

**ESTRO**



**CORE CURRICULUM  
FOR  
MEDICAL PHYSICS EXPERTS  
IN RADIOTHERAPY**

**3rd revised edition**



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## Acronyms/Glossary

ABS - American Brachytherapy Society  
ACROP - Advisory Committee in Radiation Oncology Practice  
AI - Artificial intelligence  
ALARA - As low as reasonably achievable  
ART - Adaptive radiotherapy  
BED - Biologically effective dose  
BEV- Beam's eye view  
BT - Brachytherapy  
CBCT - Cone-beam CT  
CPD - Continuous professional development  
CT - Computed tomography  
CTV - Clinical target volume  
DIBH - Deep inspiration breath hold  
DRR- Digitally reconstructed radiograph  
ECTS - European Credit Transfer and Accumulation System  
EFOMP - European Federation of Organisations for Medical Physics  
EPID - Electronic portal imaging device  
EPR - Electronic patient record  
EQD2 - Equivalent dose at fractionation of 2 Gy  
EQF - European Qualifications Framework  
ESTRO - European Society for Therapeutic Radiology and Oncology  
EUD - Equivalent uniform dose  
FMEA - Failure mode and effects analysis  
fMRI - functional MRI  
GDPR - General Data Protection Regulation  
GPRS - General Packet Radio Service  
GTV - Gross tumour volume  
HDR - High dose rate  
HVL - half-value layer  
IAEA - International atomic energy agency  
ICRU - International Commission on Radiation Units and Measurements  
ICT - Information and communication technology  
IGRT - Image-guided radiotherapy  
IMRT - Intensity-modulated radiotherapy  
IORT - Intra-operative radiotherapy  
ITV - Internal target volume  
LDR - Low dose rate  
LET - Linear energy transfer



MDE – Medical Device Engineers  
MDR- Medical Device Regulation  
MLC – Multileaf collimator  
MRI – Magnetic resonance imaging  
NTCP – Normal tissue complication probability  
OAR – Organ at risk  
OIS - Oncology Information System  
PACS - Picture Archiving and Communication System  
PDD – Percentage depth dose  
PDMS - Patient Data Monitoring System  
PDR – Pulsed dose rate  
PET – Positron emission tomography  
PRV – Planning organ at risk volume  
PTV – Planning target volume  
QA – Quality assurance  
QC – Quality control  
RBE – Relative biological effectiveness  
RT – Radiotherapy  
SBRT - Stereotactic body radiotherapy  
SGRT – Surface guided radiotherapy  
SPECT – Single positron emission tomography  
SRS - Stereotactic radiosurgery  
SRT - Stereotactic radiotherapy  
SSD – Source surface distance  
TBI - Total body irradiation  
TCP – Tumour control probability  
TMR – Tissue-maximum ratio  
TLD – Thermoluminescent dosimeter  
TPR - Tissue-phantom ratio  
TPS - Treatment planning systems  
TSEI - Total skin electron irradiation  
US - Ultrasound  
VMAT - Volumetric modulated arc therapy



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## I. Introduction

In this document we refer to the education and training of Medical Physicists working in the speciality of radiotherapy (RT) to achieve 'medical physics expert' (MPE) status in RT. A certified MPE can independently practice medical physics in health care.

### I.1 Aim of the document

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 jointly issued guidelines for the education and training of medical physicists within RT [1]. 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 first revision in 2011 [2] was drawn up using terminology in accordance with the EU recommendations on the European Qualifications Framework for lifelong learning (EQF) [3] in which learning outcomes were defined in terms of knowledge, skills and competences. Since publication of the 2011 core curriculum (CC), demands on knowledge, skills and competencies of medical physicists have increased due to the strongly increasing technological complexity of radiation equipment and treatments, and increasing demands 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. This updated CC is based on the CanMEDS [4], the latest EU guidelines (RP-174) [5] and EFOMP Policy Statement 12.1 [6].

The elements of the updated CC are in accordance with the recently updated CC developed by ESTRO for education and training of radiation oncologists [7]. They are also in accordance with the guidelines concerning the National Registration Schemes as given by EFOMP [8].

This document is intended to provide a common standard and framework for the training of the MPE in RT to guide national regulatory bodies in their own curriculum development.

We have defined four different levels of competences that the trainee needs to develop corresponding to increasing levels of proficiency in each specific topic (see paragraph III.0).

Once the training is complete, trainees should have reached the level of knowledge, skills and competences in each topic area listed in this CC and will therefore meet the requirements to become a Medical Physics Expert (MPE [5,6]) in RT, that is, able to act independently without supervision in the required topics and gain formal recognition from a National Competent Authority [9,10].

After certification, the MPE is expected to master his/her own general and specific competences in a specific area, and continue to develop with continuing professional development.

This competence-based CC can easily be translated to a list of deliverables as preferred by several national training schemes. The theoretical and the practical parts of medical physics training for RT are intertwined in this revised version of the CC, mimicking everyday practice in the RT department. A list of recommended literature is provided for each specific topic.



It should be noticed that only the term “MPE” appears in European documents [5,6] and in many European countries, only the Medical Physics Expert certification exists (as opposed to a Medical Physicist – not “expert”). Therefore, we will only refer to MPE in this document. In line with the latest EC guidelines and following the EC Council directive 2013/59/EURATOM, a Medical Physics Expert is defined as a Medical Physicist who has reached EQF level 8 in one or more chosen specialties of clinical Medical Physics. This core curriculum addresses the learning needs of the MPE in RT.

The homogeneous training of MPEs through Europe would support the harmonisation of training and cross-border mobility of MPEs in Europe.

## 1.2 The Medical Physics Expert

Medical Physics Experts in RT are members of the multi-disciplinary clinical teams responsible for the application of RT for treatment of mainly cancer patients, in line with the EU Council Directive 2013/59/Euratom [11]. The MPE has 3 main areas of responsibilities: 1. Leading physics aspects of RT (planning, quality assurance, choice and management of equipment, imaging and dosimetry), 2. Training of personnel, 3. Research and innovation.

1. Leading physical aspects of RT: introduction, development, modification and quality assurance of medical technology for treatment of mainly cancer patients. Involvement in the development of quality management programmes for up to date standard of care RT as well as radiation physics. The MPE is also qualified to give advice on, and to act in radiation protection matters for the patient, staff and public. The MPE is responsible for effective and correct use and installation of medical devices and the correct dose delivery for treatment, both for the individual patient as well as the entire patient group. The MPE designs, develops and assumes liability to the framework of radiation dosimetry and treatment planning for individual patients. The MPE actively follows new technical and physics developments in the field and evaluates (needs for) possible clinical application. The MPE determines and develops, together with radiation oncologists and the hospital management, the strategic and medical-physics policy related to the radiation therapy practice.

2. Training of personnel: responsibility for the training of MPE trainees. The MPE also teaches non-physicists the physics aspects in RT treatment and the safe and effective use of medical equipment and software.

3. Research and innovation: initiating and implementing innovations to improve treatment of cancer patients as well as performing scientific research, presenting results to colleagues, and applying them to patient treatment.

## 1.3 MPE training: minimum entrance level, education, residency, and certification

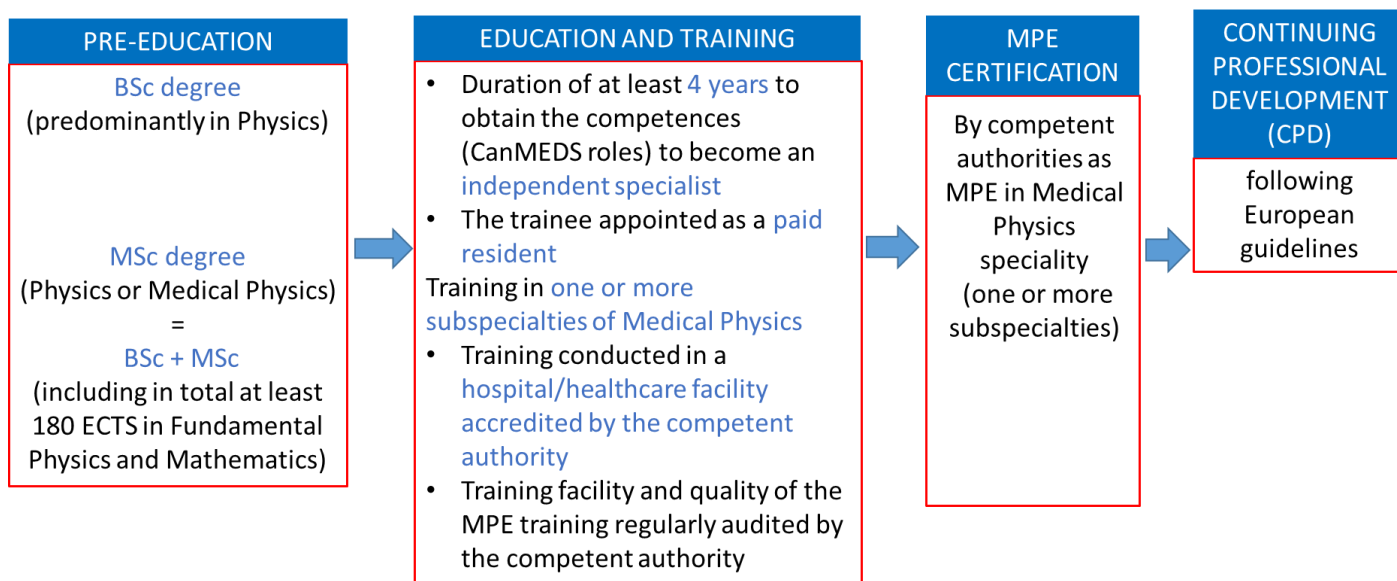




At the time of writing, the length, level and content of the education, as well as the required pre-education, still varies among the various European countries [12]. However, the European Commission Guidelines on Medical Physics Expert-RP 174- [5] and EFOMP policy statement 12.1 [6] give clear and detailed information on the role and education requirements for the Medical Physics Expert in Europe (see Figure 1 in both publications), stating as a prerequisite for MPE certification: a BSc (180-240 ECTS) in Physics or equivalent + an MSc in Medical Physics or equivalent + a structured accredited clinical residency training of two years in the Medical Physics specialty of certification + structured accredited advanced experience and, afterwards, continuing professional development (CPD, [13]) of at least 2 years.

In general agreement with the above statements [5,6] and in line with developments in the field, we suggest the following, as summarize in figure 1:

- *The minimum education level to enter an 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).*
- *The **MPE training should have a duration of at least 4 years** and the trainee must be appointed as a **paid resident**. MPE training can be in one or more subspecialties of Medical Physics. This period is required to obtain the competences (CanMEDS roles [4]) to become an independent specialist, in accordance with the CanMEDS based CC for Radiation Oncologists [7]. The MPE training should be conducted in a hospital / healthcare facility that is accredited by the competent authority responsible for this [9, 10]. The training facility and the quality of the MPE training should be regularly audited by the competent authority. After the training period the resident should obtain the national MPE certificate.*
- *Continuing professional development should be carried out following European guidelines [13] after the 4-year training.*



**Figure 1.** Qualification Framework for the Medical Physics Expert (MPE) in Europe, as proposed by this working group.

The knowledge, skills and competences described in the CC are obtained by attending courses/conferences, performing self-studies, performing clinical projects, hands-on training in the hospital, etc. The minimum time to be spent on each specific topic is given in ECTS (The European Credit Transfer and Accumulation System; 60 ECTS correspond to the workload of a full-time academic year, [14]). The total amount of ECTS for a 4-year training is 240, as shown in Table 1.

The methods to assess the competencies are described in chapter V. The competent authorities responsible for the continuous evaluation of the trainees and the following MPE certification may be different in each country [9,12].

The following should be noted:

- From this CC for MPE in RT, Chapter II (General MPE Competences) and large parts of Chapter III (especially sections 1-9) are also relevant for training in the other subspecialties (Radiology and Nuclear Medicine). In addition, the Science and Innovation (Research) part may be relevant also for other specialities than RT. So that in a medical physics schema including not only RO but also Radiology and Nuclear Medicine, the number of ECTS proposed in this CC specific for RO is realistic.
- In those European countries where the MPE certificate automatically implies a full qualification as a radiation protection officer, the amount of ECTS for section III.5. "Radiation protection in medicine" in Table 1 should be increased.
- Section III.15 is addressed to those few countries where non-encapsulated radioisotope treatments reside within the remit of the RT physics group.

- 60 ECTS of the training period should be spent to deepen knowledge of topics in this CC in addition to the minimum requirements (e.g., topics that are particularly important in the country, such as extra time for radiation protection), or on Radiology or Nuclear Medicine subjects from the corresponding CCs [15,16], given the increasing overlap of the different disciplines of Medical Physics (e.g., in those countries where the MPE is certified for several Medical Physics specialities). This freedom ECTS implies that the MPE is not an expert in everything, and he/she can further specialise in those areas after certification.

The recommended qualification framework for MPE in RO is currently far from the actual situation in many European countries [12] where the median period is three years with 50% of the time fully dedicated to RO (meaning 1.5 year fully dedicated to RO).

The proposed 4-year training programme is a complete description of knowledge, skills and competences required to be certified as an MPE, realizing that there could be some overlap with a previous MSc programme. The proposed competency profile defines competencies for the MPE profession as a whole, and individual competency sets of MPEs may vary depending on the details of their clinical practice, acknowledging that not all MPEs will necessarily possess all competencies to the same degree.

Our proposal should represent 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 towards a harmonization of the level of MPE across Europe. It should be noted that this qualification framework requires that the trainees are paid during their education and training programme, as clearly stated in figure 1.

Partnership between public and private RT institutions, to ensure the education and training can be rolled out homogeneously 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 center should be encouraged.

**Table 1.** 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. Science and innovation in radiotherapy (research)	30
<i>Deepen knowledge from this CC and/or additional topics from the CC of Medical Physicists in Nuclear Medicine and/or in Radiology [12,13]*</i>	60
<b>TOTAL</b>	240

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## II. General MPE competences

### II.1 Medical Physics Expert

The MPE in RT is a member of a multi-disciplinary team that includes radiation oncologists, MPEs, dosimetrists, biomedical engineers, radiation therapists, computer scientists, assistant medical technicians, nurses, administrators, hospital management and other healthcare professionals, working closely together to provide safe and effective radiotherapy.

Effective operation in this environment requires a broad spectrum of general competencies, in line with the following roles of an MPE. Six CanMEDS roles for medical physicists are integrated in the role of MPE:

- Communicator
- Collaborator
- Leader
- Health Advocate
- Scholar
- Professional

The Expert role reflects the level at which the knowledge of physics and medicine, and for this CC especially that of radiotherapy, radiation protection and dosimetry, are applied by the medical physicist together with clinical skills and professional values in their provision of high-quality and safe patient-centred care.

