed image guidance, but the number of units with kV imaging facilities available and the frequency of imaging were lower in low- and middle-income countries. The imaging technique used most frequently immediately prior to treatment was kV cone beam CT (CBCT) imaging, where this was available. Relationships between practices and the income and development of the countries in the survey were investigated through comparisons with the Human Development Index (HDI) value as defined by the United Nations Development Programme [9]. The HDI combines indices of life expectancy, education, and per capita income with values increasing with the level of development to a maximum of 1.0. The survey revealed that irrespective of their level of development, countries outside Europe recorded little or no information on patient doses from imaging used for treatment guidance. This was despite full CBCT scans being acquired at the start of each fraction of most radiation treatments, potentially including 30-40 fractions [8]. Equipment operators need to have a knowledge of the dose levels used to allow them to assess the impact of any change in practice. If the dose levels are not apparent from the clinical images, optimization will not be possible. This proved to be important information for finetuning the scope and recommendations in the TG 116 report to improve optimization of radiological protection for imaging in radiotherapy.

C. kV cone beam CT dosimetry project

Following the findings of the initial survey of imaging practices, a second mentee project was started in 2022 to investigate dose levels for kV-CBCT systems incorporated with linear accelerator treatment machines. This was to identify suitable dose quantities that could be measured and used for assessing patient doses and look into the feasibility of radiotherapy centres across the world carrying out surveys [10]. Another call was made for ICRP mentees in 2022, and the number was increased to 22 to extend the project to more countries with the hope of eventually initiating surveys of imaging doses in radiotherapy centres around the world. Patient dose audit is a process, widely used in diagnostic radiology, whereby median patient doses for particular procedures are determined from surveys at each centre and compared against a standard [11]. The standards used for diagnostic medical exposures are called diagnostic reference levels (DRLs). They provide a dose benchmark, against which facilities can compare their practices and identify whether optimization of imaging protocols may be required [12]. Dose reference levels (DRL_{RT}s) for imaging used in treatment planning [13] and imaging prior to radiotherapy treatment [14] have in recent years been established in the UK from national surveys. Surveys across multiple countries should provide reference data for developing a dose audit programme that can be applied more widely.

The standard dosimetry quantity recommended by the International Electrotechnical Commission (IEC) for display on CT scanners is $CTDI_{100}$, which provides an indication of CT dose levels. The accepted tool for measurement is a 100 mm long pencil radiation detector measuring air kerma. The CTDI is the measurement normalized by the nominal width of the CT beam relative to the length of the detector. The pencil detector may be used free in air to assess the output of a CT scanner or within standard cylindrical phantoms made of polymethyl methacrylate (PMMA), 150 mm long, and 320 mm and 160 mm in diameter, representing the body and head, respectively. Since the distribution of CT radiation inside the patient's body is nonuniform, i.e. radiation intensity decreases as the beam penetrates inside the body, the pencil chamber is placed in holes in the phantoms' centres and at four positions at 90º intervals around the periphery to make dose measurements. A weighted value for the $CTDI_{100}$ measurements made in a phantom ($CTDI_w$) is derived to give an indication of the dose to tissues within the region scanned and takes the form:

$$CTDI_w = \frac{1}{3} CTDI_c + \frac{2}{3} CTDI_p$$

where $CTDI_c$ is the $CTDI_{100}$ measurement at the centre of the phantom and $CTDI_p$ is the average of the four $CTDI_{100}$ measurements made at peripheral positions. The CTDI concept to capture all the radiation within the narrow fan beams of conventional CT scanners is designed for beam widths of ≤40 mm [15], but cone beams used in radiotherapy equipment are wider than both the lengths of the 100 mm ionization chamber and the standard 150 mm long phantoms [16-18].

The IEC has defined a wide beam CTDI measurement ($CTDI_{w,IEC}$) as a standard quantity for display on cone beam CT systems [15, 19], which is a development of the $CTDI_{100}$ for narrow beam CT scanners. This is closely related to the weighted $CTDI_w$ for narrow beam CT scanners. A practical method for measurement of the $CTDI_{w,IEC}$ for wide beams using $CTDI_{100}$ dosimetry equipment has been described in IAEA [19] and is based on the acquisition of $CTDI_{100}$ measurements for a reference beam of width ≤40 mm within the standard PMMA CT phantoms with a correction factor equal to the ratio of $CTDI_{100}$ measurements free in air for the wide beam of interest and the reference beam [15, 19, 20]. Calibration of the displayed quantity should be verified to enable imaging performance to be compared against national or international reference data. However, display of the wide beam CTDI on clinical linac CBCT systems has so far been variable, so its use as a dose audit quantity for large scale surveys of patient doses is impractical at the present time. Moreover, the calibration check requires a series of measurements for each kV / filter combination being used that are not straightforward. Looking towards the future, all CBCT systems should aim to display the $CTDI_{w,IEC}$ values. However, for the purposes of carrying out a dose survey at the present time, an alternative approach was required. Moreover, to enable centres to contribute dose measurements for multiple systems, this needed to be relatively straightforward, and a plan was developed (table 2).

