



# CORE CURRICULUM FOR MEDICAL PHYSICISTS IN RADIOTHERAPY

Revised edition 16 February 2011

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<b>I. INTRODUCTION</b>	<b>3</b>
<b>II. DEFINITIONS</b>	<b>7</b>
<b>III. GENERAL COMPETENCES</b>	<b>9</b>
<b>1. ORGANIZATION</b>	<b>9</b>
<b>2. PROFESSIONALISM</b>	<b>10</b>
<b>3. COMMUNICATION</b>	<b>11</b>
<b>4. COLLABORATION</b>	<b>12</b>
<b>5. SOCIAL ACTION</b>	<b>13</b>
<b>IV. RADIOTHERAPY PHYSICS KNOWLEDGE, SKILLS AND COMPETENCES</b>	<b>14</b>
Fundamental knowledge, skills and competences	15
1. Fundamentals of human anatomy and physiology	15
2. Fundamentals of oncology	16
3. Principles and applications of radiobiology and molecular biology	17
4. Overview of radiation physics	19
5. General safety principles in the medical environment	21
6. Principles of quality management	22
7. Quality and risk management in radiotherapy	23
8. Statistical methods	25
9. Organisation, management and ethical issues in health care	26
10. Health technology assessment	28
11. Information and communication technology	29
Knowledge, skills and competences specific for radiotherapy	30
12. Dosimetry	30
13. Principles of medical imaging and image handling	32
14. External beam radiotherapy	34
15. Brachytherapy	41
16. Particle therapy	44
17. Principles of unsealed source therapy	46
18. Radiation protection for ionising radiation	48
19. Mathematical modeling of treatment outcomes	50
20. Uncertainties in radiotherapy	51
Research Project	52
<b>V. ASSESMENT METHODS TO EVALUATE COMPETENCES</b>	<b>54</b>

## I. Introduction

In this document we refer to Medical Physicists working (or training for a career) in the radiotherapy speciality as 'medical physicists in radiotherapy'. Given the wide variety of professional titles in use throughout Europe, we will use the title RTT (Radiation Therapy Technologists) to refer to the staff delivering the radiotherapy to patients.

Medical physicists in radiotherapy are members of the multi-disciplinary clinical teams responsible for radiotherapy of cancer patients. Their role is to provide critical scientific input on the physical processes and technology that underpin the whole radiotherapy pathway. Generally, the medical physicists in radiotherapy design and develop the framework of radiation dosimetry, treatment planning, quality assurance of individual patient's treatments, of the radiation therapy equipment and other aspects of the treatment process including the radiation safety of the patient, staff and public. Specifically, the medical physicists in radiotherapy provide expert advice on the purchase, development, implementation and improvement of treatment techniques, equipment and processes. They also provide expert input during the treatment for individual patients. This includes having a leading role in the strategic planning, commissioning, safe utilisation and optimisation of advances of radiotherapy technologies and techniques. In summary, the medical physicists in radiotherapy play a key role in assuring the delivery of safe, state-of-the-art radiotherapy.

In order to acquire and maintain sufficient knowledge and an appropriate level of competence, both initial and continuing education and training are necessary. European legislation has challenged many professional organisations to propose harmonised professional standards of high quality. The European Union's Directives concerning basic safety standards [1] and medical exposures [2] have given a statutory requirement for physicists to be involved in the medical uses of ionising radiation; and have given impetus to the discussions of education and training requirements in medical physics. Recently, a new directive, the Euratom Basic Safety Standards Directive (Draft Version 24 February 2010) has been prepared which will revoke both directives ("*the BBS*") [1] and ("*the MED*") [2], giving a new definition of the Medical Physics Expert as well as of their responsibilities.

In 2004 the European Federation of Organisations for Medical Physics (EFOMP) and the European Society for Therapeutic Radiology and Oncology (ESTRO) issued jointly guidelines for the education and training of medical physicists within radiation oncology. These guidelines are now updated jointly by the two organisations to accommodate the contemporary requirements for the knowledge and competency needs in this rapidly evolving field of medicine. The two organisations have a longstanding commitment to improved clinical practise, science and development and education and training.

EFOMP is an umbrella organisation for national medical physics organisations; one of its main objectives is to harmonise and promote the best practice of medical physics within Europe. To accomplish its goals, EFOMP has presented various recommendations and guidelines in a number of Policy Statements, which have been unanimously adopted by EFOMP Member Organisations. The EFOMP approach to achieve harmonisation is to encourage the establishment of national education and training schemes at all levels in line with EFOMP recommendations. Guidelines for formal EFOMP recognition of National Registration Schemes for Radiotherapy Physicists were established in 1995 [3]. In Policy Statement No 9, "Radiation Protection of the Patient in Europe: The Training of the Medical Physics Expert in Radiation Physics or Radiation Technology" [4], EFOMP presents its recommendations on the role and the competence requirements of the Medical Physics Expert (MPE), as defined in the directive [2], together with recommendations on education, training and Continuing Professional Development (CPD). General criteria for structured CPD have been laid down by EFOMP in Policy Statement No 8, "Continuing Professional Development for the Medical Physicist" [5]. CPD is now being recommended as the best way to meet the requirement for a renewal mechanism. Policy Statement No. 10 "Recommended Guidelines on National Schemes for

Continuing Professional Development of Medical Physicists" [6] and Policy Statement No. 12 "The present status of Medical Physics Education and Training in Europe. New perspectives and EFOMP recommendations" [7], recommends National Member Organisations to set up their own detailed CPD Scheme. In this latest document, EFOMP also makes recommendations on education and training of Medical Physicists within the context of the current developments in the European Higher Education Area arising from "The Bologna Declaration".