The MPE draws upon an evolving body of knowledge, scientific and practical skills, and professional values. They collect, analyse, interpret and critically evaluate information, advise on treatment and patient safety procedures, perform treatment related tasks and are responsible for the quality assurance of equipment and physics related procedures. They do so within their scope of practice and with an understanding of the limits of their expertise. Their decision-making is informed by best practices and research evidence and considers the care plan as defined by the radiation oncologist, as well as the availability of resources. Their work in the clinic is up-to-date, ethical and resource-efficient, and is conducted in collaboration with other health care professionals. The Medical Physics Expert role is central to RT and draws on the competencies included in the intrinsic roles (Communicator, Collaborator, Leader, Health Advocate, Scholar, and Professional).

#### Competences

- Lead and be responsible for the medical physics issues related to clinical care, education and training, innovation and scientific research. This also includes cost-effective use of available resources and decisions on investments
- Assess RT treatment approaches and medical technology infrastructure and establishment of management plans. Prioritisation of tasks focusing on high quality care and safe application of RT, including radiation protection



- Assess required staffing levels
- Remain informed about changes in the practice of medical physics in RT on the national and international level to critically evaluate existing institutional practice
- Establish plans for availability of up to date medical equipment to support the clinical process
- Stay aware of upcoming novel legal requirements that can impact clinical practice and the roles and responsibilities.
- Actively contribute to the continuous improvement of health care quality and patient safety

## II.2 Communicator

The MPE in RT must communicate efficiently with their peers as well as with other healthcare professionals being mainly radiation oncologists, radiologists, nuclear medicine specialists, RTTs, and nurses. MPEs also communicate with hospital management, National Competent Authorities etc. They also need to communicate with service engineers and IT personnel. Communication with patients and families is also increasingly required.

### Competences

- Understand and respect opinions of all discussion partners
- Clearly explain complex physics issues to non-physicists
- Communicate with the responsible personnel of medical equipment manufacturers and suppliers
- Show empathy and good listening skills to perceive the point of view of other health care professionals
- Produce written reports with relevant and understandable information for the receiver or target group
- Assist in helping patients and the general public to identify and make use of the information and communication technology on radiation physics topics related to their care plan, radiation protection and health
- Prepare written material in the form of reports and scientific papers to be presented at seminars/conferences or to be submitted for publication in scientific journals
- Report harmful patient safety incidents and near-misses to the authorities
- *Interact effectively with other professionals, based on specific medical physics expertise*
- Discuss with patients and their families to provide them with concise information about their treatment and to answer their specific questions
- Use new communication channels effectively for the professional environment, eg. social media

## II.3 Collaborator

Radiotherapy involves teamwork and the RT MPE must therefore be able to effectively collaborate with other healthcare professionals in order to provide safe, high quality, patient-centred care. Other collaborators outside the clinical team include industry, financial experts, statisticians, radiation



protection experts, hospital management, National Competent Authorities, stakeholders and policy makers.

The MPE should be a member of the collaborative multidisciplinary group on issues regarding sub-optimal RT delivery such as lack of or outdated resources for quality improvement, patient access, capacity to deliver treatments or shortage of skilled staff. The MPE can use their technical and physics knowledge and skills to support the group using evidence-based reports on options available and to propose patient-centred innovative solutions.

Collaborative skills are broadly applicable to MPE activities, including scientific and clinical work.

## Competences

- Identify potential areas of collaboration based on one's own capabilities within the RT team
- Contribute to a constructive atmosphere with effective interactions, based on trust and mutual respect
- Negotiate shared responsibilities with physicians and other healthcare professionals exploiting possibilities for win-win solutions

## II.4 Leader

The MPE will naturally lead teams that collaborate on topics with high levels of physics input. The teams can be multi-disciplinary (e.g. involvement of physicists, radiation oncologists and RTTs), or consist of physicists only. Timely communication, active listening, networking, flexibility, creativity and mentoring are among the different skills required to motivate staff and build teams. The MPE should be central to planning and equipping new RT departments and in upgrading departments. They should promote the optimal selection of effective equipment to deliver safe, high quality treatments in line with current and emerging advances in RT technology. The MPE should take responsibility to ensure all mandatory radiation protection measures for patients are included in the design.

## Competences

- Understand the importance of taking leadership in all physics and technical issues related to safe, effective and efficient delivery of RT.
- Demonstrate leadership skills to enhance and facilitate changes in health care
- Demonstrate skills to lead a team on specific tasks Take initiatives for the development and implementation of patient safety approaches in treatment delivery and strengthen safety culture
- Prioritise tasks needed to be performed in order to ensure effective and safe patient treatment
- Chair meetings effectively and efficiently and take part in discussions concerning current and future challenges in health care including how these impact on radiation oncology
- Identify where quality improvements may be initiated in diagnostic and therapeutic equipment, patient workflow and related procedures





- Contribute to discussions concerning funding arrangements for RT service delivery institution/region/country of practice
- Demonstrate awareness of the roles and organisational structures of relevant professional societies and how medical physicists contribute to these
- Negotiate and problem-solve with other team members
- Design career paths adapted to the development of each of their team members

## II.5 Health Advocate

As part of the multidisciplinary team, the MPE has a role to be an advocate for patients receiving RT treatments. The principle of ensuring safe, high quality, effective and appropriate treatment for all patients should be upheld by the MPE.

The MPE can actively participate in patient advocacy by preparing, producing and presenting well-researched and evidenced based reports regarding advances in RT technology, radiation safety and RT techniques. These reports can be used to support decision making within a healthcare institute, which is in the patients' best interest.

### Competences

- Be a good collaborator within the healthcare profession to positively influence the multidisciplinary team on behalf of the patient
- Keep up to date with international recommendations and guidelines on quality and quality improvements in RT, including patient safety
- Be a good communicator to present technical and scientific data to non-physicist healthcare decision makers and patient populations
- Be a good communicator about the risks of ionizing and non-ionizing radiations to the public
- Be familiar with health economics when promoting the responsible and best use of resources that prioritise the needs of the patient while still balancing cost-effectiveness with clinical efficacy
- Understand the organisation of the national healthcare system and understand the principles of clinical governance
- Understand the dynamics of healthcare policy development and participate in consultation mechanisms by providing scientific knowledge to inform and promote improvements within the scope of RT
- Understand medical ethics, ethical governance, research ethics, data protection, patients' rights to privacy, dignity and respect
- Promote new recommendations to improve RT and radiation protection

## II.6 Scholar

MPEs have a solid scientific background in physics, mathematics and data science. Their contribution to RT lies in the acquired knowledge, skills and competences for the application of this particular scientific background in ensuring safe and effective treatments. MPEs need to engage in life-long learning through



a continuing professional plan, which identifies areas for improving their knowledge and skill-base and keeping up to date with technical and clinical developments related to their profession. They also need to encourage colleagues to engage in departmental quality improvement initiatives and be involved in the training and education of medical physicists and other radiotherapy professionals by providing teaching lectures, supervising clinically based projects and mentoring colleagues and trainees.

MPEs need to keep updated with relevant professional literature and regularly attend national and international scientific meetings. MPEs should be involved in multi-disciplinary journal clubs and other meetings for dissemination of newly published literature in the field of radiotherapy. Collaboration with peers in other RT departments in order to share information and benchmark their own centre against others.

MPE are also encouraged to cooperate in projects with universities and tertiary level institutions with BSc, MSc or PhD projects, co-supervise students, and publish in scientific journals and present at scientific conferences.

The MPE's scholarly abilities allow them to contribute to the application, dissemination, translation, and creation of knowledge and practices applicable to health and health care.

## Competences

- Engage in the continuous enhancement of professional activities through ongoing learning
- Recognise levels of uncertainty in practice and knowledge gaps in clinical and other professional encounters and generate focused questions to address them.
- Critically evaluate the integrity, reliability, and applicability of health-related research and literature
- Pose questions amenable to scholarly inquiry and select appropriate methods to address them
- Understand the scientific principles of research and contribute to the creation and dissemination of scholarly inquiry and the role of research evidence in healthcare
- Teach students, residents, the public, and other health care professionals
- Identify ethical principles for research and incorporate them into obtaining informed consent, considering potential harms and benefits, and considering vulnerable populations
- Perform and contribute to scientific research and innovation and dissemination of obtained results
- Apply for research calls

## II.7 Professional

As professionals, MPEs are committed to the health and well-being of patients and society through high professional standards, integrity and governmental regulation. This includes self-awareness and knowledge of limits, high standards of ethical and moral behaviour, reliability and responsibility, respect for patient dignity and autonomy.

The professional role reflects contemporary society's expectations of an MPE, which include clinical competence, a commitment to ongoing professional development, promotion of the public good, adherence to ethical standards, and values such as integrity, honesty, altruism, humility, respect for



diversity, and transparency with respect to potential conflicts of interest. It is also recognized that, to provide optimal patient care, the MPE must take responsibility for self-care concerning their own health and well-being and that of their colleagues. Professionalism is the basis of the implicit contract between society and the MPE profession.

## Competences

- Demonstrate appropriate professional behaviours and relationships in all aspects of practice, including honesty, integrity, humility, commitment, compassion, respect, altruism respect for diversity, and maintenance of confidentiality
- Provide excellence of services and ensure a patient-centric-practice
- Improve quality for patient safety
- Promote public good in healthcare to society
- Commit to the profession by complying with international, national guidelines and regulatory authorities
- Encourage research and development to advance Medical Physics practice, showing a commitment to science
- Fulfil and adhere to the professional and ethical codes, standards of practice, and laws governing practice
- Recognise and manage conflicts of interest
- Recognise and respond to unprofessional and unethical behaviour in the health care professions
- Exhibit self-awareness and manage influences on personal well-being and professional performance

## References

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- EFOMP Policy Statement No. 7.1: The roles, responsibilities and status of the medical physicist including the criteria for the staffing levels in a Medical Physics department, <https://www.efomp.org/index.php?r=fc&id=policy-statements>
- EFOMP Policy Statement 12.1: Recommendations on Medical Physics Education and Training in Europe 2014, <https://www.efomp.org/index.php?r=fc&id=policy-statements>
- EFOMP policy statement no. 15: Recommended guidelines on the role of the medical physicist within the hospital governance board, <https://www.efomp.org/index.php?r=fc&id=policy-statements>
- EFOMP policy statement 16: The role and competences of medical physicists and medical physics experts under 2013/59/EURATOM, <https://www.efomp.org/index.php?r=fc&id=policy-statements>
- COUNCIL DIRECTIVE 2013/59/EURATOM of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and



repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom.

- Radiation Protection No 174 (European Commission)
- Core curriculum for medical physicists in radiotherapy. ESTRO-EFOMP. 2011
- EFOMP school Manual, [www.efomp.org](http://www.efomp.org)
- Recommendation of the European Parliament and of the Council of 23 April 2008 on the establishment of the European Qualifications Framework for lifelong learning. Recommendation 2008/C 111/01. Official Journal of the European Union 6.5.2008.
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- Prisciandaro, J. I., Willis, C. E., Burmeister, J. W., Clarke, G. D., Das, R. K., Esthappan, J., ... & Pizzutiello Jr, R. J. (2014). Essentials and guidelines for clinical medical physics residency training programs: executive summary of AAPM Report Number 249. Journal of applied clinical medical physics, 15(3), 4-13.

## III. Specific MPE knowledge, skills and competencies

### III.0 Levels of specific competences

We have defined four different levels of competences the trainee needs to develop:

**Expert competence: to undertake independently and take responsibility for**

The MPE should be able to undertake these tasks independently, without supervision, and take full responsibility for all aspects of the outcome, report, etc. For example, commissioning of a new linac.

**Collaborative competence: to undertake alongside an MPE with expertise on that particular topic**

The MPE should be able to undertake these tasks, working alongside another MPE with specific expertise on a given topic, and make a useful contribution; however, they would not be expected to take full responsibility, as they would not be considered an expert in this topic. An example could be a MPE starting to work in a proton facility; the MPE would be fully trained in photons, but starting to work in protons.

**Contributive competence: to undertake alongside an expert in a different discipline (eg. radiation oncologist, radiation therapist, oncologist, radiologist, surgeon etc..)**

The MPE should be able to undertake these tasks, alongside an expert from a different discipline in RT and make a useful contribution from a physics perspective, however they would not be expected to take full responsibility for the final decision which would be from another discipline. An example could be to discuss the impact of image artefacts on the RT plan – this would be a two way conversations with input from both sides rather than the MPE explaining.

**Awareness competence: to be aware of other aspects of oncology**

The MPE should have a basic understanding of different aspects of oncology and how they relate to radiotherapy, but would not be expected to be an expert. For example, be aware how immunology or chemotherapy may be used in conjunction with RT and that this combination may change the patients radiotherapeutic response.

### III.1 Fundamentals of human anatomy, imaging anatomy and physiology

As part of a multidisciplinary team, the MPE in RT requires a background in basic medical sciences such as human anatomy and medical imaging to optimally apply pre- and post-treatment imaging and treatment planning in RT while collaborating with radiation oncologists and other healthcare professionals. Likewise, a basic understanding and knowledge of the human physiology is essential for treatment planning optimisation as well as to understand treatment-related adverse effects.

This knowledge is a prerequisite to better communicate with radiation oncologists.



## Expert competences

- Interpret relevant medical terminology
- Understand use of image processing to enhance visibility of structures in images
- Understand application of multi-modality imaging, including image registration
- Interpret images from various modalities (X-ray, CT, dual energy CT, CBCT, MRI, PET, SPECT and US) to recognise the various anatomical structures and physiology of the human body relevant to the RT process, especially with emphasis on their representation in 2D, 3D and functional imaging (X-ray, CT, US, MRI, PET, SPECT, etc.)

## Awareness competences

- Define the human anatomy, major organs systems and describe physiological mechanisms for repair, maintenance, and growth
- Explain basic knowledge of cell physiology and function such as hypoxia, apoptosis, angiogenesis, carcinogenesis, etc.

## Core curriculum items

- Nomenclature of human anatomy
- Anatomy of skeletal structures
- Anatomy and physiology of head and neck, brain, thorax, abdomen and pelvis
- Anatomy and physiology of the following systems: muscular, respiratory, digestive, urinary, reproductive, and circulatory
- Function of bone marrow
- Anatomy and function of brain and central nervous system
- Cell physiology and function
- Structures and organs of the human body in the images (X-ray, CT, US, MRI, PET, SPECT, etc.) used to visualize them

## Time to be spent on this topic: 2 ECTS

## Recommended literature

- Sherman and, Luciano's Human Physiology, McGraw-Hill, 2004.
- McKinley M, O'Loughlin V, Human Anatomy, 5<sup>th</sup> Edition. McGraw-Hill, 2016.
- Marieb EN, Hoehn KN, Human Anatomy and Physiology, 10<sup>th</sup> Edition. Pearson, 2015.
- Moore KL, Dalley AF, Agur AMR. Clinically Oriented Anatomy, Eighth, International Edition. Lippincott Williams and Wilkins, 2017.
- Widmaier E., Raff H., Strang K. Vander's Human Physiology. 15<sup>th</sup> Edition. McGraw-Hill Education, 2018.
- Jonathan D. Spratt, Lonie R Salkowski, Marios Loukas, Tom Turmezei, Jamie Weir, Peter H. Abrahams. Weir & Abrahams' Imaging Atlas of Human Anatomy, 5<sup>th</sup> Edition. Elsevier Science & Technology, 2016.