A dosimetry quantity called the Cone Beam Dose Index (CBDI) has been proposed by Amer et al. [21]. The CBDI relates to the level of dose to the patient capturing the effect of kV and filtration. The CBDI involves measurement of the cumulative dose for a CBCT scan with a 100 mm pencil detector within standard cylindrical PMMA CT phantoms, but with the 150 mm long phantom lying entirely within the cone beam. Dose measurements are made at the centre and periphery of the phantom and combined to give a weighted value $CBDI_w$ as for the standard $CTDI_w$ (equation 1). This method has been applied in clinical practice [22-24] and the recent UK study of CBCT doses has demonstrated the feasibility of applying the method in a patient dose survey [14], so this approach was adopted as the measurement to be used.

Initial discussions with the mentees revealed that few radiotherapy centres had access to 100 mm pencil detectors or standard cylindrical PMMA CT phantoms. A small survey of the availability of radiation measurement instruments and phantoms showed that less than 50% of centres in the mentees' home countries had access to CT measuring equipment. However, almost all centres had 0.6 cc Farmer ionization chambers and slabs of solid water or similar phantom material with holes to take a Farmer chamber that were used for dosimetry on radiation therapy beams [25]. A cubic phantom measuring 300 × 300 × 300 mm^3 comprised of slabs of solid water or similar material could be assembled with slabs containing holes for the Farmer chamber at the centre and two others at the top and bottom of the pile. The slabs are taped together to enable measurements to be made in different orientations to replicate measurements with the cylindrical CT body phantom. The equivalent diameter of the phantom averaged over a 360º rotation is approximately 337 mm and so is similar in attenuating properties to the 320 mm CT body phantom. This method could be developed as a first line of attack, where the recommended CT measurement equipment was not available. The $CBDI_w$ for cylindrical phantom and 100 mm detector was chosen as the standard to be taken forward, with other approaches being designed to give a measurement that could be compared with the standard in the early stages of the project (table 2).

Table 2. Steps in development of dose measurement method and initial patient data collection

1 <u>Project design</u>

Identification of a suitable quantity for measurement of cone beam dose
- Review of dosimetry quantities available and practicality of measurements
- Choice of cone beam dose index (CBDI) measurement with 100 mm detector inside a 32 cm diameter cylindrical phantom as method of choice

2 <u>Survey of equipment available in RT centres</u>

Survey of radiation dose measuring instruments and potential phantom materials available in radiotherapy departments

- 100 mm pencil radiation detectors
- 0.6 cc Farmer chambers
- Cylindrical CT PMMA phantoms
- Slabs of water-equivalent material

3 <u>Selection of experimental method used by each centre</u>

Identification of options for phantoms that all centres can use
Investigation into the use of phantoms measuring 300 mm x 300 mm x 300 mm constructed from water-equivalent slabs as an alternative to CT body phantom.
Comparison of measurements and determination of adjustment factors to give CBDI values with the following experimental configurations (by centres with different experimental equipment):

- Cylindrical 320 mm and 160 mm CT phantoms with 100 mm CT chamber
- Cylindrical 320 mm and 160 mm CT phantoms with 6 cc Farmer chamber
- Slab phantom measuring 300 mm × 300 mm × 300 mm with 6 cc Farmer chamber

Select experimental configuration to be used for measurements based on available equipment and take measurements at their own centres

4 <u>Dosimetry measurements</u>

Make measurements at other centres or ask colleagues to make measurements with the chosen method for each beam quality (kV and filtration) to be assessed.

- Applications may use different mAs values, but the same beam quality
- Single measurements can be used for different treatments with the same kV and filters.

Analyze results for normalized dose and compare different CBCT systems
- Analyse data calculating the doses per mAs
- Apply calibration / conversion factors
- Investigate reasons for differences based on kV, filtration, field size, etc.