ESTRO, is a multidisciplinary society of individual radiation oncologists, medical physicists in radiotherapy, radiobiologists and RTTs. It is a partner member of the European Cancer Organization (ECCO). ESTRO has developed, the role, for improving standards and practice, for providing teaching, training and resources and for fostering research and development in radiotherapy throughout Europe. It actively co-operates with other international and national radiation oncology societies, medical physics organisations, etc. ESTRO has taken a multi-national European lead in developing and delivering guidance frameworks in various areas of radiation oncology, eg. in education [8] and quality assurance [9,10,11]. In these areas it has a record of producing consensus documents, which have been endorsed by a wide range of relevant national societies. It has provided support for the development of guidelines and curricula recommendations for all the main specialities working directly in radiation oncology [12,13]. Recently, ESTRO has established the European School of Radiotherapy and Oncology, which offers a large number of courses for medical physicists within the field of radiation oncology. Moreover, a masterclass in radiotherapy physics for radiation oncology is under development. ESTRO has previously worked successfully in conjunction and cooperation successfully with EFOMP on educational issues [14,15]; both organisations have recognised that there is a common interest. ESTRO has participated in or contributed to many EU initiatives, for example to the 'Guidelines on education and training in radiation protection for medical exposures' [16].

### **Aim and scope of the document**

This revised curriculum for medical physicists in radiotherapy arises from an ESTRO initiative to update the education and training requirements to accommodate today's competency needs in modern radiation oncology. Its structure is in accordance with the revised guidelines developed by ESTRO for education and training of radiation oncologists and RTTs.

The document is intended to provide a framework for national societies to guide their own curriculum development or to compare it to their existing documents. It is intended to provide a baseline standard for the speciality of medical physics in radiotherapy. Its structure and application, however, are intended to be flexible in order to cater for different national situations, recognising national differences in initial physics qualifications, in existing radiotherapy physics education and training programmes, structures and accreditation.

According to the EFOMP recommendations given in Policy Statement No.12 [7], this revised curriculum assumes that the entrant into specialist training as a Medical Physicist in Radiotherapy has a degree in physics (typically 180 ECTS\*). Post graduate education in Medical Physics should consist of formal university education at the level of a Master's (Master in Medical Physics, up to 300 ECTS\*), followed by accredited practical training at a Hospital (in job training) for at least two years, working under the supervision of an experienced medical physicist.

The previous guidelines for education and training jointly developed by EFOMP and ESTRO [15] aimed to provide both theoretical and practical requirements for the specific education and training of medical physics in radiotherapy. The document focused on skills and knowledge required to safely act as a medical physicist in a radiation oncology team. The current revision has been drawn up using terminology in accordance with the EU recommendations on the European Qualifications

Framework for lifelong learning (EQF) [17] in which learning outcomes are defined in terms of knowledge, skills and competences.

The theoretical and the practical parts of medical physics training for radiotherapy are not clearly differentiated in this revised version of the curriculum as they were in the previous version.

The list of items for each specific topic should therefore be used to identify suitable contents for a theoretical master's degree and for the practical hospital training. Once the training is complete, trainees should have reached the level of knowledge, skills and competences in each topic area listed in this curriculum and will therefore meet the requirements to become a Qualified Medical Physicist (QMP, according to the EFOMP structured system [3,6]), that is, able to act independently without supervision and gain formal recognition from a National Competent Authority.

In addition to the specific learning outcomes for medical physics in radiotherapy, other competences such as organization, professionalism, communication, collaboration and social actions have been included. A specific section on the assessment of competences, is also included.

Time to be spent on each specific topic is given in ECTS\*. The number of ECTS\*\* must not be used as an absolute value, but as a relative unit to help the national societies to identify the relative importance of the topics. A recommended literature is provided for each specific topic

- [1] Council Directive 96/29/ Euratom of 13 May 1996, laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation. Official Journal 29.06.1996 No. L-159, page 1
- [2] Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionising radiation in relation to medical exposure. Official Journal of the European Communities; 9 July 1977:22. No. L 190
- [3] EFOMP Policy Statement No. 6: Recommended guidelines of National Registration Schemes for Medical Physicists. Phys Med 1995; XI (4): 157-159
- [4] EFOMP Policy Statement No. 9: Radiation Protection of the Patient in Europe: The Training of the Medical Physics Expert in Radiation Physics or Radiation Technology. Phys Med 1999; XV (3): 149-153
- [5] EFOMP Policy Statement No. 8: Continuing Professional Development for the Medical Physicist. Phys Med 1998; XIV (2): 81-83
- [6] EFOMP Policy Statement No. 10: Recommended Guidelines on National Schemes for Continuing Professional Development of Medical Physicists. Phys Med 2001; XVII (2) 97-101.
- [7] EFOMP Policy Statement No. 12: The present status of Medical Physics Education and Training in Europe. New perspectives and EFOMP recommendations. Phys Med 2010; (26) 1-5.
- [8] Leer JWH, Overgaard J, Heeren G. The European core curriculum on radiotherapy. Radiother Oncol 1991;22:153-5. EC Erasmus Programme (Grant agreements STV88-B-0193, STV 89-B-0209 and ICP 90-B-0170). Leer JWH, Overgaard J, Heeren G. The European core curriculum on radiotherapy. Int J Radiat Oncol Biol Phys 1991; 24:813-4. also p. 153-155. EC Erasmus Programme (Grant agreements STV88-B-0193, STV 89-B-0209 and ICP 90-B-0170). Leer JWH, Davelaar J, Overgaard J, Heeren G. Education in radiation oncology in Europe. Int J Radiat Oncol Biol Phys 1992; 24:819-23. EC Erasmus Programme (Grant agreements STV88-B-0193, STV 89-B-0209 and ICP 90-B-0170).
- [9] Europe Against Cancer Projects: EDRO-Education for Radiation Oncology (Grant agreements. 200054 05F02 and S12300039); The development of an education network for radiotherapy technologists (Grant agreement 201535; MORQA (Reduction of Radiation Morbidity through QA

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\* ECTS: European Credit Transfer and Accumulation System

of Dosimetry and Evaluation of Morbidity) Projects 1 and 2 (Grant agreements CAN 99CVF2-030 and 2000/CAN/210).