- e-Anatomy the interactive atlas of human anatomy. IMAIOS SAS (<https://www.imaios.com/en/e-Anatomy>). <https://doi.org/10.37019/e-anatomy> (2019).

## III.2. Fundamentals of clinical oncology and multimodal treatment

In order to effectively communicate on relevant patient information and to operate within the multidisciplinary team, a basic understanding of the fundamentals of cancer development, diagnostics and multidisciplinary treatment is required.

### Awareness competences

- Describe the development of cancer, the nature of the various forms of cancers, their molecular and cellular features as well as diagnostics of cancer
- Interpret cancer staging
- Describe the various (combined) treatment options; e.g., surgery, chemotherapy immunotherapy, hormone therapy, highly focalized ultrasound, radiofrequency ablation, hyperthermia, etc.
- Describe the common side effects in RT

### Core curriculum items

- Carcinogenesis
- Oncogenes and tumour suppressor genes
- Types of cancers, their characteristics and prevalence
- Pathways of tumour dissemination
- Tumour microenvironment
- Epigenetics and cancer
- Principles of diagnostics and staging of cancer (TNM classification)
- Principles of surgical, medical and radiation oncology
- Principles of other therapeutics, including, chemotherapy, immunotherapy, hormone therapy, highly focalized ultrasound, radiofrequency ablation, hyperthermia and the combined effects of these therapies with RT
- Common side effects in RT for major tumour sites including systems for grading of side effects (eg. Common Toxicity Criteria)

**Time to be spent on this topic: 2 ECTS**

### Recommended literature

- Ruddon RW, Cancer Biology, Oxford University Press, 2007
- Introduction to the Cellular and Molecular Biology of Cancer, Eds. Margaret Knowles and Peter Selby, Oxford University Press, 2005.
- Raymond E Lenhard Jr, Robert T Osteen, Ted Gansler Eds. Clinical Oncology, American Cancer Society.
- D Hanahan and RA Weinberg, "The Hallmarks of Cancer", Cell 2000;100(1):57-70 and "Hallmarks of Cancer: The next generation", Cell 2011;144(5):646-74.



- F Bray, J Ferlay, I Soerjomataram, RL Siegel, LA Torre, A Jemal. CA Cancer J Clin. 2018 Nov;68(6):394-424. doi: 10.3322/caac.21492. ([www.cancer.org](http://www.cancer.org))

### III.3. Core radiation physics

The medical physicist in RT should have a good knowledge of radiation physics in order to understand how ionising radiation is applied in medical diagnostics and therapy. Since X-rays of energies ranging from kV to several MV, gamma-rays of several MeV and proton and heavy ions, are nowadays applied in medical diagnostics and/or radiotherapy, a broad knowledge of nuclear and atomic physics is required for the MPE in radiotherapy. Knowledge of general concepts of radiation quantities and units as well as radioactive decay and radiation interactions with materials and matter is required. As the theory of radiation physics has already been studied at the BSc/MSc level, this should really be a review as well as the practical RT applications.

#### Expert competences

- Explain the difference between the physical interactions of indirectly and directly ionising radiation
- Explain the different mechanisms of generation of ionising radiation, including radioactive decay
- Describe different mechanisms of energy loss and energy deposition of various types of radiation through various media
- Use radiation quantities and units correctly

#### Core curriculum items

- Physical and radiation quantities and units
- Types and sources of ionising radiation
- Atomic and nuclear structure
- Nuclear models
- Radioactivity (including activation of nuclides and modes of radioactive decay)
- Interaction of photons with matter (types of indirectly ionizing photon radiation, types of photon beam interaction and photon beam attenuation)
- Interaction of electrons (stopping power, linear energy transfer, etc.), protons, heavy charged particles and neutrons (slow and fast)

**Time to be spent on this topic: 2 ECTS**

#### Recommended literature

- Johns & Cinungham, The Physics of Radiology
- Andreo et al. Fundamentals of Ionising radiation Dosimetry
- Graham DT, Cloke P. Principles and Applications of Radiological Physics. 6<sup>th</sup> Ed. Churchill Livingstone 2011
- Podgorsak EB. Radiation Physics for Medical Physicists. 3<sup>rd</sup> Ed. Biol Med Phys, Biomedical Engineering. Springer 2016





- Attix FA. Introduction to Radiological Physics and Radiation Dosimetry. John Wiley & Sons, 2008.
- Hobbie RK. Intermediate Physics for Medicine and Biology. 5<sup>th</sup> Ed. Springer Int. Publishing Switzerland, 2015
- ICRU Report 85a. Fundamental Quantities and Units for Ionising Radiation 2011, <http://www.icru.org/>

## III.4. Radiobiology and radiobiological modelling in external beam photon and electron therapy

Fundamental knowledge of the effect of ionizing radiation on tissues and biology is important in order to assess the effect on different tissues and organs of different types of radiation and dose levels from  $\mu\text{Sv}$  to  $\text{Sv}$  (radioprotection dose levels to therapy dose levels).

The MPE has to understand: dose-effect relationships including volume effects, clinically relevant effects, the effect of model- and parameter uncertainties, and changes in treatment/imaging schedule (e.g. following a treatment interruption), balance of imaging vs. treatment dose levels, priorities of different types of tissues in avoidance, response to different types of radiation.

Radiotherapy treatment planning becomes more and more individualized, including direct TCP/NTCP optimization, spatio-temporal fractionation and optimization, radio-sensitization, radio-immunotherapy and other innovative treatment strategies, requiring specific knowledge of radiobiology to develop new treatment strategies and to adapt treatment planning. In addition, the MPE may play a role in calculating alternative fractionation regimens and outcome analysis, which requires a comprehensive understanding of radiobiological modelling. Finally, the new FLASH radiotherapy delivery might become a real option in the future, so the MPE has to understand the basic principles.

Specific aspects related to brachytherapy and particle therapy are reported in section III.13 and III.14, respectively.

### Expert competences

- Apply radiobiological knowledge to the therapeutic application of ionising radiation
- Apply radiobiological knowledge to the field of radioprotection
- Perform dose fractionation schedule calculations
- Apply models for tumour and normal tissue response
- Critically assess radiobiological calculations performed by commercial treatment planning systems

### Collaborative competences

- Use patient-specific and population-specific biological features such as hypoxia, cell density and biological activity in NTCP and TCP models
- Evaluate the limitations in existing TCP/NTCP as well as EUD models and the parameters established from published data as well as the underlying biological rationale and limitation of the model



- Describe the basic principles of FLASH radiotherapy

## **Contributive competences**

- Choose the appropriate model for conventionally fractionated regimen as well as (extreme) hypofractionated and accelerated regimen

## **Awareness competences**

- Describe the mechanisms for radiation damage to tissue
- Describe the radiobiological background of treatment strategies (e.g., hypofractionation, hyperfractionation, stereotactic regimens) in radiation therapy
- Describe the basics of radiation sensitivity of tumour and normal tissue
- Describe the combined use of drugs with radiation, such as for radio-sensitization

## **Core curriculum items**

- Cell cycle
- Lethal and sublethal cell damage, cell kill and repair mechanisms
- Cell survival
- Biochemical damage
- Dose response (also analysis from clinical data and patient series)
- Stochastic and deterministic tissue damage
- Relation to radiation protection schemes
- Radiobiological background of treatment strategies / radiation schemes in RT
- Radiobiological models in RT and their application and limitations
- Tumour kinetics
- Tumour response pathways
- Linear-quadratic and other response models
- LET and RBE
- Fractionation and  $a/b$ -ratio
- Time effect in RT
- BED and EQD2
- Tumour control probability models
- Impact of hypoxia and microenvironment on radiation effects
- Biological response modifiers including radio-sensitization
- Acute, early and late effects in healthy tissues
- Quantitative Analyses of Normal Tissue Effects in the Clinic (QUANTEC)
- Serial and parallel type organs
- Normal tissue complication probability models
- Systems for toxicity scoring
- Interaction of radiation with immune system
- Models of DNA damage

**Time to be spent on this topic: 4 ECTS**



## Recommended literature

- NCRP publication 51, "Radiation Protection Guidelines for 0.1-100 MeV Particles
- H.D. Thames & J.H. Hendry, "Fractionation in Radiotherapy", Taylor & Francis, 1987
- E. Hall, A.J. Giaccia, "Radiobiology for the radiologist", Lippincott, Wilkins & Williams, 2006
- W. Duncan & A.H.W. Nias, "Clinical Radiobiology", Churchill Livingstone, 1988
- "Radiation Protection in Radiotherapy" IPSM report no. 46
- F.A. Mettler & A.C. Upton, "Medical effects of ionizing radiation", W.B. Saunders, 1995
- Introduction to the Cellular and Molecular Biology of Cancer, Eds. Margaret Knowles and Peter Selby, Oxford University Press, 2005
- G.G. Steel, "Basic clinical radiobiology", Arnold, 2009
- C.S. Sureka and C. Armilia, Radiation Biology for Medical Physicists, 1st Edition CRC Press
- Basic Clinical Radiobiology 5th edition. Edited by Michael C. Joiner, Albert J. van der Kogel (2018)
- Quantec data. The Use of Normal Tissue Complication Probability (NTCP) Models in the Clinic. Int J Radiat Oncol Biol Phys. 2010 Mar 1; Vol 76
- Rancati T, Fiorino C. Modelling radiotherapy side effects practical applications for planning. CRC press Taylor and Francis Group.
- Dale R and Jones B (eds.), Radiobiological Modelling in Radiation Oncology, The British Institute of Radiology, 2007
- M Goitein. Radiation Oncology: A Physicist's-Eye View
- Wigg, D R, Applied Radiobiology and Bioeffect Planning  
Jack Fowler with Alexandru Dasu and Iuliana Toma-Dasu. Optimum Overall Treatment Time in Radiation Oncology.

## III.5. Radiation Protection

The acceptance by society of the risks associated with radiation is conditional on the benefits to be gained from its use. Nonetheless, the risks must be restricted and mitigated by the application of radiation safety standards.

The MPE in RT must have a broad scientific knowledge of radiation protection. They must be prepared to address the needs of protecting the patient, personnel and the general public in the RT department and outside. They must understand the physical and biological effects of radiation for exposed individuals, the relevant regulations, methods of compliance and record keeping. This knowledge will allow them to assess the radiation risk and optimise the medical exposures. They will be asked to apply the ALARA and dose limitation principles in the design of radiation therapy facilities, treatment and imaging protocols. It should be noted that the RT procedure is by essence radiation protection of the patient in the sense that the optimal dose distribution is a balance between the benefit (destruction of the target volume) and the risk (irradiation of healthy organs).

### Expert competences

- Explain the principles of radiation safety procedures



- Assess and optimize radiation safety procedures
- Assess risk factors of radiation (stochastic and deterministic)
- Optimise medical exposures
- Verify and ensure that the clinical physics program is following applicable national radiation safety regulations (e.g. radioactive materials licenses, occupational dose limits, and review of radiation surveys for any new construction)
- Perform radiation surveys of an area using appropriate dose-rate meters
- Define radiation protection emergency procedures
- Discuss the use of personal dosimeters
- Monitor personal dosimetry of the personnel
- Teach radiation protection principles and rules to other professionals in the department and in the hospital (architects, etc.)
- Perform design and shielding calculations for a linac room, simulator/CT room, brachytherapy source room and specific challenges like doors, ducts, mazes, etc.
- Communicate with authorities for license application, audits preparation and other related regulatory duties

### **Core curriculum items**

- Effects of radiation on tissues, on the embryo and foetus
- Leukaemogenesis and carcinogenesis
- Genetic and somatic hazards for exposed individuals and populations
- Scientific basis of radiation protection
- Basic principles of radiation protection: justification, optimisation (ALARA principle) and dose limitation
- Quantities and units in radiation protection
- Radiation monitoring: classification of areas, personal monitoring
- Administration and organisation of radiation protection. National and international legislation and organisations
- Design and facilities including: treatment rooms, imaging rooms, sealed and non-sealed source storage
- Management of radiation safety, including hazard assessment, contingency plans
- Radioactive material management, transport and waste disposal
- Patient protection
- Secondary cancer induction and risks

**Time to be spent in this topic: 5 ECTS**

### **Recommended literature**

- NCRP report series (reports 38 (1971), 49 (1976), 50 (1977), 51 (1977), 53 (1977), 54 (1977), 79 (1884), 82(1985), 84(1985), 112(1991), 116(1993), 122(1995), 128(1998), 151 (2005), 182 (2019))
- ICRU report series (reports 20(1971), 22(1972), 61(2000))



- ICRP report series (reports 60(1990) and 103 (2007))
- FAO, IAEA, ILO, OECD NEAY, PAHOWHO, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).
- IAEA Safety Standards Series No. SF-1 (2006), No 38 (2006), No. RS-G-1.5(2006), No 47 (2006) and No 16 (2000)
- AAPM Report No 50, Fetal Dose from Radiotherapy with Photon Beams, 1995
- Hortin et al, IPEM Report 75, Design and Shielding of Radiotherapy Treatment Facilities

## III.6. Risk Management, Quality Control and Safety in the Medical Environment

The complexity of the RT process continues to increase, which requires a high level of safety control, constant quality improvement, and upgrading of the medical physics services.

Quality management is of utmost importance in the training of the MPE, since it is one of their main responsibilities. During their professional practice, they will have to master different methodologies for efficient and effective quality management in order to be able to allocate time and resources for cost effective quality assurance. The MPE must understand and take responsibility for the quality from a broader perspective including the complete RT process: pre-treatment imaging, treatment planning, treatment delivery and treatment imaging, and reporting.

Therefore, they need to be involved in quality indicator specification and monitoring, quality improvement strategies and technology evaluation. They should also be involved in prospective risk management whenever a new technique, technology or any change in the procedures is introduced in the RT department. Finally, the MPE should have a deep knowledge of methods for retrospective and prospective risk analysis in order to be an integral part of the patient safety committee.

