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BRINGING UP-TO-DATE RADIOTHERAPY TRAINING FOR MSc STUDENTS: A METHODOLOGICAL APPROACH

The field of radiotherapy is pivotal in contemporary cancer treatment, necessitating comprehensive training programs to cultivate skilled professionals. This paper explores the essential components of radiotherapy training, encompassing theoretical education, practical experience, and the integration of new technologies, as implemented in an introductory Radiotherapy Physics course within the MSc Medical Radiation Physics and Technique program at the University of Plovdiv "Paisii Hilendarskii". Additionally, it addresses the challenges and advancements in the field, highlighting the importance of continuous education and professional development.

Keywords: ***medical physics, radiotherapy physics, radiotherapy practical training, education.***

Introduction

Short notes on the Medical Physics Education in Bulgaria. Over the past decade, the field of Medical Physics has experienced a notable increase in popularity, largely attributed to its formal recognition as a profession by the International Labour Organization (ILO) in 2012. Radiotherapy, an essential modality in cancer treatment, utilizes high-energy radiation to target and destroy malignant cells. The efficacy of radiotherapy is critically depending on the expertise of trained professionals who design and implement individualized treatment plans. This is a domain where the skills of medical physicists are extensively applied and highly valued. Consequently, training students in radiotherapy is of paramount importance.

Although Medical Physics training is no longer a novel concept, its development in Europe underwent a comprehensive process of international law harmonization beginning in 1994 at the European Conference on Post-Graduate Education in Medical Radiation Physics (Roberts, Tabakov, & Lewis, 1995), and only recently concluded. Bulgaria has been actively involved in this process and was among the first countries to implement a structured approach to graduate and postgraduate Medical Physics education. It was established during the last decade of the XX century at the University of Plovdiv "Paisii Hilendarski", at the University of Sofia "St. Kliment Ohridski", at and at the University of Shumen "St. Konstantin Preslavski" (Dimitrova, Hristov, & Milieva, 2011; Litov, & Dimitrova, 2010). The

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programs in Plovdiv and Sofia are only active at the time being. However, the scope, duration, and emphasis of their curricula vary, as they fall under the academic authority of each university, resulting in a lack of a centralized and unified approach to the skills and knowledge imparted during education (Димитрова, 2014).

Two Postgraduate Specializations were delivered by the National Center for Radiobiology and Radiation Protection, Ministry of Public Health, since 1982 – Medical Radiological Physics and Medical Sanitary Physics (Minister of Health. (2018). Currently the postgraduate programs for medical physicists are running at the Medical University of Sofia and at the Medical University of Varna.

Recently a joint MSc program in Medical Physics in English was established between the two main academic institutions in Bulgaria – the University of Sofia and the University of Plovdiv (Todorka, & Dimitrova, 2021). It has combined the advantages of both universities' programs and has involved the best lecturers and clinical specialists. Since the joint program is in English, both universities have kept their original and slightly different programs in Bulgarian.

The involvement of qualified experts in Radiation Protection during any activity with ionizing radiation in Bulgaria, including medical applications, is mandated by EC Directive 97/43/Euratom (European Commission, 1997). The academic education and training in Medical Physics (MP) is aligned with the EFOMP and IOMP Policy Statements (European Commission, 1997; EFOMP, 1984a, 1984b, 1998; IOMP, 2012a, 2012b). The statute of Medical Radiological Physicists is established through state regulations for Standard in Radiotherapy (IOMP, 2012b) and Standard in Medical Imaging (Министъра на здравеопазването, 2021), and the regulation for Radiation Protection in Medical Treatment of the Personnel (Министъра на здравеопазването, 2018).

According to IOMP Policy Statement No. 2, the minimum educational qualification for a Medical Physicist is a university degree or equivalent (level corresponding to a master's degree) majoring in medical physics or a related scientific field (IOMP, 2012b). This also includes requirements for professional training and certification. Recently, the medical physics community in Bulgaria has achieved this standard.