- [10] Thwaites DI, Scalliet P, Leer JWH, Overgaard J. Quality assurance in radiotherapy (ESTRO advisory report to the Commission of the European Union for the Europe against cancer programme, Grant agreement Soc 95202083). *Radiother Oncol* 1995;35:61-73.
- [11] Leer JWH, McKenzie A, Scalliet P, Thwaites DI. Practical guidelines for the implementation of a quality system in radiotherapy ESTRO physics for clinical radiotherapy booklet 4. Brussels: ESTRO; 1998.
- [12] Baumann M, Leer JWH, Dahl O, De Neve W, Hunter R, Rampling R, Verfaillie C, on behalf of European Core Curriculum for Radiotherapists Working Party of the European Society for Therapeutic Radiology and Oncology and the European Board of Radiotherapy. Updated European core curriculum for radiotherapists (radiation oncologists). Recommended curriculum for the specialist training of medical practitioners in radiotherapy (radiation oncology) within Europe. *Radiother Oncol* 2004; 70: 107-113.
- [13] Coffey M, Degerfält J, Osztavics A, van Hedel J, Vandeveld G. Revised European core curriculum for RTs. *Radiother Oncol* 2004; 70: 137-158.
- [14] Belletti S, Dutreix A, Garavaglia G, et al. Quality assurance in radiotherapy: the importance of medical physics staffing levels, recommendations from a joint ESTRO/EFOMP task group. *Radiother Oncol* 1996;41:89-94.
- [15] Eudaldo T, Huizenga H, Lamm IL, McKenzie A, Milano F, Schlegel W, Thwaites D.I, Heeren G.. Guidelines for education and training of medical physicists in radiotherapy. Recommendations from an ESTRO/EFOMP working group. *Radiother Oncol* 2004;70:125-135.
- [16] European Commission. Radiation Protection 116. Guidelines on education and training in radiation protection for medical exposures. Directorate General Environment, Nuclear Safety and Civil Protection. Luxembourg; 2000.
- [17] 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.

## II. DEFINITIONS

### 1. Medical Physicist (MP)

According to the International Organisation for Medical Physics (IOMP):

“A medical physicist is a health professional who is qualified with a university degree or equivalent (level corresponding to masters degree) majoring in physical or engineering science with specialist education and training in the concepts and techniques of applying physics in medicine”.

From the International Atomic Energy Agency (IAEA):

“A medical physicist is a healthcare professional who specialises in the application of physics in medicine and has the knowledge and responsibility for the radiation protection of patients, staff and the public”.

### 2. Qualified Medical Physicist (QMP)

EFOMP definitions:

In Policy Statement No. 7:

“A Qualified Medical Physicist is an individual who is competent to practice independently and to register as a Medical Physicist, in one or more of the subfields of medical physics”.

In Policy Statement No. 12:

“To work as a Medical Physicist in a hospital environment, it is needed to hold a university degree in physics or equivalent and a master degree (master in Medical Physics or equivalent), followed by an accredited clinical training: at least 2 years’ training experience on-the-job. Only after completion of all parts of training can a physicist be considered a Medical Physicist and able to work independently as a Qualified Medical Physicist (QMP). The Qualified Medical Physicist should have a formal recognition from a National Competent Authority”

The AAPM also defines the Qualified Medical Physicist:

“A Qualified Medical Physicist is an individual who is competent to practice independently one or more of the subfields of medical physics”.

### 3. Medical Physics Expert

This title regarding the level of an individuals expertise arose from an European directive; The definition was introduced in 1997 in the Council Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure. The Euratom Basic Safety Standards Directive (Draft Version 24 February 2010) which will revoke both the Council Directive 96/29/ Euratom of 13 May 1996, concerning basic safety standards for the protection of the health of workers and the general public (*“the BBS”*) and the Council Directive 97/43/Euratom of 30 June 1997, concerning the health protection of individuals in relation to medical exposure (*“the MED”*) gives a new definition of the Medical Physics Expert:

“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 to act is recognized by the competent authorities”.

#### 4. ECTS: European Credit Transfer and Accumulation System

1. Is a learner-centred system for credit accumulation and transfer based on the transparency of learning outcomes and learning processes. It aims to facilitate planning, delivery, evaluation, recognition and validation of qualifications and units of learning as well as student mobility. ECTS is widely used in formal higher education and can be applied to other lifelong learning activities.
2. Is a tool that helps to design, describe, and deliver programmes and award higher education qualifications. The use of ECTS, in conjunction with outcomes-based qualifications frameworks, makes programmes and qualifications more transparent and facilitates the recognition of qualifications. ECTS can be applied to all types of programmes, whatever their mode of delivery (school-based, work-based), the learners' status (full-time, part-time) and to all kinds of learning (formal, non-formal and informal).

From the "ECTS Users' Guide". European Commission. ISBN: 978-92-79-09728-7;  
[http://ec.europa.eu/education/lifelong-learning-policy/doc/ects/guide\\_en.pdf](http://ec.europa.eu/education/lifelong-learning-policy/doc/ects/guide_en.pdf)

#### 5. Learning outcomes

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 competence.

*(Recommendation 2008/C 111/01. Official Journal of the European Union 6.5.2008)*

#### 6. Knowledge

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.

*(Recommendation 2008/C 111/01. Official Journal of the European Union 6.5.2008)*

#### 7. Skills

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).

*(Recommendation 2008/C 111/01. Official Journal of the European Union 6.5.2008)*

#### 8. Competence

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.

*(Recommendation 2008/C 111/01. Official Journal of the European Union 6.5.2008)*

### III. GENERAL COMPETENCES

#### 1. Organization

##### Short description:

The medical physicist in radiotherapy is a member of a multi-disciplinary team that includes: radiation oncologists, medical physicists, RTTs, computer scientists, assistant medical technicians, nurses, administrators, hospital management and other healthcare professionals, who work together to provide the radiotherapy. Therefore, they must be able to participate in organising and structuring the radiotherapy process and associated tasks and responsibilities .