Carry out Monte Carlo simulations of different experimental approaches and compare with experimental measurements

5 <u>Patient dose assessments</u>

- Collect data on standard treatment protocols for specified treatments
- Calculate cumulative doses for each application by multiplying by the mAs
- Collate results for different centres within each country
- Compare cumulative doses for each application at different RT centres
- Identify units for which doses are higher and try to identify reasons

Mentees were asked to take measurements at their own centres to establish the technique and would later ask colleagues to carry out similar measurements at other centres. Preliminary measurements were performed in most of the countries and results were reported in terms of air kerma per mAs (tube current exposure time product). Comparisons between measurements of the CBDI with 100 mm detectors in cylindrical phantoms and ones with Farmer chambers in slab phantom cubes were made in centres, which had both sets of equipment, to evaluate adjustment factors that could be used by the participants who did not have access to CT measurement equipment, so that correction factors could be developed using a combination of results from practical measurements and Monte Carlo simulations. One mentee undertook the role of creating spreadsheets for collection of the data to allow ready comparisons to be made, another carried out Monte Carlo simulations of the different experimental arrangements, and others investigated issues relating to calibration of Farmer chambers for kV x-rays and differences in CBCT systems such as collimation and filtration. Virtual meetings every two months were an important forum for educating mentees on the principles and methods for patient dose surveys, sharing results, and discussing experimental methods, calibration of equipment, and progress in the project. This part of the project has just been completed and a paper submitted to a scientific journal [25].

D. Patient dose surveys

The next phase of the project involves collection of exposure factor data on standard treatment protocols for specified treatments at each centre. The protocol data are combined with the $CBDI_w$ data for each centre to provide information on cumulative patient dose levels used for imaging. This is the point at which doses linked to patient imaging can be compared to identify radiotherapy centres in which further optimization is required. The aim is to extend the survey through organizations within the mentees' countries and this has already been initiated via the Medical Physics Society in Poland. This project, which ultimately aims to implement national dose reference values for CBCT in Poland, is planned for a period of 2-3 years. During its course, it is planned to carry out a survey and dosimetry measurements at radiotherapy facilities in Poland in accordance with the guidelines and based on the results developed by the TG116 ICRP. The results obtained will serve as a basis for the national guidelines of the Polish Society of Medical Physics on the use of CBCT in radiotherapy and for the legal regulations on radiation protection in medicine.

The link with the ICRP has proved valuable in providing evidence of the wider scale of involvement in the projects, which has encouraged other centres to participate. In the initial stages, the dose reference level values based on $CBDI_w$ values determined in the UK survey [14] are being used as approximate comparators, until appropriate values are determined from the present survey. When analyses of the results identify centres where doses are higher, this may indicate that optimization is required, and here discussion among the mentee group and TG members will be crucial. This is the most important phase of the project and it is hoped that it will continue into the future. It will require the knowledge and experience of the TG 116 members involved and allow the mentees to develop their own expertise in the subject by carrying out investigations with TG member guidance. Cross fertilization of ideas between members of the mentee group is also proving to be an important component. The measurements proposed should give dose values suitable for benchmarking and comparing the performance of equivalent CBCT protocols for similar treatments.

IV. DISCUSSION

The ICRP Mentorship Programme has to date engaged 76 mentees worldwide across 13 TGs, with 65 currently active. TG116 mentees represent an age range of 25 to 62 years, with a median age of 33. While younger scientists are typically preferred, including older participants has expanded geographic reach and enabled the sharing of knowledge with younger colleagues in continuation of the work. This diversity enhances the programme's ability to address global radiological protection challenges.

The mentorship programme fosters a support structure for early-career scientists by integrating them into TGs initiatives that align with the ICRP's objectives. This collaborative model aids in developing new techniques, expanding knowledge, and addressing challenges specific to diverse socioeconomic and cultural contexts. It is important to emphasize that the mentorships are not a one-way process. For mentees, participation offers unique opportunities to contribute to meaningful projects, while for TGs, mentees' involvement enriches the development of their reports by providing insight from underrepresented regions and ensures broader application of recommendations.

TG116's mentorship initiative demonstrates how experimental measurements, computational analysis and international collaboration can address radiotherapy imaging challenges. For example, the evolution of the CBCT dosimetry project demonstrates the program's ability to adapt and respond to mentee's resource limitations. By engaging mentees in conducting surveys, refining dosimetry methodologies, and collecting imaging dose data, the program has provided actionable, practical, useful knowledge and recommendations about radiological protection practices across varying HDI levels. These findings have been included into TG-116's recommendations and highlighted areas for further optimization. Moreover, the mentorship model creates a dynamic feedback loop. Mentees experiences in experimental methods and surveys enable them to identify practical challenges, which TG members help address through iterative guidance via discussion of results through virtual meetings. For example, mentees' difficulty with accessing standard CTDI measurement equipment prompted the development of alternative methods using locally available resources, such as Farmer chambers, and water equivalent phantoms. This adaptability underscores the program's role in bridging resource gaps in low- and middle-income countries.