### Expert competences

- Describe and apply Quality Systems in RT
- Build a process chart
- Analyse and apply different methodologies for prospective and retrospective risk assessment and management
- Explain quality improvement strategies (peer review, lean, internal audits, etc.)
- Describe and plan how a comprehensive clinical quality audit is run
- Identify national regulations on quality systems in RT
- Explain an emergency plan

### Contributive competences

- Define and monitor relevant quality indicators in RT

### Core curriculum items

- Concepts of quality system, quality management, risk assessment and management
- National and international regulations on quality management in RT



- Building a process chart
- Prospective risk assessment and management (FMEA and risk matrices)
- Accidents in RT and critical incident report system (CIRS)
- Quality indicators definition and monitoring
- Quality improvement methods (identify a process step with potential for quality improvement, propose a quality improvement initiative, define quality indicator, monitor)
- Clinical quality audits
- Dosimetry audits
- Methods for technology assessment

**Time to be spent on this topic: 5 ECTS**

### **Recommended literature**

- IAEA. Lessons Learned from Accidental Exposures in Radiotherapy, Safety Reports Series No. 17 (2000)
- IAEA Method for the Development of Emergency Response Preparedness for Nuclear or Radiological Accidents, IAEA-TECDOC-953 (1997)
- IEC standards publications (specifically IEC standards publications (specifically: IEC 601-2-8 (1987), IEC 60601-1-4 (1997), IEC 60601-2-11 (1997), IEC 60601-2-1 (1998), IEC 60601-2-17 (1998), IEC 60601-2-29 (1999), 62C/62083 (in preparation)
- Thwaites D, Scalliet P, Leer JWH, Overgaard J. Quality assurance in radiotherapy: European Society for therapeutic Radiology and Oncology Advisory Report to the Commission of the European Union for the "Europe against Cancer Programme". *Radiother Oncol* 1995; 35: 61–73
- ISO, Quality Management and Quality Assurance Standards — Part I. Guidelines for Selection and Use, ISO 9000, ISO, Geneva (1994). WHO, Quality Assurance in Radiotherapy, WHO, Geneva (1988)
- Cionini L et al. Quality indicators in radiotherapy. *Radiother Oncol* 2007; 82(2): 91-200
- Stelios C. The European Federation of Organisations for Medical Physics
- Policy Statement No.13: Recommended guidelines on the development of safety and quality management systems for medical physics departments. *Physica Medica* (2009), DOI: 10.1016/j.ejmp.2008.11.002
- AAPM Recommendations, TG-40, TG-56 and TG-100
- Kutcher GJ, Coia L, Gillin M, Hanson W, Leibel S, Morton R, Palta JR, Purdy JA, Reinstein LE, Svensson GK, Weller M, and Wingfield L. Comprehensive QA for radiation oncology: Report of AAPM Radiation Therapy Committee Task Group 40. *Med Phys* 1994; 21:581–618
- AAPM Report No. 47. "AAPM Code of Practice for Radiotherapy Accelerators." (American Institute of Physics, New York, 1994)
- Fraass B, Doppke K, Hunt M, Kutcher G, Starkschall G, Stern R, and Van Dyk J. "American Association of Physicists in Medicine Radiation Therapy Committee Task Group 53: Quality assurance for clinical radiotherapy treatment planning," *Med Phys* 1998; 25:1773–1829
- International Organization for Standardization, "Quality management and quality assurance Standards. 1. Guidelines for selection and use," ISO 9000, ISO, Geneva 1994



- Halvorsen PH, Das IJ, Fraser M, Freedman DJ, Rice RE, III, Ibbott GS, Parsai EI, Robin TT Jr., and Thomadsen BR, "AAPM Task Group 103 report on peer review in clinical radiation oncology physics," J Appl Clin Med Phys 2005; 6: 50–64
- Radiotherapy risk profile. Technical Manual. World Health Organization. (2008)
- ESTRO Booklet series (Booklets 2 and 7)
- NCS Report 11. Quality control (QC) of simulators and CT scanner and some basic QC methods for treatment planning systems, current practice and minimum requirements. NCS, September 1997
- IPEM Report 81: Physics aspects of Quality Control in Radiotherapy, 1999

### III.7. Organisation, management and ethical issues in health care

The MPE in RT should understand the structure of, and be able to participate in, the management of a hospital department. The MPE should have basic knowledge of the organisation and management of the local healthcare system and of the relevant guidelines and recommendations from national or international organisations. In addition, they should be trained in ethics in medical practice and research, encouraging a diversity of perspectives, cross-cultural dimensions of healthcare, and inclusivity in team-building and project management.

#### Expert competences

- Play a leading role in departmental issues on safe, effective and efficient treatment, related to equipment and physics
- Participate in departmental and physics management teams
- Compare EU Directives, national regulations and guidelines and/or recommendations from national and international organisations on the provision of equipment and staff in RT
- Apply equipment management (e.g., servicing, purchasing of new equipment, etc.)
- Understand how to make staff provisions and allocate roles and responsibilities
- Undertake procurement of new equipment
- Apply team management and projects management
- Describe and apply ethical considerations in medical practice and research
- Apply equity, diversity and inclusion criteria

#### Awareness competences

- Discuss the position of the trainee's own institution as part of the organisation of healthcare at local and national levels
- Discuss the financial structure for funding of RT at the local and national level
- Discuss the development of medical physics and RT in the trainee's country and outline the development in the European Union

#### Core curriculum items



- National and local system, global view of other European systems
- National regulations and EU directives in medical application of ionizing radiation
- Guidelines and recommendations from national and international organizations
- Principles of hospital / department management and project management, etc.
- Principles of personnel management
- Staff provision calculation
- Allocation of roles and responsibilities
- Ethical considerations in medical practice and research
- Equity, diversity and inclusion criteria

**Time to be spent on this topic: 3 ECTS**

### **Recommended literature**

- Directive 96/29/EURATOM laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation.
- Directive 97/43/EURATOM on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure
- Shortell SM, Kaluzny AD. Essentials of Healthcare Management. Delmar Publisher
- Brown M. Healthcare Management. Strategy, Structure & Programs. Healthcare Management Review. An Aspen Publication
- Duncan W. Handbook of Healthcare Management. Blackwell Science
- Ghaye T. Building the Reflective Healthcare Organisation. Willey-Blackwell
- Griffith JR, White KR. The Well-Managed Healthcare Organization. 6<sup>th</sup> Ed. Health Administration Press US
- Walshe K, Smith J. Healthcare Management. Open University Press
- Moulin M. Delivering Excellence In Health And Social Care. Open University Press
- Sherriff SB, Dendy PP. The European Federation of Organisations for Medical Physics. Policy Statement No 11. Guidelines on Professional Conduct and Procedures to be implemented in the event of alleged misconduct. Phys Med 2003; 19(3): 227-229
- Clinical Ethics: A Practical Approach to Ethical Decisions in Clinical Medicine, Sixth Edition (Jonsen, Clinical Ethics
- The Oxford Textbook of Clinical Research Ethics, Ezekiel J. Emanuel, Christine C. Grady, et ál. 2011
- Hospital Administration and Management: A Comprehensive Guide, Gupta
- Human Resource Management in Health Care: Principles and Practice, Jr. L. Fleming Fallon (Author), Charles R. McConnell (Author)
- The Power of a Positive Team: Proven Principles and Practices that Make Great Teams Great
- WHO, Standards and Operational Guidance for Ethics Review of Health-Related Research with Human Participants;  
[https://apps.who.int/iris/bitstream/handle/10665/44783/9789241502948\\_eng.pdf;jsessionid=8D3ABD670498416293B4C47F1C16DE29?sequence=1](https://apps.who.int/iris/bitstream/handle/10665/44783/9789241502948_eng.pdf;jsessionid=8D3ABD670498416293B4C47F1C16DE29?sequence=1)





- [https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/scientific-support-eu-policies/european-group-ethics-science-and-new-technologies-ege\\_en](https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/scientific-support-eu-policies/european-group-ethics-science-and-new-technologies-ege_en)

## III.8. Information and communication technology (ICT)

The MPE must have a good understanding of ICT in the clinical field. Part of this is knowledge of the main systems for information sharing, storage, and retrieval in a hospital, and of the formats most common for medical data, such as DICOM. The MPE should be able to advise on the use and purchase of medical equipment within the hospital IT system. The use of applications like a PDMS, a PACS, OIS including the Record and Verify system, an EPR, or the use of a patient monitoring system are fields an MPE typically advises on, often in close collaboration with the IT department. Knowledge on general ICT-security regulation for collection, storage and transmission and data protection legislation is necessary.

The MPE is also required to communicate effectively with IT professionals from inside and outside the hospital organisation in order to work with the different healthcare processes, medical technology and the increasing availability of healthcare data. Finally, the MPE is also responsible for safe (and legal) use of in-house developed software, in line with MDR.

### Expert competences

- Advise the IT department and the hospital on the needs, use, and maintenance of IT as related to RT
- Advise on the use of ICT in line with GDPR / MDR

### Contributive competences

- Discuss ICT concepts of RT equipment and connections, e.g., in the hospital IT network, with other healthcare professionals, to assist with the specification, commissioning, implementation, problem solving and safe operation
- Discuss healthcare data connectivity standards with colleagues from other disciplines to facilitate the integration of general systems within RT departments
- Discuss hardware configuration, operating systems and typical software applications

### Core curriculum items

- Data exchange formats and standards (for example: FTP) and their implementation (DICOM)
- Relevant data and ICT security standards for collection, storage and transmission and data protection legislation
- Data safety (integrity and privacy, protected sub-nets, etc.)
- Data anonymization/ pseudo-anonymization, e.g., for clinical trials
- Operational relationships between hospital information systems and management systems used in RT and oncology
- Data warehousing for archiving and storage and relevant legislation regarding the required time
- DICOM – general understanding of DICOM and its operation including DICOM-RT
- PACS – general understanding of PACS and its operation
- OIS – general understanding of the integration of OIS and its operation, including Record and



Verify Systems, Systems

- GDPR and MDR, National regulations regarding the use of medical software, both developed in-house and commercially

**Time to be spent on this topic: 4 ECTS**

### **Recommended literature**

- W. Buchanan, Mastering networks. 2010
- ACR-AAPM-SIIM Practice Parameter for Electronic Medical Information Privacy and Security <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Elec-Info-Privacy.pdf?la=en>
- ACR-AAPM-SIIM Technical Standard for Electronic Practice of Medical Imaging <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Elec-Practice-MedImag.pdf?la=en>
- Digital Imaging and Communications in Medicine (DICOM) <https://www.dicomstandard.org/>
- Maria Y. Y. Law, Brent Liu, DICOM-RT and Its Utilization in Radiation Therapy, RadioGraphics 29(3) <https://pubs.rsna.org/doi/pdf/10.1148/rg.293075172>
- Educational Course on DICOM-RT <https://ssrpm.ch/cours-dicom-rt/>
- IAEA Human Health Campus: Imaging Informatics <https://humanhealth.iaea.org/HHW/MedicalPhysics/DiagnosticRadiology/TechnologyManagement/ImagingInformatics/index.html>
- Worldwide implementation of digital imaging in radiology. IAEA Human Health Series 28 <https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1647web.pdf>
- UK Imaging Informatics Group – Introduction to PACS <http://www.pacsgroup.org.uk/forum/messages/419/5961.html?0>
- IPEM Report 93: Guidance for the Commissioning and Quality Assurance of a Networked Radiotherapy Department
- Siochi et al. Information technology resource management in radiation oncology, JACMP, <https://doi.org/10.1120/jacmp.v10i4.3116>
- ACPSEM ROSG Oncology-PACS and OIS working group recommendations for quality assurance, John Shakeshaft, Mario Perez, Lindsay Tremethick, Abdurrahman Ceylan & Michael Bailey, Australasian Physical & Engineering Sciences in Medicine volume 37, pages3–13(2014)
- IAEA Human Health Reports No. 7: Record and verify systems for radiation treatment of cancer: acceptance testing, commissioning and quality control (2013)
- Python in medical physics <https://docs.pymedphys.com/>
- Pylinac (Python for linac QA) <https://pylinac.readthedocs.io/en/stable/overview.html>
- Pydicom (Python for working with DICOM) <https://pydicom.github.io/>
- Standardizing Nomenclatures in Radiation Oncology (2018) Nomenclatures in Radiation Oncology

## **III.9. Data processing, statistics, modelling and artificial intelligence**

Complex quantitative data analysis is becoming increasingly important in RT with many new developments. Examples that purely relate to the technical responsibilities of MPE are the use of artificial



intelligence (AI) in novel approaches of (pre-)treatment QA, conversion of CBCT pixel values into Hounsfield units, and the generation of pseudo CT's from MRI, treatment planning and equipment QA. From the clinical perspective, the MPE will, more and more, encounter advanced (statistical) data analysis approaches in e.g., image segmentation, predictive modelling, outcome data analysis, multi-modality imaging, radiomics, development and application of imaging biomarkers, and genetic profiling. With their high-level numerical/mathematical background, the MPE in a RT department is a bridge between the radiation oncologist and manufacturers and suppliers of systems based on complex data analysis. It is a primary task of the MPE to ensure that the tools are used safely and effectively, in line with current regulations e.g. related to the GPRS and MDE. In many cases, tools need to be validated or configured for the local situation, which is also a major responsibility of the MPE. The MPE may also be involved in clinical innovation and research studies, as well as development of new applications based on advanced data analysis. To fulfil these responsibilities, the MPE must have knowledge and skills on data collection and advanced data processing and analysis including AI tools/deep learning. A sound knowledge of statistics is a pre-requisite for success.

## **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**

- Discuss the principles of (big) data collection, storage and handling of data
- Discuss 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
- Discuss the major pitfalls in the training, validation and use of statistical modelling approaches in RT and ability of coping with them
- Discuss and apply 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.