##### Competences:

- demonstrate an understanding of local and national healthcare organisational structures;
- demonstrate an awareness of trends in healthcare structure development;
- ability to work effectively, in terms of time, equipment and other resources as part of the multi-disciplinary team;
- ability to manage own workload to ensure effective input to the team;
- demonstrate an understanding of the required technological infrastructure for a radiotherapy department and an awareness of how to establish the necessary interactions with other disciplines within the hospital (e.g. diagnostic radiology and other fields of oncology);
- ability to organise various aspects of the routine radiotherapy physics service;
- ability to organise networks for research and development within the scientific community of medical physicists in radiotherapy;
- ability to effectively manage projects in order to contribute to a multidisciplinary team (e.g., research, implementation, development, quality assurance)
- ability to effectively balance all routine, innovative, research, teaching and training and outside activities.

## 2. Professionalism

### Short description:

The medical physicist in radiotherapy must have a high standard of professionalism and integrity. This includes self-awareness and knowledge of limits, high standards of ethical and moral behaviour, reliability and responsibility, respect for patient dignity, and autonomy.

### Competences:

- able to cope with own emotions and criticism;
- display appropriate behavior;
- know their own limitations of knowledge and competency and to work within them, thereby knowing when to seek advice;
- take the responsibility for their own actions and know when to take responsibility for radiotherapy physics actions of other members of the physics team;
- understanding of relevant national professional codes and the need to work within them;
- understand the requirements of data protection, privacy and dignity legislation;
- understand organisational policies and national legislation to ensure they behave correctly towards colleagues, patients and other members of the public in carrying out their duties;
- understand the principles of medical ethics and practice medical physics ethically consistent with the obligations of a medical physicist.

### 3. Communication

#### Short description:

The medical physicist in radiotherapy must be able to communicate in an efficient and unambiguous way, with a variety of healthcare professionals, to ensure the safe and accurate provision of healthcare services. This includes the accurate communication of information within the radiotherapy or oncology department, with other departments/ hospital staff, colleagues from other hospitals, vendors and other professionals in the industry and the general public.

Eventually, it is also necessary to be able to give information to the patient (and their carers) or answer their questions, in these situations it is often necessary to use non–scientific language, avoiding ‘technical jargon’ whilst ensuring clear and understandable information is given. To prepare the medical physicist in radiotherapy for the encounter with cancer patients and their families, it is important to learn basic skills and strategies needed for effective communication.

#### Competences:

- demonstrate an understanding and correct use of specific terminology;
- ability to discuss technical and clinical aspects of radiotherapy with members of the multidisciplinary team using appropriate terminology;
- ability to discuss general radiotherapy aspects with staff/ public who do not have any knowledge of radiotherapy;
- ability to prepare written material (research and routine) in the form of notes, resumes, reports and scientific papers to be presented at seminars/ conferences or to be submitted for publication in scientific journals;
- having the ability to communicate in a language/languages other than their mother tongue; in particularly english as the commonly used scientific language;
- ability to communicate clearly with patients and their family and provide them with concise information about their treatment;
- ability to recognise and respond to the emotions of patients and their family and to deal with one’s own emotional response to the challenges in working with cancer patients.

#### Core curriculum items:

- impact of communication on the patient’s wellbeing;
- communication skills in the interaction between patients and healthcare professionals.

## 4. Collaboration

### Short description:

In order to secure the best possible healthcare for the patients, the medical physicist in radiotherapy must be able to collaborate with other healthcare professionals involved in the radiotherapy process. Moreover, the ability to collaborate constructively also relies on a sound understanding of one's own role within the clinical team and the necessary interactions with individuals and healthcare professional groups.

### Competences:

- demonstrate the ability to work and consult effectively within a multidisciplinary team;
- demonstrate an understanding of the role of the medical physicist within the team;
- being able to work within the framework of cross-disciplinary research collaboration to improve the routine clinical service;
- be able to work in an international team of scientists and healthcare providers;
- is able to demonstrate leadership capability whenever necessary.

## 5. Social Actions

### Short description:

As a healthcare professional the role of the medical physicist in radiotherapy implies certain social actions that have consequences for the patient, the healthcare organisation and society.

### Competences:

- to demonstrate an understanding of, and be able to act within, relevant national legal frameworks, regulations and guidelines;
- demonstrate the ability to act according to best use of resources in the interest of the patient and society;
- have the ability to take adequate action (within own competency limitations) in response to incidents/accidents;
- show consideration for the ethical, religious, cultural or moral values of other people;

### Core curriculum items:

- national and European healthcare legislation;
- ethical guidelines;
- national and European regulations on the use of ionizing radiation in medicine;
- national and international guidelines.

### Recommended literature for the general competences:

- Kun LE, Ang K, Erickson B, Harris J, Hoppe R, Leibel S, Davis L, Hattery R. Maintenance of certification for radiation oncology. *Int J Radiat Oncol Biol Phys* 2005; 62(2): 303-308.
- Thomas SR, Hendee WR, Paliwal BR. The American Board of Radiology Maintenance of Certification (MOC) Program in Radiologic Physics. *Med Phys* 2005; 32(1): 263-267.
- Faulkner A, Maguire P. *Talking to cancer patients and their relatives*, Oxford University Press, 1994

## IV. RADIOTHERAPY PHYSICS KNOWLEDGE, SKILLS AND COMPETENCES

The field of radiation therapy physics is a dynamic, quickly evolving discipline. This requires constant development, introduction and implementation of new advanced imaging and treatment technologies along with optimisation of existing techniques. Because of their key role in these processes, medical physicists in radiotherapy are required to have broad scientific interests and need to constantly learn and acquire new knowledge. An excellent knowledge of radiation therapy physics remains the central competence, whilst interdisciplinary knowledge is also needed for active involvement in development of new combinatory therapeutic technologies.