In 2022 the professions "Physicist, Medical Physics" (code 21117026) and "Physicist, Medical Physics Expert" (code 21117027) were incorporated into the National Classification of Occupations and Nominations (NCPD) under the proposal of the University of Plovdiv and the University of Sofia. This inclusion was supported by the Bulgarian Society of Biomedical Physics and Engineering (BSBPE), The Union of Scientists in Bulgaria – Plovdiv (USB – Plovdiv), the National Center for Radiobiology and Radiation Protection (Ministry of Public Health), and the Medical Universities Hospitals in Plovdiv and Sofia.

The profession "Physicist, Medical Physics" requires a master's degree in medical physics. The profession "Physicist, Medical Physics Expert" requires a master's degree in medical physics, and a three-year postgraduate specialization, including

5 years of clinical practice after that. The specializations in Radiation Medical Physics are dedicated to Medical Imaging, Nuclear Medicine and Radiation Therapy.

In recent years, practical training in radiotherapy at the university level was limited for various reasons. Our students visited the Radiotherapy Clinic at the Saint George University Hospital for Active Treatment, where they were introduced to all facilities, including accelerators, Cyberknife, and treatment planning rooms. They had opportunities to discuss different issues with clinical medical physicists and radiation therapy doctors. Many students prepared their diploma theses at this clinic. However, only graduates employed in a radiotherapy department were able to perform hands-on training in treatment planning.

We have recently adopted a new approach to involve students more actively in practical sessions. In this paper, we provide an in-depth analysis of the training program, methodologies, and challenges faced in preparing students for careers in radiotherapy, as implemented in the introductory Radiotherapy Physics course within the MSc Medical Radiation Physics and Techniques program at the University of Plovdiv "Paisii Hilendarski". The training was conducted at the Radiotherapy and Radiosurgery Department of Pulmed University Hospital in Plovdiv.

Overview of the Radiotherapy Physics Course at the University of Plovdiv "Paisii Hilendarski". The MSc program in Medical Radiation Physics and Techniques at the University of "Paisii Hilendarski" was introduced in 1997 as part of the EC TEMPUS S-JEP09826 PHARE project (Roberts, Tabakov, & Lewis, 1995). The current MSc program has preserved the TEMPUS core courses while adapting to the recent development in this field and the new accreditation requirements (Dimitrova, 2014a, p. 127–130; Dimitrova, 2014b, p. 254–261; Dimitrova, 2015).

During the past decades, Radiotherapy Physics curricula have focused predominantly on theoretical disciplines. While this approach provides Medical Physics graduates with a good understanding of the theoretical principles underlying Physics application in medicine, it leaves them somewhat lacking in practical skills, creating a gap between university-level training and the hands-on abilities required for a successful career in radiotherapy. Recently, several new radiotherapy sites were established in Bulgaria, and existing departments have upgraded their facilities with modern radiotherapy equipment. This development has significantly increased the demand for skilled medical physicists in the field. As educators, we felt a responsibility to update and enhance the existing Radiotherapy Physics course curriculum. Our goal was to align it with contemporary advances in modern radiotherapy and to make it more relevant to the current needs and requirements of the radiotherapy physics profession. The MSc program in Medical Physics is structured as a three- or four-semesters education, depending on the prior training of the enrolled students. Students without fundamental Physics background (Chemistry, Biology and Engineering) are required to undertake an additional semester of coursework. The Radiotherapy Physics course is offered in the second semester of the first year, comprising 30 hours of lectures, 15 hours of seminars and 15 hours of practical training.

Aiming to enhance the learning experience, each lecture adhered to a standardized structure: a brief outline of the scope, clearly stated learning objectives, a comprehensive and systematically organized exposition of the topic under discussion, and several slides at the end, summarizing the key points.

The initial part of the course maintains a predominantly theoretical focus. However, basic topics covered in detail in previous modules of the MSc program were reduced or excluded altogether. Main topics included a brief summary of interactions of ionizing radiation with matter, presented from the perspective of their significance in the range of modalities used in radiotherapy, basic properties of clinical photon and electron beams, and essential radiobiological consepts such as fractionation rationales and the LQ model. Cobalt-60 teletherapy machines and orthovoltage X-ray units were also included, however the focus was on contemporary linear accelerators, including C-arm and ring linacs, Cyberknife, and specialized systems for radiosurgery.

