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Original Article

The 3rd ESTRO-EFOMP core curriculum for medical physics experts in radiotherapy

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ABSTRACT

Purpose: To update the 2011 ESTRO-EFOMP core curriculum (CC) for education and training of medical physics experts (MPE)s working in radiotherapy (RT), in line with recent EU guidelines, and to provide a framework for European countries to develop their own curriculum.

Material and methods: Since September 2019, 27 European MPEs representing ESTRO, EFOMP and National Societies, with expertise covering all subfields of RT physics, have revised the CC for recent advances in RT. The ESTRO and EFOMP Education Councils, all European National Societies and international stakeholders have been involved in the revision process.

Results: A 4-year training period has been proposed, with a total of 240 ECTS (European Credit Transfer and Accumulation System).

Training entrance levels have been defined ensuring the necessary physics and mathematics background. The concept of competency-based education has been reinforced by introducing the CanMEDS role framework. The updated CC includes (ablative) stereotactic-, MR-guided- and adaptive RT, particle therapy, advanced automation, complex quantitative data analysis (big data/artificial intelligence), use of biological images, and personalized treatments. Due to the continuously increasing RT complexity, more emphasis has been given to quality management. Clear requirements for a research project ensure a proper preparation of MPE residents for their central role in science and innovation in RT.

Conclusion: This updated, 3rd edition of the CC provides an MPE training framework for safe and effective practice of modern RT, while acknowledging the significant efforts needed in some countries to reach this level. The CC can contribute to further harmonization of MPE training in Europe.

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Radiotherapy (RT) is a highly technical therapeutic approach to treat mostly cancer patients with ionising radiation. An appropriately trained multidisciplinary team, including radiation oncologists, medical physicists, RT technicians/radiation therapists/radiographers and oncology nurses, has the responsibility to ensure a safe and effective treatment for all patients. As a scientist trained in physics and specialized in medical physics, the medical physicist has a unique role in this multidisciplinary team [1]. The training of medical physicists in RT covers, beside physics topics, also medical, radiobiological, information technology and managerial aspects of RT.

The medical physicist in RT has three main responsibilities: (1) leading physics aspects of RT (including choice, commissioning and management of equipment, treatment planning, quality assurance, imaging, patient-specific dosimetry and radiation protection), (2) training of personnel, and (3) research and innovation. The medical physicist can also be involved in consultations with patients and their families on physics related topics, as described in Table 1.

The European Society for Radiotherapy and Oncology (ESTRO) and the European Federation of Organisations for Medical Physics (EFOMP) have a longstanding commitment to improve and harmonize clinical practice, science, education, and training of medical physics professionals. In 2004, ESTRO and EFOMP issued joint guidelines for the education and training of medical physicists within RT [2]. These guidelines aimed to provide both theoretical and practical requirements for education and training of medical physicists in RT. The document focused on skills and knowledge required to safely and effectively act as a medical physicist in a RT team. The 2nd edition of the CC, established in 2011 [3], was drawn up using terminology in accordance with the EU recommendations on the European Qualifications Framework for lifelong learning (EQF) [4] in which learning outcomes were defined in terms of knowledge, skills and competences. Since the publication of the 2011 core curriculum (CC), demands on knowledge, skills and competencies of medical physicists have increased due to the large increases in technological complexity of radiation equipment and treatments, and the resulting high demand on quality and risk management.

This current revised CC for MPEs in RT arises from a need to update the education and training requirements to accommodate the MPE competency needs in modern RT in the 2020′s and to facilitate the further harmonization of national education schemes in Europe.

In line with the latest EC guidelines and following the EC Council directive 2013/59/EURATOM [10], a Medical Physics Expert (MPE) is defined as a Medical Physicist who has reached EQF level 8 in one or more chosen specialities of clinical Medical Physics and can therefore independently practice Medical Physics in health care. It should be noticed that only the term "MPE" appears in European documents [6,7] and in many European countries, only the Medical Physics Expert certification exists (as opposed to a Medical Physicist – not "expert") [11]. Therefore, in this document we refer to the education and training for MPE status in RT.

The revised CC aims to provide a common standard and framework for the training of the MPE in RT to guide the development of a national MPE core curriculum with the final goal of elevating and harmonizing the level of education and training of the MPE in RT across Europe, thus facilitating cross-border mobility of the MPE, in the same way as it is for the radiation oncologists.

In this paper we report on the update process, the major changes introduced in the updated CC and the recommendations of the working group regarding implementation.