The mentorship initiative's impact extends beyond technical advancement. By connecting mentees through virtual meetings, the program cultivates a global scientific community, facilitating cross pollination of ideas and long-term collaborations. Several mentees have presented findings at national and international conferences, and co-authored several scientific publications [8, 10, 25], demonstrating the program's role in professional development. Additionally, ICRP's reputation provides mentees with institutional credibility, encouraging support from supervisors, employers and national organizations.

However, challenges remain. Limited resources in some regions constrain participation, and sustaining momentum for long-term projects requires institutional buy-in. Addressing these barriers will be critical for expanding the programme's reach to low- and middle-income countries and ensuring its sustainability. Strengthening partnerships with international organizations such as the IAEA, IOMP and EURADOS could help scale mentorship opportunities and secure funding for follow-up initiatives.

Not surprisingly, the different TGs have varying needs for expertise, but the TG116 group mentees were predominantly medical physicists and the main requirements for participation were:

- Enthusiastic early career scientists seeking an opportunity to get involved in research and development;
- Participants having sufficient skill to carry out measurements or local supervisors to assist in measurements;
- A willingness of medical physics departments to allocate time for young staff to participate in a research project;
- An umbrella organisation with sufficient standing to provide credibility for any project;
- Medical physicists with sufficient experience, time, and willingness to act as mentors for applicants;
- Sufficient information technology facilities within the organisation to provide virtual communication facilities for meetings;
- Sufficient organisational flexibility to enable projects to evolve as knowledge and experience grow.

So, what are the benefits and why should people participate in the ICRP mentorship programme? These can perhaps be summarized as:

- Facilitating transfer of knowledge and experience to early career professionals;
- Giving the potential to create global scientific communities which could continue through the scientific careers of individuals in a diverse range of countries who may be able to aid and assist each other to develop and implement new ideas in the future;
- Allowing mentees to undertake measurements and generate data from institutions around the world that would be difficult or impossible through other routes.
- Overall, the ICRP Mentorship Programme exemplifies how targeted mentorship can advance scientific expertise, address global disparities in radiological protection, and inspire early-career professionals. By continuing to support mentee-driven projects and fostering international collaboration, the programme holds the potential to transform radiological protection practices worldwide.

V. CONCLUSIONS

There are many young, enthusiastic and motivated scientists around the world. The ICRP Mentorship Programme provides a valuable means through which these individuals can cooperate in carrying out tasks. Active participation in projects, especially ones that generate results from experimental measurements or computation, with back-up from a virtual forum of more experienced colleagues, can enable early career medical physicists, who may have limited contact with local medical physics colleagues, to develop their knowledge and scientific expertise. It is hoped that the ICRP mentee programme together with other strategies and initiatives can inspire the next generation of medical physicists, in geographical regions where their presence is most needed.

In the context of TG 116, the direct involvement in the process of delivering radiotherapy to patients and close collaboration with physicians means that many medical physicists are eager to participate in initiatives to improve the quality of treatment. The problem of taking account of dose from imaging is at the heart of the concerns of many radiotherapy facilities, particularly in the absence of national guidelines. The medical physics community needs to develop ways in which they can be involved in development and demonstrate the value of medical physicists in healthcare. One way of doing this is through initiatives such as those described in this paper.

VI. ACKNOWLEDGMENTS

The authors wish to thank other Mentees involved in the projects for their enthusiastic participation in the surveys and measurements: Habib Alsaleh, Anson Ho-Yin Cheung, Mirta Dumancic, Hein Fourie, Marianna Koutrouli, Anja Lazovic, Lavanya Murugan, Aliaksandr Miadzvetski, Isabelle Nilsson, María Cristina Plazas d' Leon, Zakiya Al Rabhbi, Yiannis Roussakis, Liang Runcheng, Ana Cravo Sá, Samara Prass dos Santos, Francisco Mosquera-Pena Sánchez, Hossam Ragab Shaaban, Snezana Vostini.

The authors wish to thank the other members of TG 116 for their support: Daniel Berger, Aurelie Isambert, Stine Korreman, Choonsik Lee, Tom Merchant, Ung Ngie Min, William Small, Jenia Vassileva.

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