The second part of the course was focused on the practical aspects of the medical physicist's role and responsibilities in radiotherapy. It included a detailed demonstration of the workflow in a radiotherapy clinic, starting from the initial CT scan of the patient to the final treatment delivery. Emphasis was placed on the use of various imaging modalities for volume contouring and patient position verification. Additionally, a specialized lecture was also delivered to address the various types of planning tools and strategies available, as well as the procedures for preparing dosimetric plans for common treatment sites such as pelvis, breast, head-and-neck, etc. Students were also introduced to basic concepts in advanced treatment planning and delivery techniques such as intensity-modulated radiation therapy (IMRT), volumetric modulated arc therapy (VMAT), image-guided radiation therapy (IGRT) and surface guided radiation therapy (SGRT). Finally, a dedicated lecture on quality assurance (QA) was added to the curriculum, covering basic concepts in quality management in radiotherapy.

Practical Session. A significant modification introduced this year in the Radiotherapy MSc course was the reorganization of practical sessions. The specificity of practical training necessitates close cooperation with hospitals, which is often arduous to implement. This poses several challenges in ensuring students receive adequate practical experience. In previous years, practical sessions were conducted as formal visits to clinical radiotherapy departments, where students observed key workflow points. The sessions were conducted by members of the local medical physics staff, typically individuals with extensive work experience but limited academic skills. These staff members were responsible for selecting the topics and information to be included, as well as determining the manner in which they were presented.

This year, a more integrated approach was adopted to bridge the gap between theoretical knowledge and practical skills. The practical sessions were conducted in a new radiotherapy center at Pulmed University Hospital, experienced in all major modern radiotherapy applications. Importantly, the sessions were led by Plovdiv University staff rather than local medical physicists, thus ensuring better coherence between the lectures and practical training. The practical session was divided into five parts as follows.

1. ***Linear accelerator construction and principle of operation.*** The department was equipped with two linear accelerators: a C-arm linac specifically designed for radiosurgery treatment and a fast-rotating O-ring linac (Fig. 1). Students had the opportunity to examine both types of accelerators, including inspecting some of the internal components, discussing the functions of the main parts, and assessing the differences between the two designs.

Fig. 1. O-ring linear accelerator Halcyon - view under the covers

2. ***Patient pathway in a radiotherapy department.*** Students participated in a comprehensive tour of the department, which followed the entire radiotherapy preparation and delivery process. At each stage, detailed explanations and demonstrations were provided to elucidate the procedures involved. The main steps of the tour are listed below.

CT-scanning: Discussion of main differences between diagnostic and radiotherapy scanners, main scanning parameters and reconstruction options. Demonstration of different pieces of immobilization equipment, their construction, functionalities and application (Fig. 2). Discussion of workflow: immobilization, CT-scanning, patient mark-up, CT image reconstruction and image transfer to the treatment planning system.

Fig. 2. Demonstration of head-and-neck immobilization

3. ***Visual demonstration of basic properties of photon and electron beams.*** The basic properties of clinical photon and electron beams were comprehensively discussed during the lectures, particularly regarding the dependence of dose distribution on source-to-surface distance (SSD), depth of irradiation, beam energy, and field geometry. A visual demonstration was conducted using a digitally generated water phantom in the treatment planning system to illustrate how variations in these parameters affect the dose distribution.

4. ***Demonstration of selected Quality Assurance activities.*** Due to the constraints on time available for practical sessions in the department, a selected number of quality assurance (QA) procedures were demonstrated and explained to the students. These included the integrated daily check of basic linac parameters, output constancy measurement using an ion chamber positioned in a water-equivalent plastic phantom, and isocenter size verification for gantry and collimator rotation (Fig. 3).

Contouring: Summary of planning volumes used in radiotherapy with visual demonstration of examples for two common treatment sites: lung and prostate. Summary and demonstration of critical structures relevant to different localizations.

Planning*:* Review of 3D-conformal planning techniques and demonstration of example plans for breast and prostate. Demonstration of IMRT and VMAT optimization process. Basic properties and functionalities of optimization cost functions. Plan assessment using dose-volume histograms (DVH) for target and organ-at-risk structures.