Material and methods

In September 2019, the ESTRO Physics Committee and EFOMP created a working group to update the CC for training of MPEs in RT, which met at the ESTRO office in Brussels. All European Medical Physics National Societies (NS) were invited to identify a representative to participate. The group included representatives of 17 NS, and members of the ESTRO physics committee (chair and members of the Education Council), of the Young ESTRO Committee, and of the EFOMP Professional Matters, Education & Training, Science, and European Matters Committees, representing in total 19 European countries. During this first meeting, it was agreed to launch a survey on the current education and training for MPEs in Europe, focusing, in particular, on the existence of a national training scheme, its format and duration, required entry-level education and financial support for trainees [11]. Additionally, presentations were given on national curricula of countries in which the process of updating the educational program was ongoing. A total of 28 involved Medical Physicists were divided into five working groups, each with a coordinator, according to their specific expertise. Each working group reviewed different sections of the 2011 2nd edition of the CC, identifying the areas that required revision. A second meeting was organized in Brussels in February 2020 to discuss the results of the survey and to define the final structure of the document. A first draft was developed considering:

* the 2011 2nd edition of the ESTRO-EFOMP Core Curriculum [3].
* the latest EC guidelines on MPE (RP-174) [6].
* EFOMP Policy Statement (PS) 12.1 [7].
* EC Council directive 2013/59/EURATOM [10].
* the CanMEDS 2015 Physician Competency Framework [5].

The first draft was reviewed by the ESTRO Educational Council to include considerations from all other RT professionals (Radiation Oncologists, Radiation Therapists, and Radiobiologists). All 36 National Member Organisations (NMOs) belonging to EFOMP were involved in two review rounds, and the final draft was then additionally reviewed by international stakeholders worldwide (Amer-

Table 1
CanMED framework adapted to Medical Physics Experts.

General competences	
Communicator	Communicate efficiently with peers, other healthcare professionals, hospital management, National Competent Authorities, service engineers, IT personnel. Communication with patients and families is also increasingly required
Collaborator	Effectively collaborate with other healthcare professionals in order to provide safe, high quality, patient-centred care
Leader	Take leadership in all physics and technical issues related to safe, effective and efficient delivery of RT. Motivate staff and build teams
Health advocate	Participate in patient advocacy by preparing, producing and presenting well-researched and evidenced based reports regarding advances in RT technology, techniques and radiation safety
Scholar	Engage in life-long learning through a continuing professional plan
	Contribute to the application, dissemination, translation, and creation of knowledge and practices applicable to health care
Professional	MPEs are committed to the health and well-being of patients and society through high professional standards, integrity and governmental regulation

ican Association of Physicists in Medicine, Australian College of Physical Scientists and Engineers in Medicine, Association of Medical Physics of India, Commission on Accreditation of Medical Physics Education Programs, Canadian Organization of Medical Physicists, Canadian College of Physicists in Medicine, International Atomic Energy Agency).

Results

The final version of the 3rd edition of the ESTRO/EFOMP Core Curriculum for Medical Physics Experts in Radiotherapy is available in the Electronic Appendix, and has been endorsed by 32 of 36 NMOs in the EFOMP registry. The remaining 4 NMOs have not replied yet: with 3 of them not even replying to our invitation to the revision process, suggesting a lack of interest in this project.

The document is structured in five chapters:

* Recommendations for the MPE qualification framework in Europe, including minimum entrance level, education, residency, and certification.
* General MPE competences. CanMED roles framework adapted to MPE.
* Content-specific MPE knowledge, skills and competences.
* Research and innovation.
* Assessment methods to evaluate competences.

* *Recommendations for the MPE qualification framework in Europe.*

In the first chapter, recommendations on the pre-education and the MPE training programme are provided.

It is proposed to integrate the CC in the Qualification Framework for MPEs in Europe as summarized in Fig. 1, in agreement with the EC guidelines RP174 [6] and the EFOMP PS12.1 [7] and in line with developments in the field. The minimum education level to enter the MPE training program should be a BSc degree, predominantly in physics, followed by an MSc degree in Physics or Medical Physics (BSc + MSc including in total at least 180 ECTS focused on fundamental physics and mathematics). It is understood that a candidate with these qualifications would also have a solid basis in computing and programming skills.

The knowledge, skills and competences described in the CC may, depending also on their nature, be obtained by attending courses at the university/conferences, performing self-directed study, performing clinical projects and hands-on training in the hospital, intertwining the theoretical and the practical parts of the training. The minimum time to be spent on each specific topic of the content-specific MPE knowledge, skills and competences has been defined in terms of ECTS. The recommended total duration of training is 4 years (240 ECTS), as shown in Table 2, compared to 160 of the 2011 CC.