## **Core curriculum items**

- Central limit theorem
- Probability functions and applications: normal, binomial, Poisson, students' t, chi-square, etc.
- Statistical inference testing depending on the problem at hand – assessment of statistical significance, p-values, confidence intervals, parametric and non-parametric tests, multiple testing
- Type I and type II statistical errors, statistical power, sample size calculations



- ROC analyses
- Co-variance, correlation, regression,  $R^2$
- Analysis of variance (anova)
- Superiority and non-inferiority clinical trials, cohort studies, case-control studies
- Survival analysis – Kaplan-Meier curve, censoring, log-rank test, Cox proportional hazards regression, hazard ratio
- regression and classification, decision boundary,
- Machine learning: Supervised and unsupervised learning
- Important machine learning models: linear and logistic regression, neural networks, Principal Component Analysis, support vector machine, decision trees, k-means cluster analysis
- Deep learning including convolutional neural networks, back-propagation
- Machine learning: training, bias-variance trade-off, overfitting
- Handling co-linearity of predictors (Variance inflation factor, VIF)
- Model selection and regularization: forward and backward stepwise predictor selection, ridge regression, t LASSO
- AI/machine learning in contouring, treatment planning, treatment outcome
- Model validation: external, cross-validation.
- K-fold cross-validation, leave-one-out cross-validation, bootstrap
- Texture analysis as applied in radiomics

**Time to be spent on this topic: 8 ECTS**

### **Recommended literature**

- Nickoloff E. Applications of Statistics to Medicine and Medical Physics. Medical Physics Publishing 2011
- Standardizing Nomenclatures in Radiation Oncology (2018) Nomenclatures in Radiation Oncology
- An introduction to Statistical Learning, Eds. Gareth James et al., Springer
- The Elements of Statistical Learning; Data Mining, Inference and Prediction, Eds. Trevor Hastie et al., Springer
- El Naqa. A guide to outcome modelling in radiotherapy and oncology. 2018  
<https://www.routledge.com/A-Guide-to-Outcome-Modeling-In-Radiotherapy-and-Oncology-Listening-to/El-Naqa/p/book/9781498768054>
- Modelling Radiotherapy Side Effects - Practical Applications for Planning Optimisation (p440-452). Eds. Tiziana Rancati and Claudio Fiorino. CRC Press, Taylor & Francis Group 2019
- Dale R and Jones B (eds.), Radiobiological Modelling in Radiation Oncology, The British Institute of Radiology, 2007
- Big data in radiation oncology, Jun Deng, Lei Xing, CRC press, Francis and Taylor 2019
- A Guide to Outcome Modelling In Radiotherapy and Oncology Listening to the Data, Issam El Naqa, CRC press, Francis and Taylor 2018



- Radiation Oncology: A Physicist's-Eye View, Chapter 5, <https://www.springer.com/gp/book/9780387726441>
- <https://www.ncbi.nlm.nih.gov/pubmed/30449653>
- Vogelius IR, Petersen J, Bentzen SM. Harnessing data science to advance radiation oncology. Mol Oncol. 2020 Apr 7. doi: 10.1002/1878-0261.12685
- Cui S, Tseng HH, Pakela J, Ten Haken RK, El Naqa I. Introduction to machine and deep learning for medical physicists. Med Phys. 2020;47(5):e127-e147
- El Naqa I, Das S. The role of machine and deep learning in modern medical physics. Med Phys. 2020;47(5):e125-e126
- Mahadevaiah G, Rv P, Bermejo I, Jaffray D, Dekker A, Wee L Artificial Intelligence-Based Clinical Decision Support in Modern Medical Physics: Selection, Acceptance, Commissioning, and Quality Assurance Med Phys. 2020;47(5):e228-e235
- Avanzo M, Wei L, Stancanello J, Vallières M, Rao A, Morin O, Mattonen SA, El Naqa I. Machine and deep learning methods for radiomics. Med Phys. 2020;47(5):e185-e202
- Luo Y, Chen S, Valdes G. Machine learning for radiation outcome modeling and prediction. Med Phys. 2020;47(5):e178-e184
- Rogers W, Thulasi Seetha S, Refaee TAG, Lieveise RIY, Granzier RWY, Ibrahim A, Keek SA, Sanduleanu S, Primakov SP, Beuque MPL, Marcus D, van der Wiel AMA, Zerka F, Oberije CJG, van Timmeren JE, Woodruff HC, Lambin P. Radiomics: from qualitative to quantitative imaging. Br J Radiol. 2020;93(1108):20190948
- Challen R, Denny J, Pitt M, Gompels L, Edwards T, Tsaneva-Atanasova K. Artificial intelligence, bias and clinical safety. BMJ Qual Saf. 2019;28(3):231-237
- Shen C, Nguyen D, Zhou Z, Jiang SB, Dong B, Jia X. An introduction to deep learning in medical physics: advantages, potential, and challenges. Phys Med Biol. 2020;65(5):05TR01
- Sahiner B, Pezeshk A, Hadjiiski LM, Wang X, Drukker K, Cha KH, Summers RM, Giger ML. Deep learning in medical imaging and radiation therapy. Med Phys. 2019;46(1):e1-e36
- Jia X, Ren L, Cai J. Clinical implementation of AI technologies will require interpretable AI models. Med Phys. 2020;47(1):1-4
- Cabitza F, Rasoini R, Gensini GF. Unintended Consequences of Machine Learning in Medicine. JAMA. 2017 Aug 8;318(6):517-518
- Jarrett D, Stride E, Vallis K, Gooding MJ. Applications and limitations of machine learning in radiation oncology. Br J Radiol. 2019;92(1100):20190001
- Meyer P, Noblet V, Mazzara C, Lallement A. Survey on deep learning for radiotherapy. Comput Biol Med. 2018;98:126-146
- Walsh S, de Jong EEC, van Timmeren JE, Ibrahim A, Compter I, Peerlings J, Sanduleanu S, Refaee T, Keek S, Larue RTHM, van Wijk Y, Even AJG, Jochems A, Barakat MS, Leijenaar RTH, Lambin P. Decision Support Systems in Oncology. JCO Clin Cancer Inform. 2019;3:1-9
- Welch ML, McIntosh C, Haibe-Kains B, Milosevic MF, Wee L, Dekker A, Huang SH, Purdie TG, O'Sullivan B, Aerts HJWL, Jaffray DA. Vulnerabilities of radiomic signature development: The need for safeguards. Radiother Oncol. 2019;130:2-9



- <https://www.intechopen.com/books/artificial-intelligence-applications-in-medicine-and-biology/radiation-oncology-in-the-era-of-big-data-and-machine-learning-for-precision-medicine>

## III.10. Dose determination

### III.10.1 Reference dosimetry

Accurate dose measurement is one of the most important tasks of the MPE in RT. The concept of absorbed dose and kerma, and dosimetric quantities and units should be well understood. The MPE in RT must be able to explain and apply the principles of the calibration chain from the national primary standard to hospital field instruments and understand the physics and techniques of the different dosimetry detectors involved. The MPE in RT must be able to determine the absorbed dose in a clinical beam under reference conditions by applying national or international recommended protocols (reference dosimetry). The MPE in RT must be able to compare the different measurement systems that are available for dosimetry. A critical understanding of their advantages and limitations is required to be able to select the most appropriate system for each dosimetric problem. This appreciation should include acceptance testing, calibration and quality control of these measurement systems as well as estimation of the uncertainty of measurements (see section III.9). Dosimetry audits are an important step in a well-designed quality control program and the MPE should be able to set up and run such programs.

Specific aspects related to brachytherapy and particle therapy are described in sections III.13 and III.14, respectively.

#### Expert competences

- Explain and determine the fundamental theoretical aspects of all reference dosimetry measurements for external beams (X-rays, electrons of therapeutic energy)
- Determine the appropriate equipment (detector/phantom) and methodology for reference dosimetry in different irradiation conditions for photons and electrons
- Determine the appropriate equipment and methodology for reference dosimetry of un-flattened MV photon beams
- Determine the appropriate equipment and methodology for small-field dosimetry
- Explain the calibration of dosimeters in primary and secondary standard laboratory (ionization chamber, calorimeter, chemical dosimeter)
- Explain and implement dosimetric standards and traceability
- Define and implement a program for acceptance testing, calibration and quality control of the measurement systems

#### Collaborative competences

- Discuss the fundamental theoretical and practical aspects for reference dosimetry in a magnetic field



- Explain the challenges in reference dosimetry in FLASH radiotherapy

## Core curriculum items

- Concept of absorbed dose and kerma
- Fundamental physics of dosimetry (e.g. electrometry, properties of dosimeters)
- The cavity theory
- Principle of build-up and (lack of) charge equilibrium
- Relationship between different dosimetric quantities and units
- Calibration chain dose detectors
- Dosimetric standards
- Cross-calibration of dosimeter with reference dosimeter
- Dosimetry recommendations air-kerma standards
- Dosimetry recommendations and national/international codes of practice for the determination of absorbed dose to water
- Dose to medium/Dose to water
- Evaluation of uncertainties in the process of dose determination
- Types of dosimeters used for reference dosimetry and their principles of operation (mainly ionization chambers)
- Measurement systems and phantoms
- Reference condition for different treatment units and techniques (incl. flattened and un-flattened beams and small fields)
- Small field dosimetry
- Dosimetry Audits
- Dosimetry in a magnetic field
- Technical specifications, acceptance testing, calibration, QC of dosimeters
- Dosimetry for FLASH radiotherapy

**Time to be spent on this topic: 15 ECTS**

## III.10.2 Non-reference dosimetry

The MPE in RT has the essential role to ensure that the treatment is delivered as expected, by characterising the beams produced by the treatment machines, configuring the beam model in the TPS and validating the dose calculation engine. Non-reference dosimetry includes all relative dose determination which, together with treatment unit calibration (section III.10.1), ensure a safe treatment delivery to the patient. Ongoing quality control using similar methodologies ensures that treatment beam models in the TPS agree with the beam as delivered by the treatment unit.

Specific aspects related to dose measurements for patient-specific quality assurance are described in section III.12.5.



Specific aspects related to brachytherapy and particle therapy are described in sections III.13 and III.14, respectively.

## Expert competences

- Explain the terminology used in clinical dosimetry
- Perform required dose measurements in air, in water and solid phantoms for photon and electron beams using the appropriate detectors for large and small fields
- Choose the most appropriate detector and methodology for non-reference dosimetry, being aware of their potential limitations
- Commission the beam model, dose engine in a TPS and also input/output devices, transfer data, etc.
- Design performance tests to validate TPS beam models and dose engines
- Explain the influence of treatment parameters (SSD, field size, etc.) on relative dosimetry
- Explain the influence of beam modifiers on the beam characteristics

## Collaborative competences

- Explain how to perform relative dosimetry in FLASH radiotherapy

## Core curriculum items

- Terminology used: output factors, PDD, beam profiles, TMR, TPR, OAR)
- Detectors to perform relative dosimetry in different irradiation conditions for photons and electrons beams (ionisation chambers, diodes, film, TLD, semiconductors, diamond detectors, alanine, scintillation detectors, gel, etc.)
- Beam quality specification (quality index for photons, range and energy parameters for electron beams, HVL for kV X-ray beams)
- Protocol for absorbed dose determination in a clinical photon and electron beams
- In-air and in-phantom characteristics of clinical beams
- Relative dosimetry: central axis dose distribution in water
- Output factors: effects of head scatter and phantom scatter, dependence on treatment parameters
- Beam profiles (penumbra region, flatness, symmetry, etc.)
- Effects of beam modifiers: hard wedges, virtual wedges, compensators, bolus etc.
- Requirements and methods of data acquisition for treatment planning

**Time to be spent on this topic: 10 ECTS**

## Recommended literature

- Mijnheer B, Clinical 3D Dosimetry in Modern Radiation Therapy (Imaging in Medical Diagnosis and Therapy), Boca Raton, FL; CRC Press, 2017
- Report of AAPM Task Group 235 - Radiochromic Film Dosimetry: An update to TG-55, AAPM 2020
- AAPM TG 191 Clinical Use of Luminescent Dosimeters: TLDs and OSLDs, AAPM 2019





- Dosimetry of small static fields used in external photon beam radiotherapy: Summary of TRS-483, the IAEA-AAPM international Code of Practice for reference and relative dose determination, AAPM 2018
- Recommendations for clinical electron beam dosimetry: Supplement to the recommendations of Task Group 25, AAPM 2009
- AAPM Medical PhysSmilowitz JB, et al. J Appl Clin Med Phys. 2015
- Absorbed Dose Determination in External Beam Radiotherapy, An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water. TRS-398, IAEA, Vienna, 2000
- Implementation of the International Code of Practice on Dosimetry in Radiotherapy (TRS 398): Review of testing results, IAEA-TECDOC-1455, IAEA 2005
- Calibration of Reference Dosimeters for External Beam Radiotherapy, TRS-469, IAEA 2009
- Andreo P, Burns DT, Nahum AE, Seuntjens J, Attix FH. Fundamentals of ionizing radiation dosimetry. Wiley-VCH 2017
- Dosimetry of small static fields used in External beam radiotherapy- International code of practice for relative and reference dose determination, TRS 483
- D.J. O'Brien et al, Reference dosimetry in magnetic fields, formalism and ionization chamber correction factors, Med Phys, 43 (2016), 4915-4927
- Comprehensive Audits of Radiotherapy Practices: A Tool for Quality Improvement Quality Assurance Team for Radiation Oncology (QUATRO), IAEA, Vienna link: [https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1297\\_web.pdf](https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1297_web.pdf)[https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1297\\_web.pdf](https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1297_web.pdf)
- Review of Radiation Oncology Physics: A handbook for Teachers and Students, IAEA, Vienna, 2005
- On-site Visits to Radiotherapy Centres: Medical Physics Procedures, IAEA, Vienna, [https://www-pub.iaea.org/MTCD/Publications/PDF/te\\_1543\\_web.pdf](https://www-pub.iaea.org/MTCD/Publications/PDF/te_1543_web.pdf)[https://www-pub.iaea.org/MTCD/Publications/PDF/te\\_1543\\_web.pdf](https://www-pub.iaea.org/MTCD/Publications/PDF/te_1543_web.pdf)
- J.R. Greening Fundamentals of Radiation Dosimetry 2019 CRC Press ISBN: 9780203755198
- Michael W. Kissik, Sharareh Fakhraei – Lectures on Radiation Dosimetry Physics: A Deeper Look into the Foundations of Clinical Protocols 2016 ISBN: 9781930524934
- Indra J Das Radiochromic Fil: Role and Applications in Radiation Dosimetry 2012 CRC Press ISBN: 9780367781750
- Determination and use of scatter correction factors of megavoltage photon beams. Report 12 of the Netherlands Commission on Radiation Dosimetry

### III.11. Imaging for Radiotherapy

Medical imaging is essential in state-of-the-art RT (see section III.12). It is used to (1) plan the desired treatment, (2) verify the treatment delivery, (3) modify the treatment delivery if necessary and (4) evaluate or monitor treatment response. In modern RT, imaging plays an indispensable role in patient positioning, ensuring the accuracy of treatment delivery as well as in treatment adaptation. Functional and 3D molecular imaging modalities (e.g., PET, SPECT, MRI, and fMRI) provide non-invasive, quantitative



information about biological and physiological processes of relevance to treatment planning and assessment of treatment response.

### III.11.1 Principles of medical imaging and image handling

The MPE must be able to discuss all relevant imaging modalities to be able to liaise with the radiology and nuclear medicine departments and ensure that imaging equipment in the RT process is used appropriately, effectively and safely.