The medical physicists in radiotherapy have to demonstrate and apply their knowledge in clinical practice through skills and appropriate attitude. Therefore medical physicists should be able to:

- examine medical information critically and apply it appropriately to practice decisions;
- maintain and enhance professional knowledge through ongoing lifelong learning (e.g. develop and maintain a personal continuing-education plan);
- facilitate the learning and promote the scientific expertise of students, colleagues and other healthcare professionals;
- perform a systematic review and interpretation of scientific literature;
- follow the current research and development in radiation therapy, understand and implement new technologies in clinical practice;
- carry out, conduct and supervise scientific research and development in radiotherapy physics;
- optimise the quality, the practical effect and the scientific value of research;
- build, have and maintain a good national and international network;
- recognise the limits of their expertise.

The following sections provide more detail on the required areas of base knowledge (Core Curricular) and required competencies (demonstration of knowledge application) for the contemporary medical physicist in radiotherapy.

# FUNDAMENTAL KNOWLEDGE, SKILLS AND COMPETENCES

## 1. Fundamentals of human anatomy and physiology

### Short description:

Basic understanding and knowledge of human anatomy is required to safely undertake treatment simulation and planning in radiation oncology. It is also a prerequisite for communication and exchange of patient and disease related treatment information. Likewise a basic understanding and knowledge of the human physiology is essential to the understanding of treatment-related adverse effects, and is required for treatment optimisation. As a part of a multidisciplinary radiation oncology team the medical physicist in radiotherapy requires a background in basic human anatomy and physiology.

### Competences:

- demonstrate an understanding of human anatomy and physiology;
- ability to recognise the various anatomical structures of the human body relevant to the radiotherapy process, especially with emphasis on their representation in 3D and 2D imaging;
- demonstrate an understanding of the consequences of treatment-related adverse effects and how this influences treatment planning.

### Core curriculum items:

- nomenclature of human anatomy;
- the anatomy of skeletal structures;
- the anatomy of muscles;
- the anatomy and physiology of organs and tissue at risk in radiotherapy;
- the anatomy and physiology of the most frequent cancer sites.

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

### Recommended literature:

- Widmaier E, Raff H, Strang K. (<http://www.amazon.co.uk/exec/obidos/search-handle-url?%5Fencoding=UTF8&search-type=ss&index=books-uk&field-author=Arthur%20J.%20Vander>), Sherman and, Luciano's Human Physiology, McGraw-Hill, 2004.
- McKinley M, O'Loughlin V, Human Anatomy, McGraw-Hill, 2005.
- Marieb EN, Hoehn KN, Human Anatomy and Physiology, Benjamin Cummings, 2006.

## 2. Fundamentals of oncology

### Short description:

In order to effectively communicate and operate within the multi-disciplinary team a basic understanding of the fundamentals of cancer development, diagnostics and treatment is required. Furthermore, the knowledge enables the better application of the medical physicist's function in contemporary radiotherapy.

### Competences:

- ability to participate in a multidisciplinary radiation oncology team with respect to the communication and exchange of relevant patient information;
- demonstrate a basic understanding of the development of cancer, the nature of the various forms of cancers, their molecular and cellular features as well as diagnostics of cancer;
- demonstrate knowledge of the various treatment options;
- ability to integrate knowledge of multi-modal therapy into the planning of radiation therapy of cancer patients.

### Core curriculum items:

- carcinogenesis;
- onogenes and supressorgenes;
- major signalling pathways of importance for repsonse to radiation;
- pathways of tumour dissemination;
- principles of diagostics and staging of cancer;
- principles of surgical, medical and radiation oncology.

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.

### 3. Principles and applications of radiobiology and molecular biology

#### Short description:

Modern radiation oncology increasingly utilises multi-modality treatment which is a combination of radiotherapy and chemotherapy. This includes novel drugs that target specific molecular pathways which interact with the response to radiation on the molecular level. This development requires the medical physicist in radiotherapy to have a good knowledge of radiobiology and its clinical implications in order to appreciate the basis of therapy strategies in radiation oncology. .

Individualised therapy, optimisation and the development of novel treatment strategies will likely require incorporation of detailed knowledge of the molecular and cellular treatment response mechanisms into the treatment planning process. Furthermore, the availability of new radiation modalities, such as protons or light ions, and the increasing inclusion of patient related individual biological information into treatment planning will require a broader knowledge of biology. Therefore, medical physicists in radiotherapy have to be trained in the fundamentals of cellular and molecular biology as well as tumour and radiation biology.

#### Competences:

- ability to demonstrate the understanding of the fundamentals of cellular, molecular and radiation biology of tumour and normal tissue;
- demonstrate a basic understanding of the mechanisms involved in novel drugs commonly used in combination with radiation;
- ability to understand the basics of how radiation sensitivity of tumour and normal tissues is caused by combined medical and radiation therapy;
- ability to practically apply radiobiological knowledge to the fields of radioprotection as well as to diagnostic and therapeutic application of ionising radiation;
- ability to demonstrate the understanding of the radiobiological background of treatment strategies in radiation therapy.

#### Core curriculum items:

- fundamentals of cellular and molecular biology;
- the physical and biological background of the effect of electromagnetic, electron and heavy particle irradiation to living cells;
- the response to radiation on molecular, cellular and macroscopic levels;
- deterministic and stochastic effects of ionising radiation;
- the response of tumours and normal tissue to therapeutic levels of radiation;
- early and late radiation effects;
- effects of fractionation, dose rate, radiosensitisation and reoxygenation;
- the linear quadratic model;
- therapeutic ratio, tumour control probability, normal tissue complication probability, tolerance doses;
- dose-volume effects.

Time to be spent in this topic: 3 ECTS

**Recommended literature:**

- Alberts B, Bray D, Hopkin K, Johnson A, Lewis J, Raff M, Roberts K, Walter P. Essential cell biology, Garland, 2009
- Steel GG, Basic Clinical Radiobiology, Arnold, 2009
- Hall E, Giaccia AJ, Radiobiology for the radiologist, Lippincott, Wilkins & Williams, 2006
- Introduction to the Cellular and Molecular Biology of Cancer, Eds. Margaret Knowles and Peter Selby, Oxford University Press, 2005
- Hanahan D and Weinberg RA. The Hallmarks of Cancer. Cell 2000; 100: 57-70.