The general MPE competences and large parts of content-specific MPE knowledge, skills and competences (chapters 2 and 3) are also relevant for training in the other Medical Physics subspecialties (Radiology and Nuclear Medicine). In addition, the Research and innovation chapter (4) represents an important part of the CC and could have links to another sub-speciality, but should be co-supervised by an MPE in RT. Out of the total 240 ECTS, 115 are specific to RT, 65 can be considered as common for all sub-

Table 2
Minimum number of ECTS for the different topics.

Specific MPE physics knowledge, skills and competencies	ECTS
III.1. Fundamentals of human anatomy, images of anatomy and physiology	2
III.2. Fundamentals of oncology and multimodal treatment	2
III.3. Core radiation physics	2
III.4. Radiobiology and radiobiological models	4
III.5. Radiation protection in medicine	5
III.6. Risk management, quality control and safety in the medical environment	5
III.7. Organisation, management and ethical issues in health care	3
III.8. Information and communication technology	4
III.9. Data processing, statistics, modelling and artificial intelligence	8
III.10. Dose determination	
III.10.1 Reference dosimetry	15
III.10.2 Non-reference dosimetry	10
III.11. Imaging for radiotherapy	
III.11.1 Principles of medical imaging and image handling	15
III.11.2 Imaging for treatment simulation	5
III.11.3 In-room imaging for set-up verification and on-line adaptive RT	5
III.12. External beam radiotherapy with photons and electrons	
III.12.1 Clinical use of treatment equipment	6
III.12.2 Treatment techniques for high energy electron and photon beams	10
III.12.3 Treatment planning	15
III.12.4 Techniques for managing geometrical and anatomical uncertainties and variations (margins, IGRT, ART)	6
III.12.5 Patient-specific quality assurance	6
III.13. Brachytherapy	12
III.14. Particle therapy	8
III.15. Principles of unsealed source therapy	2
IV. Research and innovation in radiotherapy	30
*Deepen knowledge from this CC and/or additional topics from the CC of Medical Physicists in Nuclear Medicine and/or in Radiology [14,15]**	60
TOTAL	**240**

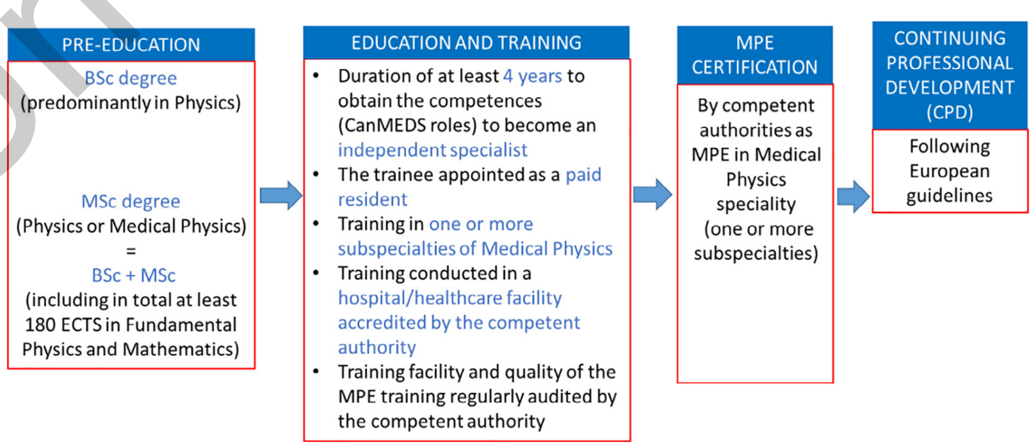

Fig. 1. Qualification Framework for the Medical Physics Expert (MPE) in Europe, as proposed in the updated CC. The proposed CC covers the second box for the RT subspecialty.

specialities and 60 ECTS of the training period are not allocated to any specific topic in the present CC. These 60 ECTS should be spent gaining a deeper knowledge of topics in this CC in addition to the minimum requirements (e.g., topics that are particularly important for the country of training), or on Radiology or Nuclear Medicine subjects from the corresponding CCs [14,15]. In addition, the total of 240 ECTs is necessary to develop required general MPE competences (Chapter 2).

The 4-year period of the postgraduate MPE training is required to obtain the competences to become an independent specialist, in accordance with the CanMEDS-based CC for Radiation Oncologists [8]. Hospitals, universities, or healthcare facilities that provide MPE training should be accredited by an official competent authority. The competent authority should have oversight of all training in the country, should regularly ensure that the MPE training is appropriate and provide a mechanism for registering and approving continual professional development [16].