#### Expert competences

- Explain the physics and principles of operation of conventional and CT simulator devices
- Explain the physics and principles of operation of MRI and PET for treatment planning purposes
- Interpret images from different imaging modalities
- Describe the physics and principles of imaging in the RT process, including the sources of image errors, artefacts, uncertainties and resolution limits
- Use major image registration algorithms (rigid, affine, deformable)
- Explain how to validate image registration algorithms (estimate uncertainties)

#### Collaborative competences

- Perform acceptance testing, commissioning and quality control of imaging devices
- Explain the different acquisition protocols in CT, MR and PET imaging and the effect of the adjustable parameters in terms of image quality and radiation dose to the patient (for CT and PET)
- Explain the effect of contrast media in different imaging modalities (CT, MRI and PET) and the limits of the imaging modalities for the appropriate applications
- Outline the methodology for quantitative imaging
- Explain functional imaging techniques such as dynamic 4D-CT, fMRI (e.g. diffusion-weighted MRI, dynamic contrast-based MRI and MRI spectroscopy), PET and SPECT and the specific strengths and weaknesses in RT for the various major tumor sites
- Explain standardization techniques for functional and quantitative imaging
- Outline basic MR and RF safety principles

#### Core curriculum items

- Image handling, digital image processing, reconstruction algorithms
- Noise and measures of image quality
- Practical applications of anatomical and functional imaging modalities in RT (radiography, fluoroscopy, CT, dual energy CT, CBCT, MRI, US, PET, SPECT)
- Physics and principles of different imaging systems on treatment units (portal imaging devices, flat panels, kV and MV CBCT, US)
- Quantitative imaging biomarkers



- Image registration (rigid, affine, deformable)
- QA of image registration
- Imaging dose
- QA programmes (incl. model observer and geometrical accuracy)
- Optimization strategies (dose/image quality)

**Time to be spent in this topic: 15 ECTS**

## III.11.2 Imaging for treatment simulation

The first step of the RT process is the immobilisation and simulation of the patient, which is followed by pre-treatment imaging. Treatment planning (section III.12.3) relies on 3D anatomical models created with CT, MRI, PET, and sometimes multimodality imaging for each individual patient. Patient imaging is the basis for definition of target volumes and organs at risk but also the quantitative foundation for simulation of the treatment. To meet the different needs, multiple imaging modalities are often applied, e.g. MRI for target volume definition and CT as the basis for dose calculation. Then, image registration techniques are applied.

Specific aspects related to brachytherapy and particle therapy are described in sections III.13 and III.14, respectively.

### Expert competences

- Explain strengths and weaknesses of immobilisation devices and their application for each tumour site
- Define CT-scan acquisition and reconstruction protocols for treatment planning
- Explain the fundamentals and apply algorithms and systems for (auto-)segmentation of images
- Manage (4D) pre-treatment imaging to plan treatments of intra-fractionally moving tumours (for motion encompassing techniques, gating, breath-hold, tumour tracking)
- Explain principles and techniques for 4DCT imaging and their application in RT
- Describe immobilisation devices and their applications

### Collaborative competences

- Define acquisition and reconstruction protocols for all other imaging modalities for treatment planning
- Describe MRI-only treatment, i.e., without a planning CT

### Core curriculum items

- Commissioning and QA of immobilization, alignment (lasers) and imaging systems
- Multimodality image registration for target volume delineation and planning (MRI and PET/SPECT images with the planning CT-scan)
- Image registration algorithms and their QA (as described in III.11.1)



- MRI-only treatment workflow

**Time to be spent on this topic: 5 ECTS**

### III.11.3 In-room imaging for set-up verification and adaptive RT

Most treatment machines have integrated imaging systems to image the daily 3D/4D patient anatomy relative to the isocentre. In-room imaging can be used for correction of inter-fraction or intra-fraction set-up errors (image-guided radiotherapy, IGRT, tumour tracking) or for tumour set-up monitoring (DIBH, gating). Moreover, imaging can be used in adaptive radiation therapy (ART), which is based on multiple treatment plans for a single patient.

Specific aspects related to brachytherapy and particle therapy are reported in section III.13 and III.14, respectively.

#### **Expert competences**

- Explain the physics and technical principles of in-room imaging devices
- Define acquisition and reconstruction protocols for all in-room imaging modalities
- Perform acceptance testing, commissioning and quality control of in-room imaging devices
- Specify, justify and rank the criteria for selecting in-room imaging devices for positioning, treatment adaptation, motion monitoring
- Explain the use of image registration for set-up verification and correction, bony anatomy vs. soft tissue, implanted fiducials, handling of rotations and deformations
- Explain principles of on-line and offline adaptive re-planning: plan library based, plan-of-the-day, on-line and offline re-planning
- Estimate and optimize dose in IGRT

#### **Core curriculum items**

- Patient alignment and set-up using different in-room imaging devices (planar kV or MV, (4D)CBCT, MR, US, SGRT)
- Acquisition and reconstruction protocols for all in-room imaging modalities
- Commissioning and QA of in-room imaging devices
- Image registration algorithms and their QA (as described in III.11.1)
- Imaging dose in IGRT

**Time to be spent in this topic: 5 ECTS**

#### **Recommended literature**

- Bushberg JT et al. The essential physics of medical imaging, Third Edition 2013
- IPEM, Report 80: Quality control in magnetic resonance imaging, IPEM, York (1995).



- IPEM Topical Report: A 2018 IPEM survey of MRI use for external beam radiotherapy treatment planning in the UK, Phys Med Biol, 2019, Vol 64-17
- Kirby M. Calder KA, On-Treatment verification Imaging: A study guide for IGRT 2019 CRC Press
- Murphy M et al. The management of imaging dose during image-guided radiotherapy: Report of the AAPM Task Group 75, Med Phys 2007; 10:4041-4061.
- Liney G. Van der Heide U. MRI for Radiotherapy 2019 springer
- PET/CT Acceptance Testing and Quality Assurance AAPM 2019
- GX Ding, P Alaei et al, Image guidance doses delivered during radiotherapy: Quantification, management, and reduction: Report of the AAPM Therapy Physics Committee Task Group 180, Med. Phys. 45 (5), May 2018
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## III.12. External beam radiotherapy with photons or electrons

### III.12.1 Clinical use of treatment equipment

The MPE in RT is responsible for the safe and effective operation of all equipment. External beam RT devices include all treatment units used to irradiate the patient with kV and MV X-ray beams, gamma rays, electron beams or proton and ion beams, as well as all add-on devices used for in room image guidance.

In this section, we will refer only to treatment units using photon or electrons.

#### **Expert competences**

- Explain the physics and technical principles of all treatment units (basic principles of acceleration with RF), the sources of interlocks, and the sources of deviations in dosimetric or mechanical parameters
- Explain the possibility and limitations of all treatment units (eg field flatness, beam stability, dose rate)
- Perform acceptance testing, commissioning and quality control of at least one treatment unit
- Operate treatment units safely
- Specify, justify and rank the criteria for selecting treatment units
- Describe the relevant parameters and implications of communication protocols for all treatment units and in-room imaging equipment
- Explain the necessary QA for all add-on equipment on the linac
- Communicate with engineers (e.g., recalibration or replacement of parts)
- Train personnel for safe and effective use of new technology in RT
- Perform all activities in line with the MDR

#### **Collaborative competences**

- Explain the challenges of dose delivery in FLASH radiotherapy

#### **Awareness competences**

- Discuss with engineers about systems, such as air conditioning and cooling water, influencing the correct functioning of the treatment units

#### **Core curriculum Items**

- Physical and technical principles of the following treatment units: Gantry-based linacs, Tomotherapy, Robotic linac, Gamma knife, kV X-ray units, Cobalt units (if used at a national level), C-arm systems for megavoltage photon and electron beams, Ring-mounted systems
- Commissioning and QA of a treatment unit and all add-on devices
- Communication protocols for all treatment units and in-room imaging equipment
- Physical and technical principles of FLASH radiotherapy



**Time to be spent on this topic: 6 ECTS**

## III.12.2 Treatment delivery techniques for photon and electron beams

Radiotherapy during recent decades has developed from simple 2D techniques and 3D conformal RT, to IMRT and VMAT. Special techniques are used for particular clinical situations. It has also developed a closer reliance on imaging for patient monitoring during each stage of the process (IGRT, see also section III.12.4).

### **Expert competences**

- Explain the capabilities and limitations of current and state-of-the-art treatment techniques for all relevant treatment sites
- Implement the most common treatment techniques, from commissioning to treatment simulation, planning, verification, delivery and quality assurance
- Compare institutional treatment protocols with national and international treatment protocols (including ESTRO guidelines ACROP)
- Discuss alternative treatment techniques such as proton, ion beam or brachytherapy

### **Collaborative competences**

- Discuss the most appropriate technique according to the tumour site and intent of treatment with the multi-disciplinary team
- Discuss advantages and disadvantages of non-coplanar treatments

### **Awareness competences**

- Be aware of RT treatment schemes (radiation + chemo + surgery + hyperthermia + nuclear medicine treatments, etc.)

### **Core Curriculum Items**

- Conventional (2D and 3D) techniques: wedges, bolus, beam shaping using BEV, coplanar and non-coplanar beam angle configurations, weighting and normalization, field matching
- IMRT (fixed-gantry) with MLC-based static or dynamic delivery
- Rotational techniques: VMAT, helical Tomotherapy, conformal arcs, conformal dynamic arcs, wave arcs
- Non-coplanar (robotic and static) RT specific techniques: SRS and SRT, SBRT
- Electron treatment techniques: choice of energy, applicators, bolus, etc.
- IORT, TBI, TSEI, orthovoltage therapy



**Time to be spent in this topic: 10 ECTS**

## III.12.3 Treatment planning

Treatment planning refers to all procedures used to determine the optimal irradiation plan for a patient. Treatment planning is performed with a computerised TPS, which relies on computer hardware, software and networking. Using dosimetric data of the treatment beams obtained with phantom measurements during commissioning of the linac and 3D anatomical models created with multimodality imaging for each individual patient, dose distributions of different irradiation techniques can be optimized and calculated by dedicated algorithms. Detailed knowledge of the effect of beam arrangements, modification devices, beam weights, dose prescription, normalisation, optimisation techniques and algorithms are necessary to produce a good treatment plan. Plan evaluation methods are essential to clinically accept the treatment plan. The MPE is responsible for the acceptance and commissioning of the treatment planning systems. They are responsible for the development of guidelines, class solutions and AI based optimisation models to ease and guarantee high quality treatment plans. Finally, they are responsible for the evaluation of patient-specific dose distributions in treatment planning procedures. Moreover, the MPE is responsible for proper training of the planners and for advising radiation oncologists.

### Expert competences

- Describe and apply the ICRU terminology regarding the target volumes, organs at risk, dose prescription, and plan evaluation
- Explain the limitations of dose calculation algorithms for heterogeneity corrections in low/high density tissue and tissue interfaces where charged particle equilibrium is not fully established
- Explain fluence map optimisation, MLC segmentation, direct aperture optimization
- Explain the relationship between clinical optimality and Pareto-optimality
- Create optimized plans for simple techniques, using beam modifiers such as wedges, blocks, MLCs, compensators and bolus
- Create optimized plans for some of the sophisticated and special techniques (e.g. IMRT, VMAT, SRS, SBRT, TBI, TSEI)
- Assess plan quality including compliance to dose-volume objectives and constraints, complexity and robustness
- Explain dose prescription, dose evaluation (uniformity index, conformity index, dose-volume constraints, etc.) and dose reporting according to international recommendations
- Perform treatment planning for re-irradiations, taking into consideration previous plans
- Summarize common approaches for tumor dose prescription in treatment plans and explain differences, pros and cons
- Perform manual calculation of MU
- Describe algorithms and systems for automated plan generation (e.g. multi-criteria optimization, knowledge based, etc.) including awareness of their strength and weaknesses
- Perform TPS QA





- Acceptance and quality assurance of the planning system
- Train planners and doctors on the use of treatment planning system

### **Collaborative competences**

- Describe the strengths and weaknesses of biological planning
- Train and validate automated planning models

### **Core Curriculum Items**

- ICRU terminology regarding target volumes and organs at risk (GTV, CTV, ITV, PTV, PRV, etc.)
- ICRU recommendation (ICRU 50, 62, 71, 83, 91) for dose prescription
- Recording and reporting dosimetric parameters according to international recommendations (ICRU 50, 62, 71, 83, 91)
- Conversion of Hounsfield units to electron density for dose calculation
- Dose calculation algorithms (A, B, C) for photon and electron beams
- Monitor unit calculation
- Treatment planning for the most common irradiation techniques
- Virtual simulation and tools: BEV, DRR
- Effect of various beam arrangements, beam modification devices (wedges, MLC, bolus) and beam weights on dose distribution
- IMRT and VMAT planning: forward vs. inverse planning, fluence optimisation; segmentation of fluence profiles, direct aperture optimisation
- Plan optimisation and evaluation methods: uniformity and conformity criteria, constraints, DVHs, dose-area histograms, and biological parameters (TCP, NTCP, EUD)
- Application of biological models, in particular LQ-model for calculation of BED, EQD2
- 4D TPS, 4D dose accumulation
- Management of implanted devices (prosthesis, dental filings, expander valves, pace makers) in the treatment plan, including the effects of high Z materials on the dose calculation
- Archiving, back-up and restore of plans
- TPS QA including initial setup and acceptance

**Time to be spent with this topic: 15 ECTS**

## **III.12.4 Techniques for managing geometrical and anatomical uncertainties and variations (margins, IGRT, ART)**

In order to safely deliver the treatment plan, in-room imaging prior (and during) treatment delivery may have a key role, especially for high dose hypofractionated treatments. Patient set-up and target localisation can be verified with various IGRT techniques and protocols, including on-line and off-line protocols. The measurements can also provide input for margin calculations for future patients. Adaptive RT (ART), defined as the use of multiple treatment plans per treatment course can be performed via on-



line selection of plans from a patient-specific library of plans. Otherwise, off-line or on-line re-planning may be performed.

### **Expert competences**

- Determine CTV-PTV and PRV margins for new patients on the basis of previously treated patient data and validate clinically used margins
- Implement at least one IGRT technique
- Apply appropriate IGRT correction protocols (on-line and off-line) according to the clinical indication

### **Collaborative competences**

- Implement at least one technique to manage respiratory motion
- Implement at least one ART technique
- Describe the most commonly used IGRT techniques
- Describe the most commonly used techniques to manage respiratory motion
- Describe the most commonly used ART techniques

### **Contributive competences**

- Define adequate action levels for off-line plan adaptation in collaboration with the radiation oncologist

### **Core curriculum items**

- Patient alignment and set-up on treatment units
- IGRT techniques and strategies on the treatment unit to optimise the set-up and target localisation
- Techniques to control breathing motion during treatment (respiratory gating, breath hold and tumour tracking)
- Geometric setup protocols based on bony anatomy and based on tumour position
- Assessment of systematic and random uncertainties for margin definition for conventionally and hypofractionated treatments
- Approaches for establishment of CTV-PTV margins
- Real-time adaptive RT for moving targets (gating and tumour tracking)
- Adaptive RT based on multiple plans for patients, e.g., library of plans approaches, on- and off-line re-planning, estimation of accumulated dose
- ART workflow and QA

**Time to be spent in this topic: 6 ECTS**

## **III.12.5 Patient-specific quality assurance**



Treatment verification includes all procedures to verify the different steps of the treatment: pre-treatment imaging and contouring, planning according to the planning protocol, transfer of the plan to the R&V system, dosimetric verification of the plan, patient/target positioning.