## 4. Overview of radiation physics

### Short description:

The medical physicist in radiotherapy should have a good knowledge of radiation physics in order to understand the manner in which ionising radiation is applied in medical diagnostics and radiotherapy. Since X-rays of energies ranging from kV to several MV, gamma-rays of several MeV and a variety of corpuscular radiations, including heavy ions, are nowadays applied in medical diagnostics and radiotherapy, a broad knowledge of nuclear and atomic physics is required for the medical physicist in radiotherapy. Medically relevant descriptions of the different sources of ionising radiation, such as beam specifications for radiodiagnostics or radiotherapy, should be included. Emphasis should be given to the knowledge of the physics of interaction of different types of radiation with matter, as it forms the basis for understanding the advantages and limitations of various diagnostic and therapeutic techniques, leading to insight of their biological effect (radiobiology). Elements of statistical methods applied to estimate the uncertainty of radioactivity measurements with an overview of medical uses of radiation should also be included.

### Competences:

- ability to recognise the difference between the physical interactions of indirectly and directly ionising radiation;
- ability to specify the different mechanisms of generation of ionising radiation, including radioactive decay;
- ability to describe different mechanisms of energy loss of various types of radiation through various media;
- demonstrate an understanding of the basic concepts of dosimetry and principles of operation of several dosimeters;
- ability to quantitatively describe radiation fields applied in radiodiagnostics and radiotherapy;
- ability to quantitatively describe the various radioactive sources used in nuclear medicine for diagnostics and radiotherapy;
- demonstrate an understanding of and the ability to apply principles of radiation protection in radiodiagnostics and in radiotherapy;
- ability to identify a physical problem and to develop an experimental procedure of resolving it using appropriate measurement equipment;
- ability to estimate measurement uncertainties and their categories.

### Core curriculum items:

- ionising radiation;
- x-ray generation;
- radioactivity (units and quantities);
- poisson statistics;
- radiation sources and source types (e.g. sealed, unsealed, applications);
- interaction of photons with matter;
- scattering and attenuation of a photon beam in matter;
- interaction of electrons, heavy charged particles and neutrons (slow and fast);
- linear energy transfer (LET);
- overview of medical uses of radiation;
- overview of clinical specification of radiotherapy beams.

Time to be spent on this topic: 7 ECTS

Recommended literature:

- Dendy PP, Heaton B. Physics for Diagnostic Radiology. 2<sup>nd</sup> Ed. IoP Bristol and Philadelphia 1999
- Graham DT, Cloke P. Principles of Radiological Physics. 4<sup>th</sup> Ed. Churchill Livingstone 2003
- Hobbie RK. Intermediate Physics for Medicine and Biology. 3<sup>rd</sup> Ed. Springer-Verlag 1997
- Podgorsak EB. Radiation Physics for Medical Physicists. Biol Med Phys, Biomedical Engineering. Springer 2005.

## 5. General safety principles in the medical environment

### Short description:

Whilst undertaking their work the medical physicist in radiotherapy may be exposed to many radiological, electrical, chemical, mechanical and biological hazards; They must therefore be familiar with potential hazards and necessary precautions. A sufficient appreciation of best practice concerned with safety and risk management must be gained to be able to contribute, facilitate, implement and improve safety management systems.

### Competences:

- ability to discuss and manage safety;
- ability to identify and minimize risks in order to avoid preventable incidents;
- ability to plan an investigation following an incident to analyse its causes and consequences and suggest changes to practice to avoid repetition;
- ability to measure and improve effective safety performance;
- ability to define emergency plan;
- ability to manage and control human factors and safety-related behavior;
- ability to assess national regulations;
- ability to perform risk analysis for new equipment or a new treatment technique, implementing the necessary of the below stated aspects and identifying quality control checks for associated equipment.

### Core curriculum items:

- principles of safety and risk management;
- electrical, electro-magnetic, and magnetic safety;
- mechanical safety;
- biosafety;
- principles of radiation protection, ionising radiation and non-ionising radiation (microwave, RF and magnetic fields, ultraviolet, lasers, ultrasound).

Time to be spent on this topic: 1 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)).

## 6. Principles of quality management

### Short description:

Quality management requires an organisational structure (quality system) wherein responsibilities, procedures, processes and resources are clearly defined. It should be supported by the department management in order to work effectively and should be as comprehensive as is required to meet the overall quality objectives. It must have a clear definition of its scope and of all the quality standards to be met and requires collaboration between all members of the radiotherapy team. The quality system must incorporate compliance with all the requirements of national legislation, accreditation, etc. and requires the development of a formal quality assurance program that details the quality assurance policies and procedures, quality control tests, frequencies, tolerances, action criteria, required records and personnel.

### Competences:

- ability to participate in quality management and facilitate quality improvement;
- ability to define quality objectives;
- ability to measure effective quality performance;
- ability to improve effective quality performance;
- ability to define control tests, frequencies, tolerances, action criteria, records and personnel;
- ability to assess the national legislation, accreditation requirements.

### Core curriculum items:

- meaning of quality, quality assurance and quality control;
- quality standards;
- assessment of quality;
- quality management systems, records, audit and improvement of quality.

Time to be spent on this topic: 1 ECTS

### Recommended literature:

- 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 (article in press)
- AAPM Recommendations, TG-40, TG-56 and TG-100

## 7. Quality and risk management in radiotherapy

### Short description:

The complexity of the radiotherapy process continues to increase which requires a high level of safety and constant quality improvement. The quality management of this process should be continuously improved and modified to meet these evolving needs and demands. As part of the multi-disciplinary team medical physicists are obliged to contribute to the implementation and maintenance of the departmental safety and quality management system to achieve the following objectives:

- increase the safety of the patient undergoing diagnostic and therapeutic procedures related to radiotherapy physics;
- increase the safety, quality and efficiency of the medical physics services;
- increase its cost effectiveness;
- introduce the concept of improvement and upgrading of the radiotherapy physics services.