Dosimetric verification: Review of basic concepts of dosimetric verification of the treatment plan. Demonstration of 2D-dosimetric verification using Electronic Portal Imaging Device (EPID) and gamma-analysis, including typically used clinical tolerances and interpretation of results.

Fig. 3. Demonstration of output constancy check with solid water phantom as part of linac daily

Patient position verification and treatment delivery: review of patient position verification strategies and demonstration of 2D and 3D-image matching techniques.

5. Manual calculation of monitor units (MU) required to deliver prescription dose to the target.

While it is acknowledged that in the contemporary era of fully computerized treatment planning, the need to manually calculate the monitor units (MU) required to deliver a prescription dose to a specific point within an irradiated volume is rare, the authors believe that this is a powerful educational tool for consolidating the understanding of dose dependence on various treatment parameters. Therefore, it was included in the course both as part of class discussion and as a set of individual problem-solving tasks for students designed to reinforce fundamental dosimetric concepts.

Discussion and conclusions

Summary and Perspectives. The feedback received at the end of the course was overwhelmingly positive. Learners commended the clarity and systematic organization of the presentations, which improved their understanding of the material. The summary slides at the end of each lecture were particularly well-received, for their role in effectively recapping key points and facilitating review and retention of the course content.

The practical session garnered favorable responses as well. It provided a valuable opportunity for trainees to gain a visual and hands-on understanding of the theoretical knowledge they had acquired. This integration of practical experience with theoretical instruction was praised for helping learners bridge the gap between abstract concepts and real-world application, thereby enriching their overall educational experience.

Overall, the course was lauded for its comprehensive approach, combining clear and structured theoretical instruction with practical learning opportunities. This methodology not only reinforced the learners' understanding of complex concepts but also prepared them more effectively for professional practice in the field of radiotherapy.

One notable shortcoming of the course was that, despite our best efforts, the practical session remained primarily demonstrative in nature. Consequently, students did not receive an adequate amount of one-on-one, hands-on experience. This limitation has been identified as a critical area for improvement in future iterations of the course.

To address the limitations of the current course structure, the department of Physics at the University of Plovdiv has recently acquired a commercial treatment planning system for educational purposes only, thanks to the project EU project BG05M2OP001-2.016 – Modernization of higher education institutions, Operational Program Science and Education for Smart Growth (European Commission, 2014). The System will be integrated into the curriculum of the Radiotherapy Physics course. This radiotherapy planning will be integrated into the curriculum of the Radiotherapy Physics course. Advanced technology will enable students to actively engage in the creation of treatment plans themselves, rather than merely observing demonstrations. The inclusion of this system is designed to provide students hands-on experience, fostering a more interactive and immersive learning environment. By allowing students to apply theoretical knowledge in a practical setting, this approach aims to improve their practical skills and better prepare them for professional careers in radiotherapy. We are confident that the integration of this new planning system will effectively address existing curriculum limitation and will address the current limitations and lead to a more comprehensive and effective educational experience for future cohorts.

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ВПРОВАДЖЕННЯ СУЧАСНОЇ ПІДГОТОВКИ З ПРОМЕНЕВОЇ ТЕРАПІЇ ДЛЯ СТУДЕНТІВ-МАГІСТРІВ ІЗ МЕДИЧНОЇ ФІЗИКИ: МЕТОДОЛОГІЧНИЙ ПІДХІД

Сфера променевої терапії є вирішальною для сьогочасного лікування раку, що вимагає комплексних навчальних програм для плекання кваліфікованих фахівців. Досліджено основні складові навчання променевій терапії, що охоплює теоретичну освіту, практичний досвід та інтеграцію нових технологій, як це реалізовано у вступному курсі фізики променевої терапії в магістерській програмі з медичної радіаційної фізики та техніки в Університеті Пловдива "Паїсій Хилендарський". Окрім дослідження основних складових навчання променевій терапії, розглянуто проблеми та досягнення в цій галузі, а також наголошено на важливості безперервної освіти й професійного розвитку.

Ключові слова: ***медична фізика, фізика променевої терапії, променева терапевтична практика, освіта.***

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