The dosimetric verification of the irradiation plan according to the regulation of the corresponding country may include pre-treatment verification in a phantom and in-vivo dosimetry during treatment. In-vivo dosimetry may include verification of the delivered dose in single points or planar dosimetry, such as transit dosimetry with portal imaging. Log files from the linac or from dedicated transmission detectors may also be used to reconstruct patient dose. Reconstruction of dose may be based on the planning CT-scan or a daily CBCT.

## **Expert competences**

- Critically evaluate systems and software for patient-specific QA regarding types of errors that can be detected and cannot be detected
- Implement commercially available systems for patient-specific QA, assessing strengths and limitations
- Perform independent dose calculations (point calculations or independent 3D calculations)
- Commission an independent dose calculation software
- Commission systems for pre-treatment and in vivo patient specific dosimetry
- Perform pre-treatment dosimetric verification of standard and advanced RT technique plans in a phantom and/or using the EPID
- Perform in-vivo dosimetry using appropriate detectors
- Explain the pros/cons of log file based vs. measurement based vs. EPID based pre-treatment QA
- Evaluate and give alternatives in case of pre-treatment or in vivo measurements out of tolerance

## **Collaborative competences**

- Assess commercial or home-made algorithms for independent dose calculation

## **Contributive competences**

- Develop a decision flow chart for patient-specific QA

## **Core Curriculum Items**

- Basic dosimetry source data
- Instruments for patient-specific QA – phantoms and detectors
- Dosimetric verification of standard 3D-CRT plans
- Dosimetric verification of special technique plans
- Dosimetric verification of IMRT and VMAT plans
- Verification of treatment plan by independent dose calculations (based on original plan and/or log-files)



- Implement and assess systems for patient specific dosimetry (pre-treatment and in-vivo)
- Check correct transmission of treatment plan from treatment planning system to R&V
- Reconstruction of delivered doses based on log-files
- Setting tolerances for plan acceptability

**Time to be spent in this topic: 6 ECTS**

**Total ECTS for External beam radiotherapy with photons and electrons: 42 ECTS**

## Recommended literature

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- IPEM Report No 94. Commissioning and quality assurance of linear accelerators, IPEM, York, 2006
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- Webb S. Contemporary IMRT Developing Physics and Clinical Implementation. IOP Publishing Ltd. Bristol, UK, 2005
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- Mackie TR, Holmes T, Swerdloff S, Reckwerdt P, Deasy JO, Yang J, Paliwal B, Kinsella T. Tomotherapy: a new concept for the delivery of dynamic conformal therapy. Med Phys 1993; 20: 1709-1719
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- ICRU report series (reports 50(1993) and 62(1999))
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- Hussein M, Heijmen BJ, Verellen D, Nisbet A, Automation in intensity-modulated radiotherapy treatment planning - a review of recent innovations. Br J Radiol. 2018: 20180270
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- Keall PJ, Mageras GS, Balter JM et al. The management of respiratory motion in radiation Oncology. Report of AAPM Task Group 76. *Med Phys* 2006; 33:3874-3900
- Bertholet J, Knopf A.C., Elben B. et al. Real-time intrafraction motion monitoring in external beam radiotherapy, *PMB*, 64 (15) 2019
- Bortfeld T, Schmidt-Ullrich R, De Neve W and Wazer DE, *Image Guided IMRT*, Springer, Berlin & Heidelberg, 2006
- van Dyke J (Ed.). *The Modern Technology of Radiation Oncology Volume 2. Medical Physics Publishing, Madison, Wisconsin, 2005*
- Podgorsak EB (Tech. Ed.). *Radiation oncology physics: a handbook for teachers and students*.
- Jacob Van Dyk. *The Modern Technology of Radiation Oncology. Volumes 1 (1999), 2 (2005) and 3 (2013)*. Medical Physics Publishing Corporation. McDermott PN. *Tutorials in Radiotherapy Physics: Advanced Topics with Problems and Solutions*. CRC Press, 2016
- ESTRO booklet no. 5. *Practical guidelines for the implementation of In Vivo Dosimetry with diodes in External Radiotherapy with photon beams (Entrance Dose)*. Huyskens DP et al. 2001
- *Physics of Radiotherapy X-Rays from Linear Accelerators*, Metcalfe P., Kron T., Hoban P., Medical Physics Publishing, 2007, ISBN: 9781930524361
- *Handbook of Radiotherapy Physics, Theory and Practice*, ed: P. Mayles, A. Nahum, J-C. Rosenwald, 2007, Taylor & Francis, ISBN 0-7503-0860-5
- Ahnesjö and Aspradakis (1999), *Dose calculations for external photon beams in radiotherapy, Physics in Medicine and Biology* 44, R99-155
- *Introduction to Megavoltage X-Ray Dose Computation Algorithms*, Ed. Jerry Battista
- *Tutorials in Radiotherapy Physics Advanced Topics with Problems and Solutions*, Patrick N. McDermott

### III.13. Brachytherapy

Brachytherapy (BT) is a technique using sealed radioactive sources placed inside or in close proximity to the tumour. Due to the nature of the modality, specific dosimetry protocols and procedures must be applied, as well as measurement systems and treatment planning systems.



## Expert competences

- Describe the basic operation of the commercially available after-loading systems
- Assess the advantages and limitations of the locally available after-loading systems and BT sources
- Apply calibration protocols for the BT sources used locally
- Assess the functional characteristics of the source calibration equipment, and perform equipment QA
- Participate in the brachytherapy process from operating theatre through localisation, treatment planning and delivery
- Discuss the use of the different sealed brachytherapy sources
- Describe the dosimetry systems for intracavitary brachytherapy and interstitial brachytherapy
- Describe the commonly used dose calculation algorithms (based on TG-43) and modern model-based dose calculation algorithms
- Take responsibility for the acquisition, use and disposition of sealed radioactive sources
- Take responsibility for advice on systems for purchase, commissioning and QA of brachytherapy systems, delivery mechanism and individual planning techniques

## Collaborative competences

- Assist in the preparation of brachytherapy sources for clinical use
- Describe the basic principles of imaging systems for brachytherapy
- Describe the principles of electronic brachytherapy
- Describe optimisation algorithms for HDR, LDR, PDR and their limitations
- Describe the radiobiology principles in brachytherapy
- Perform independent verifications of the calculated dwell times of intracavity insertions and interstitial implants
- Setup a quality control program of the brachytherapy sources, applicators and equipment, including the TPS and record and verify system
- Undertake basic radiation safety procedures, such as leakage tests on the sources, disposal of sources, prevention and actions in case of source loss
- Discuss national and international regulations for the use and transport of radioactive materials

## Core curriculum items

### Clinical use of treatment equipment

- Sources: radionuclide types and source design applicators
- Afterloading systems, Equipment systems for permanent brachytherapy
- Source calibration equipment
- Imaging systems for brachytherapy (C-arm, simulator, CT, MRI, US)

### Source specification

- Quantities and units: activity, reference air kerma rate, exposure rate, etc.



- “source strength” determination according to national and international protocols, including IAEA recommendations
- Interpretation of the source calibration certificate from the manufacture

## Dosimetry measurement methods

- standard applications, classical implantation and dose calculation systems: interstitial, the “Paris System” and intracavitary, the “Manchester System”

## Special brachytherapy techniques

- permanent prostate seeds, stereotactic brain implants, eye plaques, 90Y microsphere to hepatic malignancies, partial breast irradiation, electronic brachytherapy

## Treatment planning

- Dose calculation algorithms
- Source and points position reconstruction algorithms for different imaging modalities (radiographic films, CT, MRI, US)
- Optimisation algorithms and constraints for LDR, HDR, PDR
- Dose-volume histograms in BT, DVH-related planning evaluation parameters
- Brachytherapy and external beam RT plans summation considering radiobiology aspects for combined treatment
- National and international protocols for treatment planning, including ICRU 38, ICRU 58, ICRU 89, GEC ESTRO and ABS recommendation

## Quality Assurance

- QA of after-loading equipment (HDR, PDR), treatment planning systems (reconstruction algorithms and calculation algorithms), sources and applicators, imaging systems in BT, dosimetry systems, networks, etc.
- National and international recommendations and local protocols
- Overall QA of the BT treatment process
- Verification, checking and QA of individual patient treatment plans
- In-vivo dosimetry in brachytherapy
- Radiation Protection and Radioactive substances regulation

**Time to be spent in this topic: 12 ECTS**

## Recommended literature

- Comprehensive Brachytherapy: Physical and Clinical Aspects. Venselaar J., Baltas D., Meigooni A., Hoskin P., Imaging in Medical Diagnosis and Therapy, William R. Hendee, Series Editor. CRC/Taylor & Francis Group, Boca Raton, FL, 2013. Hardback 535 pp. ISBN: 9781439844984



- The GEC ESTRO Handbook of Brachytherapy. Gerbaulet A, Pötter R, Mazeron JJ, Meertens H and Van Limbergen E, Editors. Ash D, Briot E, Haie-Meder C, Lartigau E, Scalliet P, Venselaar J and Wambersie A. ISBN 90-804532-6. 2002
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- AAPM Report series (report 43 (1995), 56 (1997), 59 (1998), 64 (1999), 43 Updated (2004), 43 Supplement (2007), 128 (2008), 98 (2008), 137 (2009), 138 (2011), 144 (2011), 129 (2012), 186 (2012), 229 (2012), 192 (2014), 167 (2016), 43 Supplement 2 (2017), 182 (2019))
- Salembier C, Lavagnini P, Nickers P, Mangili P, Rijnders A, Polo A, Venselaar J, Hoskin P. Tumour and target volumes in permanent prostate brachytherapy: A supplement to the ESTRO/EAU/EORTC recommendations on prostate brachytherapy. *Radiother and Oncol* 2007; 83: 3-10
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- GEC-ESTRO ACROP recommendations for head & neck brachytherapy in squamous cell carcinomas: 1st update – Improvement by cross sectional imaging based treatment planning and stepping source technology. Kovács G, Martinez-Monge R, Budrukkar A, Guinot JL, Johansson B, Strnad V, Skowronek J, Rovirosa A, Siebert FA; GEC- ESTRO Head & Neck Working Group. *Radiother Oncol*. 2017
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## III.14. Particle Therapy

Owing to their favourable physical and radiobiological properties, beams of protons and heavier ions have an increasing role in RT for certain indications. MPEs in RT play a key role in developing and installing particle therapy facilities, in performing and controlling the technical and clinical operation of the equipment and in the technological, physical, biological and clinical research on further developments of particle therapy. In addition, MPEs working in photon RT should be able to identify patients who may benefit from being referred to particle therapy.

### Expert competences

- Explain the electronic and nuclear interactions of ions with matter and their impact on the propagation of a particle beam in water and biological tissue
- Derive the general implications on the technical equipment for accelerating and delivering ion beams, radiation protection, dosimetric measurements, quality assurance, treatment planning, radiobiology and therapeutic strategies, on the basis of the physical characteristics of ion beams
- Identify and evaluate the main performance parameters of ion therapy equipment

### Collaborative competences

- Describe the general aspects of operation of ion accelerators and beam transport systems
- Describe the general advantages and disadvantages for the use of different ion species
- Explain the main differences between the techniques of beam delivery with ion beams including intensity modulation and organ motion compensation
- Discuss the general aspects of dosimetry and quality assurance for ion beams, and in particular the differences with respect to photon beams
- Describe the current approaches to patient selection in proton therapy
- Outline the main area of developments of particle therapy

### Core curriculum items

Clinical use of treatment equipment

- Accelerators for ion beams, energy selection and transport systems
- Therapeutic ion beam delivery, including control systems and safety systems

Dosimetry of ion beams

- Protocols for the dosimetric characterisation of a therapeutic particle beam
- Dosimetric and geometric quality assurance for therapeutic ion beam delivery

Treatment techniques

- Gantry-based and fixed line-based techniques
- (Single and double) scattering beams, including for eye melanoma
- Pencil beam

Treatment planning



- Calibration curve for dose calculation on CT imaging
- Field definition for passive scattering beams and pencil beam scanning
- Management of range, anatomical and setup variations in plan optimization and plan evaluation
- Methods to consider Variable Linear Energy Transfer (LET) and Relative Biological Effectiveness (RBE)
- Treatment planning comparison between photons and ions for patient selection
- Robust optimization and plan robustness evaluation

Image guidance, adaptive radiation therapy and treatment monitoring

- 2D and 3D imaging for positioning
- Stopping power ratio calibration
  
- Motion compensation techniques
- Offline treatment adaptation
- Techniques for in-vivo range monitoring

Patient-specific QA

- Measurement-based approaches
- Approaches based on log-file analysis

**Time to be spent in this topic: 8 ECTS**

### **Recommended literature**

- ICRU report No. 78
- H Paganetti (editor), Proton therapy Physics, CRC Press, 2018
- M Durante & H Paganetti, Nuclear Physics in particle therapy: a review, Phys Med Biol 2016
- M Schippers, Beam Delivery Systems for Particle Radiation Therapy: Current Status and Recent Developments, Reviews of Accelerator Science and Technology Vol. 2 (2009) 179–200
- CP Karger et al, Dosimetry for ion beam therapy, Phys Med Biol 2010
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## **III.15. Principles of Unsealed source therapy**

*Note: this section is addressed to the few countries where this type of treatment resides within the remit of the RT physics group.*

The aim of the module is to prepare the MPE to be closely involved in therapeutic procedures using unsealed radioactive sources. The absorbed radiation dose from internally deposited radionuclides is a determining factor in assessing the therapeutic utility and risk when using unsealed sources for radiotherapy. Individualised dosimetry is currently the only accurate methodology available to calculate



absorbed dose to the target organ and surrounding tissues. This is necessary to assess the therapeutic response (effectiveness) and related toxicities.