Partnerships between public and private RT institutions, to ensure a homogenous education and training across the country, should be developed. Moreover, mobility of trainees to meet the requirements of the training in specific topics that cannot be performed in their own centre should be encouraged. The trainee should be appointed as a paid resident for the full training period.

After the training period, the resident should obtain the national MPE certificate, based on objective assessment of completion of a training program that fulfils the national guidelines. After certification, the MPE is expected to be able to independently work as a radiotherapy professional, while continuing professional development after the 4-year training, following European guidelines [13] is mandatory. Continuous education is recognized as an important part of the Qualification Framework for the MPE in Europe but details of its implementation and content are out of scope of the CC.

* *General MPE competences*

The concept of competency-based education was reinforced with respect to the previous CC edition, introducing the CanMEDS role framework to align the MPE training with the highest professional training level. As a member of a multi-disciplinary team working closely together to provide safe and effective treatments to patients, the MPE requires a broad spectrum of general competences, in line with the CanMEDS roles. The six CanMEDS roles are integrated in the role of MPE as described in Table 1.

* *Content-specific MPE knowledge, skills and competences*

The format of the 2011 curriculum was kept for each topic, with a short introduction to describe the area of interest, followed by a list of different levels of competences, a list of detailed items, and a list of updated recommended literature. However, differently from the previous edition, four different levels of competences, which the trainee needs to develop with an increasing level of proficiency, have been defined and are reported in Table 3. The applied core list of verbs was defined in collaboration with the educational specialist involved in development of the Radiation Oncologists' CC [8]. Table 4 shows an example.

The most recent advances in RT Medical Physics, such as (ablative) stereotactic and adaptive RT, MR-guided RT, wider use of particle therapy, advanced automation for crucial workflow components like contouring and planning, complex quantitative data analysis (big data/artificial intelligence), biological imaging and personalized treatments that require integration of imaging with clinical, genetic and biological data, were introduced or expanded. The basic knowledge of ultra-high dose rate radiotherapy was introduced as well. Since the complexity of the RT process continues to increase, more emphasis has been given to quality management, as one of the MPE main responsibilities. Computing and programming skills are implicitly required to reach the expert competences on data processing, statistics, modelling and artificial intelligence.

* *Research and innovation*

The high rate of technological development in RT also comes with an increasing need for MPE to have high-level training in research and innovation. A focused research project of 30 ECTS, performed under the guidance of a supervisor with extensive expertise in the chosen topic, is therefore an integral part of the training programme and should result in a written report.

* *Assessment methods to evaluate competences*

In this chapter, different methods adapted from the "CanMEDS Assessment Tools Handbook" [17] have been proposed to assess the competences. The different components of a possible assessment scheme must, however, be adapted according to the national education and training programme. Table 5 shows an example of methods to develop the competences during the learning phase and methods to assess the competences during the examination.

Table 3
Competences levels.

Competence	Definition	Example
Expert	to undertake independently and take responsibility for	commissioning of a new linac
Collaborative	to undertake alongside an MPE with expertise on that particular topic	MPE starting to work in a proton facility
Contributive	to undertake alongside an expert in a different discipline (RO, RTT, oncologist, radiologist, surgeon, ...)	to discuss the impact of image artefacts on the RT plan
Awareness	to be aware and have a basic understanding of other aspects of oncology	be aware how immunology or chemotherapy may be used in conjunction with RT

Table 4
Example of definition of competencies.

Topic: Data processing, statistics, modelling and artificial intelligence	
Expert competences	• ***Analyse***, *interpret and report experimental results, including uncertainties* • ***Apply*** *fundamental concepts of statistics relevant for data analysis in radiotherapy* • ***Differentiate, choose and apply*** *the most common statistical tools used in RT physics and clinical RT in a common software platform like Python, R, Matlab, SPSS, etc.* • ***Apply*** *regulations on data collection, processing and application in practice* • ***Perform*** *QA of AI/machine learning models*
Collaborative competences	• ***State*** *the principles of (big) data collection, storage and handling of data* • ***Describe*** *the working principles and training of major statistical modelling approaches and algorithms applied in RT (including radiomics, AI, etc.), needed for ensuring safe and effective clinical application* • ***Give*** *the major pitfalls in the training, validation and use of statistical modelling approaches in RT and ability of coping with them* • ***Describe*** *the basic principles of statistics for clinical trial design, cohort and case-control studies*
Contributive competences	• ***Co-lead*** *departmental acquisitions of RT software applications that rely on complex statistical data handling, based on the specific expertise*
Awareness competences	NA

Table 5
Example of methods to develop the competences during the learning phase and methods to assess the competences during the examination.