The Quality Assurance process in radiotherapy involves all steps of the treatment: simulation, imaging, planning, verification, delivery and reporting. In particular, it includes the commissioning and quality control of treatment units, treatment planning system, imaging systems, dosimetry systems and computer networks. Quality assurance of individual patients includes independent monitor unit calculation and, for special techniques (such as stereotactic treatments, IMRT and IMAT) dosimetric verification of the treatment plan.

### Competences:

- ability to identify and formulate improvements to upgrade the quality system;
- ability to evaluate and prevent the risks of a given procedure or protocol;
- ability to set specifications, measure performance, compare with specifications, and, if required, adjust the process to meet specifications in accordance with the recommendations and standards (including documentation and training of other professionals);
- ability to evaluate whether service agreements and software updates for major equipment ( e.g. treatment and imaging equipment, treatment-planning and patient management computer systems) are adequate to ensure patient safety and service continuity;
- ability to assess additional needs in the quality program consistent with the scope of clinical services being provided and/or in the process of implementation;
- ability to prevent and investigate incidents and implement corrective actions;
- ability to evaluate effective safety performance;
- ability to manage emergency situations;
- ability to assess human factors and safety-related behavior;
- ability to assess sources and levels of uncertainty in geometry and dose delivery and the methods for monitoring and controlling them;
- demonstrate knowledge of national and international recommendations and local protocols for quality assurance;
- ability to perform the commissioning and quality control of treatment units, treatment planning systems (TPS), imaging systems, dosimetry system and networks.

### Core curriculum items:

- meaning of quality, quality assurance and quality control;
- meaning of risk;
- quality standards;
- assessment of quality;
- assessment of risk;
- risk management;
- quality management systems, records, audit and improvement of quality;
- quality audit, analysis and improvements.

Time to be spent on this topic: 1 ECTS

### Recommended literature:

- 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

## 8. Statistical methods

### Short description:

An important technique in biomedical research is the ability to understand the properties, or knowledge, of a whole population from those of a smaller random sample of that population. This research methodology, widely applied to studies in radiation oncology and radiobiology, requires the utilisation and understanding of statistical methods. Medical physicists in radiotherapy are frequently involved in such studies, specifically they may be responsible for designing, analysing and interpreting the experiments and processing the resultant data. Moreover, they should be able to correctly and critically analyse published research results. Therefore, medical physicists in radiotherapy have to be trained in the fundamentals of statistical methods and their application to biomedical research.

### Competences:

- ability to demonstrate the understanding of the fundamentals of biostatistics;
- ability to design studies in clinical and biomedical research;
- ability to perform the most common statistical tests;
- ability to apply computational techniques and dedicated software packages for statistical data analysis;
- ability to analyse and interpret experimental results;
- ability to apply experimental outcomes to evidence based medicine approaches.

### Core curriculum items:

- descriptive statistics;
- probability distributions;
- general principles and application of statistical tests;
- survival analysis;
- study design and power analysis;
- sample size definition
- uncertainty analysis;
- regression and correlation.

Time to be spent on this topic: 1 ECTS

### Recommended literature:

- Glantz SA. Primer of biostatistics, McGraw Hill, 2005
- Rosner B. Fundamentals of biostatistics, Thomson, 2006

## 9. Organisation, management and ethical issues in health care

### Short description:

The medical physicist in radiotherapy should understand the structure of, and be able to participate in, the management of a hospital department. The trainee should acquire basic knowledge of the organisation and management of the local healthcare system and of the relevant guidelines and recommendations from national or international organisations. They should be familiar with ethical considerations in medical practice.

### Competences:

- demonstrate an understanding of the position of the trainee's own institution as part of the organisation of healthcare at local and national levels;
- demonstrate knowledge of the development of medical physics and radiotherapy in the trainee's country;
- ability to acquire EU Directives, national regulations and guidelines and/or recommendations from national and international organisations;
- demonstrate knowledge of ethical considerations in medical practice;
- demonstrate knowledge of equipment management (e.g., servicing, purchasing of new equipment, etc.);
- demonstrate understanding of written procedures of a departmental quality management system.

### Core curriculum items:

- national and local system, global view of other European systems;
- national regulations and EU directives in medical application of ionising radiation;
- guidelines and recommendations from national and international organizations;
- ethical considerations in medical practice;
- principles of management as applied to hospital departments and projects, etc.;
- principles of personnel management ;

Time to be spent on this topic: 1 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

## 10. Health technology assessment

### Short description:

Health technology assessment (HTA) is a multidisciplinary process that analyses information regarding the use of a particular health technology. It summarises medical, social, economic and ethical issues in a systematic manner, aiming to inform the formulation of safe and effective health policies that are patient focused and seek to achieve best value. HTA crosses the ideological divide between scientific investigation and political decision making, however it remains firmly rooted in the research and scientific methodologies.

For example, a HTA related to radiotherapy may seek to address these questions:

- Do we really need detailed evidence to determine effectiveness?
- Is it ethical to randomise patients between two treatment modalities when it is obvious from a theoretical point of view that one is better than the other?
- What kind of trials needs to be designed to answer the question of whether a clinical improvement is worth the added expense?

### Competences:

- demonstrate an understanding of the basic methodology employed in HTA;
- ability to perform a systematic review of the literature to evaluate the clinical effectiveness of a new technology or technique;
- ability to assess the safety and efficacy of a new technology/technique.

### Core curriculum items:

- general aspects related to an HTA report: general impressions, motivation for the report, methodology used, interpretation of available information and implementation of the finding of the report.
- development of methodology for critical assessment of health technology as a complement to randomized controlled trials.