## **Collaborative competences**

- Describe the theoretical basis for physical methods of radioisotope therapy
- Describe the types of radiomarkers (and their activity) and radiopharmaceuticals applied in radioisotope therapy
- Estimate the radiation doses received by the particular organs
- Describe methods of clinical dosimetry applied in programs for therapeutic dose estimation
- Use current recommendations on quality control in radioisotope therapy that apply to the MPE
- Discuss dosimetry applied in radiation protection

## **Core Curriculum items**

Radioisotope therapy basics

- Principles of radioisotope therapy
- Targeted and individual radioisotope therapy

Treatment techniques

- Radioiodine treatment
- Radioimmunotherapy
- Radioembolization of liver tumours
- Radioisotope synovectomy
- Metastases and analgesic treatment

Treatment planning

- Mechanism of biodistribution
- Activity measurements
- Radiopharmaceutical application techniques
- The assessment of doses during internal radiation

Quality control in radioisotope therapy

Radiation protection of personnel and patients subjected to radioisotope therapy

**Time to be spent in this topic: 2 ECTS**

## **Recommended literature**

- Toohey RE and Stabin MG. Comparative Analysis of Dosimetry, Parameters for Nuclear Medicine. Oak Ridge Institute for Science and Education 2000; TN37831
- Radiation Dose to Patients from Radiopharmaceuticals, ICRP Publication 80, International Commission on Radiological Protection, Pergamon Press, 1998



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- Zaidi H, Sgouros G, eds. Therapeutic Applications of Monte Carlo Calculations in Nuclear Medicine. Bristol, U.K.: IOP Publishing Ltd., 2003: 95-102
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## IV. Science and Innovation (research project)

The MPE has a central role in science and innovation in radiotherapy. The MPE is responsible for initiating technical and physics innovation to improve diagnostic and therapeutic applications. They should also perform and initiate scientific research in medical technology, apply the results to improve patient treatments and report in scientific meetings and journals. The MPE translates clinical problems into scientific questions and translates scientific results into clinical innovations and practice. Moreover, the MPE should be able to correctly and critically analyse published research results.

To prepare the MPE in RT for this responsibility, a focused research project should be undertaken during the training programme, either as a full-time activity within a well-defined period or on a part-time basis over a prolonged time period (e.g. integrated in other parts of the training). The project should be performed under the supervision of an MPE in RT. Preferentially the supervisor is an experienced researcher. The research project should be well structured and defined in order to fit within the given time frame and be relevant for RT physics and clinical practice. The project should result in a written report, preferably in the form of a manuscript suitable for submission to a peer-reviewed medical physics/RT journal, or as an abstract to be presented at an international congress.

### Expert competences

- Design a study in RT physics research, including motivation, statement of hypotheses, and metrics of evaluation
- Perform a structured literature review



- Evaluate critically the novelty and feasibility of research idea/project
- Evaluate critically the urgency of the proposed idea/project
- Select scientifically appropriate methodology for the research project
- Plan, prepare and perform the different phases of the research project
- Acquire first-hand experience in proper scientific evaluation, of both own and published data
- Apply appropriate statistical analyses
- Prepare a scientific manuscript, preferentially for publication in a peer-reviewed journal and/or an abstract for conference presentation

## Core curriculum items

- Literature review
- Design study methodology
- Power analysis
- Data collection and curation (i.e. identify, select, collect, standardize data)
- Selection and application of relevant data analysis methods
- Graphical presentation of results
- Selection and application of relevant statistical tests
- Science communication, writing and presentation

**Time to be spent on this topic: 30 ECTS**

## Recommended literature

- Gustavii, B., How to write and illustrate a scientific paper, Cambridge University Press 2003
- Goodman, N.W. & Edwards, M.B, Medical writing – a prescription for clarity, Cambridge University Press 2006
- Nicolas Wallimam, Research methods. The Basis. Taylor & Francis group 2011
- Cr Kothari, Research Methodology, NEW AGE INTERNATIONAL (P) LIMITED, PUBLISHERS, 1990
- Measurements and their uncertainties. Oxford press
- Glantz SA. Primer of biostatistics, McGraw Hill, 2005
- Rosner B. Fundamentals of biostatistics, Thomson, 2006
- ESTRO physics research course

## V. Assessment methods to evaluate competencies

*Adapted from the "CanMEDS Assessment Tools Handbook"*  
([http://rcpsc.medical.org/canmeds/resources/handbook\\_e.php](http://rcpsc.medical.org/canmeds/resources/handbook_e.php))

Whereas a candidate's knowledge can be assessed by means of exams, the complete set of competencies needed to act safely in a healthcare setting is substantially more complex to assess. In the following, different components of a possible assessment scheme are described. The different components must,



however, be adapted according to the national education and training programme. It is recommended that the assessment of competencies include more than one of the assessment modules listed below.

## 1. WRITTEN TESTS

### ○ **Constructed-response format (short-answer questions) (SAQ)**

The short-answer question (SAQ) format consists of a brief, highly directed question. Answers usually consist of a few short words or phrases.

### ○ **Constructed-response format (essays)**

These kinds of questions require learners to construct an answer based on their knowledge in a written or computer-based format. They require the synthesis and communication of content and often require critical thinking skills such as evaluation, analysis and judgment.

### ○ **Selected-response format (multiple-choice, matching, extended matching, pick N and true-false questions)**

Selected-response assessment tools consist of a question and a list of options from which the learner must choose the correct answer.

Common tools within this category are:

**Multiple Choice Questions (MCQs):** Consist of an opening question or stem that asks the learner to choose the most correct answer(s) from a list that also includes two to five plausible yet incorrect distractors.

**Matching:** Learners are given two lists and are asked to match each item in one column to an item in the other column.

**Extended Matching Questions (EMQs):** Learners are given a list of 10 to 20 items and are asked to match them to a series of corresponding responses. An item may be matched to more than one response.

**Pick N:** An amalgam of MCQs and extended matching, pick N items consist of an opening stem and an instruction to select any given number of correct responses from an extensive list.

**True-false:** Learners are asked to determine if a given statement is true or false.

## 2. STRUCTURED ORAL EXAMINATIONS (SOES)

Oral examinations typically consist of the review of four to ten topics/cases, each lasting five to fifteen minutes. The entire examination, therefore, lasts about one hour. Each case discussion may include problem-solving, treatment planning, interpretation of results, etc. They are usually scored using a predefined, structured template.



### 3. **DIRECT OBSERVATION (DO)**

Direct observation refers to the ongoing observation, assessment and documentation of actions taken by learners in real situations during their training period. The critical factor is that the learner is observed performing authentic actions that occur naturally as part of daily work experience.

In a strictly formal arrangement, the learner could be asked to perform a specific task and would be assessed by means of a standardised rating form. In an informal arrangement, no specific planning for the observation would be involved and the assessment would not be recorded on a standardised form.

### 4. **OBJECTIVE STRUCTURED EXAMINATIONS (OSES)**

The objective structured examination (OSE) samples the performance of learners as they rotate through a series of stations representing various scenarios. At each station, learners may encounter a standardized clinical situation, a structured oral examination, visual information (e.g., x-ray films), or a written task. Learners are usually asked to perform a specific skill, to simulate part of a clinical situation, or to answer questions based on the presented material.

OSE circuits typically consist of 8 to 15 stations grouped into a series of rooms and may include one or two rest stations. Learners are usually given 8 to 30 minutes to complete the tasks assigned per room. Assessment can be carried out using a standardised checklist, anchored global rating scales, or the evaluation of brief narrative responses.

### 5. **MULTI-SOURCE FEEDBACK (MSF)**

Multi-source feedback (MSF) is often (erroneously) termed 360-degree evaluation or assessment. MSF uses specific instruments designed to gather data about particular behaviours or professional constructs (e.g., professionalism and communication skills) of the learner.

MSF usually includes feedback solicited from two or more sources, potentially including the learner. Observers may include physicists (e.g., resident peers), allied health professionals (e.g., physicians, nurses, technologists). Feedback is typically provided by completing a questionnaire-based tool consisting of 10–40 items that is designed to assess behaviours that can be observed.

MSF can supplement traditional sources of assessment (e.g., examinations and preceptor observations) by providing input from people who do not normally have a hierarchical responsibility for providing feedback yet may have a different perspective on actual learner performance. Finally, MSF encourages reflection and promotes development of a self-improvement plan.

### 6. **PORTFOLIOS AND LOGBOOKS**

University faculties may be familiar with portfolios in the context of teaching dossiers that are used in applications for academic promotion. Portfolios are a very flexible educational tool that can be adapted to multiple purposes, settings and kinds of learners.



Portfolios are really an “instrument of instruments,” or a collection of assessment tools. Their components may include logbooks, multi-source feedback instruments, continuous quality improvement projects, learning diaries, encounter cards, essays, etc.

Logbooks are defined as those tools that are used to track the incidence of educationally relevant activities, such as the number of procedures performed (e.g., a list of QC test on a specific equipment, or the number of treatment plans).

Logbooks are structured instruments for documenting that a learning activity has taken place.

## 7. ENCOUNTER CARDS

Encounter cards are a type of in-training tool characterised by direct observations that are documented after brief encounters between the supervisor and the learner in a clinical setting. They are also known as:

- daily evaluation cards (DECs)
- daily encounter cards (DECs)
- daily operative cards (DOCs)
- daily shift cards
- daily teaching evaluation cards (DTECs)
- teaching encounter cards (TECs)
- interaction cards
- feedback forms

Encounter cards and their variants are a method of direct assessment that helps the assessor to capture observations of competencies from brief encounters with learners. Encounter cards can also be used to facilitate the more frequent assessment of teaching

### Selected Tools for Assessing the Competencies

	Organization	Professionalism	Communication	Collaboration	Social actions	Knowledge and science
Written tests (SAQ)		X		X		X
Written tests (essays)				X	X	X
Written tests (SRF)						X
Oral Exams (SOEs)		X	X		X	X
Direct Observation	X	X	X	X	X	X
Objective Structured Exam (OSEs)	X		X		X	X
Multi-source feedback	X	X	X	X	X	





Portfolios and/or logbooks	X	X	X	X	X	X
Encounter Cards	X	X	X	X		X

SAQ = Short Answer Questions

SRF = Selected Response Format (multiple-choice, matching, extended matching, pick N and true-false questions)

SOEs = Structured Oral Examinations

OSEs = Objective Structured Examinations

## ANNEX 1. Definitions

### **Medical Physics**

Medical Physics is the scientific healthcare field concerned with the application of the concepts and methods of physics in medicine. Physics is applied to the knowledge of the human body, to its preservation and to the cure of its illnesses [1]. Medical Physics regards both medical devices and medical software, their construction, proper use and safety. Medical Physics has been classified internationally as a profession and its benefits have been widely recognized [2].

### **Radiotherapy**

Radiotherapy is the branch of clinical medicine that uses ionising radiation, either alone or in combination with other therapeutic modalities, for the treatment of patients with malignant or benign diseases. It may be practiced as an independent oncological speciality or may be integrated in the broader practice of clinical oncology.

### **Medical Physics Expert**

2013/59/EURATOM [3] and Radiation Protection No 174 (European Commission) [4]:

“medical physics expert means an individual having the knowledge, training and experience to act or give advice on matters relating to radiation physics applied to medical exposure, whose competence in this respect is recognised by the competent authority”; in this document, we only refer to Radiation Oncology.

The MPE corresponds to the MPE defined by EFOMP (Policy statement No 12.1) [5]:

“MPE is defined as a clinically qualified MP who has reached EQF level 8 in his/her own specialty of clinical Medical Physics”.

Article 58 -2013/59/EURATOM highlighting the role of MPE in Radiotherapy.

Member States shall ensure that: “in medical radiological practices, a medical physics expert is appropriately involved, the level of involvement being commensurate with the radiological risk posed by the practice. In particular, in radiotherapeutic practices other than standardised therapeutic nuclear medicine practices, a medical physics expert shall be closely involved”.



## ***Radiation Protection Expert***

Radiation protection expert means an individual or, if provided for in national legislation, a group of individuals, having the knowledge, training and experience needed to give radiation protection advice in order to ensure the effective protection of individuals, and whose competence in this respect is recognised by the competent authority [3].

## ***Radiation Protection Officer***

Radiation protection officer means an individual who is technically competent in radiation protection matters relevant for a given type of practice to supervise or perform the implementation of the radiation protection arrangements [3].

## ***Accreditation***

Accreditation is a process by which a recognised body assesses and recognises that the education and/or training provided by an institution meets acceptable levels of quality. Therefore, there are two parties involved in this process: the institution that provides education and training and an external organisation, which performs the external assessment and awards accreditation as a result of positive evaluation [6].

## ***Recognition***

Recognition is a process by which a national authority recognises by registration the professional equivalence of foreign higher education diplomas or other evidence of formal qualification awarded upon the completion of a course at a higher education or training institution [4].

## ***Certification***

Certification (or 'credentialing') is the formal process by which an authorized body (governmental or non-governmental) evaluates and recognizes the knowledge and proficiency of an individual, which must satisfy pre-determined requirements or criteria [6, 7].

## ***Re-certification***

Re-certification is the process by which a certified professional is checked to have maintained their level of competences according to the prevailing demands. The maintenance of certification is achieved through continual professional development (CPD).

## ***Learning outcomes***

Learning Outcomes are defined as statements of what a learner knows, understands and is able to do on completion of a learning process, which are defined in terms of knowledge, skills and competences [8].

## ***Knowledge***

Knowledge is defined as the outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study. In the context of the European Qualifications Framework, knowledge is described as theoretical and/or factual [8].



## Skills

Skills are defined as the ability to apply knowledge and use know-how to complete tasks and solve problems. In the context of the European Qualifications Framework, skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments) [8].

## Competence

Competence is defined as the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. In the context of the European Qualifications Framework, competence is described in terms of responsibility and autonomy [8].

## References

- [1] Duck,F. The origins of Medical Physics, European Journal of Medical Physics, June 2014 Volume 30, Issue 4, Pages 397–402
- [2] EFOMP Policy Statement No. 7.1: The roles, responsibilities and status of the medical physicist including the criteria for the staffing levels in a Medical Physics department  
<https://www.efomp.org/index.php?r=fc&id=policy-statements>
- [3] Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation
- [4] Guidelines on medical physics expert. European Commission. Radiat Prot 174, 2014
- [5] Caruana CJ, Christofides S, Hartmann GH. European Federadion of Organisations for Medical Physics (EFOMP) Policy statement 12.1: Recommendations on Medical Physics Education and Training in Europe 2014; Phys Med. 2014 Sep;30(6):598-603
- [6] IAEA Human Health Serie n° 25, 2013, Roles and Responsibilities, and Education and Training requirements for Clinical Qualified Medical Physicists
- [7] IAEA TCS-71. Guidelines for the Certification of Clinically Qualified Medical Physicists
- [8] <https://eurspace.eu/ecvet/pedagogicalkit/framework-for-defining-learning-outcomes-knowledge-skills-competence/>

## Annex 2.

Table: example of learning phase and examination modalities for each item of the core curriculum

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	X		X	X	X		



Systems in Radiotherapy							
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