Quality assurance	Learning phase			Examination			
	Theoretical course with exercises	Supervised practical training	Independent study (homework)	Written test	Oral	Portfolio/ logbook	report
Describe and apply Quality Systems in Radiotherapy	X		X	X	X		
Build a process chart	X	X			X		X
Analyse and apply different methodologies for prospective and retrospective risk management	X	X			X		X
Explain quality improvement strategies (peer review, lean, internal audits, etc.)	X	X			X		X
Describe and plan how a comprehensive clinical quality audit is run	X		X		X		X
Identify national regulations on quality systems in RO			X		X	X	
Explain an emergency plan	X		X		X		X
Define and monitor relevant Quality Indicators in Radiation Oncology	X		X		X		X

Discussion

This paper introduces the updated 3rd version of the ESTRO-EFOMP core curriculum for MPE in RT and the process through which it was updated. This new version reflects the development of the profession towards new advanced technologies with a related enhanced attention for quality management, but also an increased weight on interdisciplinary and clinical skills, and on research and innovation.

To harmonize the training of MPEs throughout Europe, there is an urgent need to define the entrance level, i.e. the minimum number of years, format and content of postgraduate training to become an MPE.

The entrance level for training should consist of a solid base in physics and mathematics. Given the diversity of content and denomination degrees for physics and related sciences in Europe [11], the requirements for entrance level were defined based on the number of ECTS in physics and mathematics for a combined BSc/MSc degree. Although there is a variation in the definition of ECTS across Europe, this describes clearly, but flexibly, a strong physics and mathematics background.

The proposed 4-year education and training programme is a complete description of knowledge, skills and competences required to be certified as an MPE in RT, although there may be some overlap with a previous MSc program. The proposed competency profile defines competences for the MPE profession as a whole. However, individual competency development in the training may somewhat vary, depending on the specific details of the clinical practice or needs in a country or region, acknowledging that not all MPEs will necessarily possess all competences to the same degree but will pursue this as part of lifelong learning [13]. In particular, the CanMEDS roles framework [5] formalizes additional clinical skills and perspectives thus bringing the MPE professionals in line with their medical colleagues and more clearly defining the medical physics profession as a healthcare profession. This competence-based CC can easily be translated to a list of deliverables as preferred by several national training schemes.

The elements of the updated CC are in line with the recently updated CC developed by ESTRO for education and training of radiation oncologists [8]. They are also in accordance with the guidelines concerning the National Registration Schemes as given by EFOMP [9].

The CC revision process required extensive discussions in the working group and with NS due to the current significant differences between the various European countries in terms of the status of the education, training programs, national legislation and availability of resources. Hence, rather than proposing a set of requirements that would have been much easier to achieve, we have been ambitious and developed a CC with not only a long-term vision, but also bearing in mind the need to harmonize the education and training of MPEs in Europe at a higher level than was previously achieved.

The recommended qualification framework for MPE in RT deviates significantly from the current situation in many European countries [11] where the median period is three years with 50% of the time fully dedicated to RT. Nevertheless, with the increasing technological complexity of RT and medical physics in general, and greater demands on quality and risk management, the current median of three years of training with 50% of RT is too short to achieve the required competences. The enhanced technological complexity of modern RT also requires a high-level training of the MPE in research and innovation. Thus, the current average of three years is too short to cover all the areas in which the MPE should be trained, and a 4 years program is considered essential by CC group members, National Societies and stakeholders.

As MPEs in RT have a crucial clinical role, at least 50%, but preferably 75%, of the program should be spent in a hospital to acquire competences and skills that are most relevant to clinical work. This aligns with the current practice in Europe where the median percentage of time spent training in a hospital is current 75% [11]. Following this structure, the trainees will contribute to daily clinical work, under the supervision of an MPE, performing their tasks with an increasing level of independence. Moreover, the trainees can concentrate for a certain period of the training on specific topics, resulting beneficial for the hospital.

The high level of qualifications required to enter the training, combined with the intensive level of training for a period as long as 4 years demands that the residency (academic education and hospital training) be paid, in the same way as trainees in other medical disciplines.

The updated CC provides an MPE training framework for safe and effective practice of modern RT, while acknowledging the considerable efforts needed in some countries to reach this level.

The MPE training defined in this 3rd edition of the CC is intended as a goal that all European countries would aim to achieve in the near future, with the objective of improving the quality of education and training of MPEs and moving towards a harmonization of the level of MPE across Europe, which will contribute to raising the quality of RT treatment for the benefit of all European patients, in line with EU guidelines.

Uncited references

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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