Time to be spent on this topic: 1 ECTS

### Recommended literature:

- Does health technology assessment put patient care at risk? McEwan AJ, J Nucl Med. 2005 Dec; 46(12):1939
- Randomized controlled trials in health technology assessment: Overkill or overdue?, Bentzen S , Radiother Oncol 86 (2008) 142-147.
- A difference between systematic reviews and health technology assessment; a trade-off between the ideals of scientific rigor and the realities of policy making. Rotstein D and Laupacis A. Int J Technol Assess Health Care 2004, 20, 177-183.

## 11. Information and communication technology

### Short description:

There is a clear need for the modern medical physicist in radiotherapy to have a good understanding of Information and Communication Technology (ICT). The contemporary radiotherapy department has a number of computer systems which are used to design, manage and deliver highly complex radiotherapy. Hence the need to safely transfer data across a number of software and hardware interfaces is essential. It is not necessary for all physicists to become experts in ICT, however they are required to work effectively with IT professionals from inside and outside the hospital organisation.

### Competences:

- ability to understand and discuss ICT concepts, with other healthcare professionals, to assist with the specification, commissioning, implementation and safe operation of contemporary radiotherapy equipment;
- ability to understand and discuss healthcare data connectivity standards with colleagues from other disciplines to facilitate the integration of general systems within radiotherapy departments;
- demonstrate a good understanding of hardware configuration, operating systems and typical software applications;
- demonstrate a good understanding of the contemporary planning, treatment management, delivery and dosimetry systems.

### Core curriculum items:

- operation of the major components of computers, including hardware, software, computer topologies and networks;
- the principles of local and wide area networking (LAN, WAN) and protected (including firewalls) sub-nets as a security precaution for 'mission critical' equipment whose safety of operation may be compromised otherwise;
- IP terminology, port assignment, ftp, telnet, ping testing, network gates and router procedures, firewall technology;
- virus infection risks: different types and routes of propagation , precautionary measures;
- different types of software licensing principles;
- 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;
- the operational relationships between hospital information systems and management systems used in radiotherapy and oncology;
- data warehousing for archiving and storage and relevant legislation regarding the required time such information must be kept for;
- DICOM - general understanding of DICOM and its operation;
- PACS - general understanding of PACS and its operation.

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

### Recommended literature:

- W. Buchanan, Mastering networks. 2010

# KNOWLEDGE, SKILLS AND COMPETENCIES SPECIFIC FOR RADIOTHERAPY

## 12. Dosimetry

### Short description

Accurate dose determination is one of the most important tasks of the medical physicist in radiotherapy. The concept of absorbed dose and kerma, and dosimetric quantities and units should be well understood. The medical physicist in radiotherapy should be familiar with the principle of the calibration chain from the national primary standard to hospital field instrument and understand the physics and techniques of the different dosimetry detectors involved. Determination of the absorbed dose in a clinical beam under reference conditions by applying a national or international recommended protocol is an important issue; determination of dose in non-reference conditions should be understood. The medical physicist in radiotherapy should be familiar with the different measurement systems that are available for dosimetry and quality control in the hospital; 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 (statistical) uncertainty of measurements. Dosimetry audits are an important step in a well designed quality control program.

### Competences:

- demonstrate a good understanding of the fundamental theoretical and practical aspects of all reference dosimetry for teletherapy and brachytherapy sources;
- demonstrate knowledge of dosimetric standards and traceability;
- ability to understand and apply the relevant national or international Codes of Practice for the determination of absorbed dose to the water (e.g. IAEA);
- ability to choose the appropriate phantom;
- ability to perform absorbed dose measurements in clinical situations;
- ability to select the most appropriate detector to use to measure absolute dose and relative dose distributions in different irradiation conditions for photons and for electrons beams;
- ability to set up a system for In-Vivo dosimetry;
- ability to setup a program for acceptance testing, calibration and quality control of the measurement systems.
- ability to estimate measurement uncertainties and their categories.
- ability to calibrate ionisation chambers and diodes;
- ability to perform constancy checks (eg strontium-90 based) on ionisation chamber dosimeters;

### Core curriculum items:

#### Principles of dosimetry:

- concept of absorbed dose and kerma;
- the cavity theory;
- relationship between different dosimetric quantities and units.

Physics, techniques and instrumentation of radiation detector systems:

- calibration chain for dosimetry detectors;
- dosimetric standards and traceability;
- properties of dosimeters;
- evaluation of uncertainties;
- ionisation chambers;
- film dosimetry;
- luminescence dosimetry;
- semiconductors;
- diamond dosimeters;
- alanine dosimetry system;
- scintillation detectors;
- gel dosimetry;
- calorimetry;
- chemical dosimetry.

Dose determination and quality control in the hospital:

- dosimetry recommendations based on air-kerma standards;
- dosimetry recommendations based on absorbed dose in water;
- application of a protocol for absorbed dose determination in a clinical beam;
- determination of the absorbed dose under non-reference conditions;
- in-vivo dosimetry;
- dosimetry audits;
- measurement systems and phantoms used for dosimetry and quality control;
- choice of dosimetry systems;
- technical specification, acceptance testing, calibration and QC of practical systems.

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

**Recommended literature:**

- Absorbed Dose Determination in External Beam Radiotherapy, TRS-398, IAEA 2000.
- Calibration of Reference Dosimeters for External Beam Radiotherapy, TRS-469, IAEA 2009
- Attix FH. Introduction to Radiological Physics and radiation Dosimetry, Ed. Wiley-VCH Verlag GmbH & Co. 2004.
- Knoll GF. Radiation detection and measurement. Third edition. Ed. Wiley. 2000
- 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

## 13. Principles of medical imaging and image handling

### Short description:

Medical Imaging is an essential tool in all state-of-the-art planning and delivery techniques. In radiotherapy it is used to: (i) identify anatomy, (ii) plan the desired treatment, (iii) verify the treatment delivery, (iv) modify the treatment delivery/plan if necessary and (v) follow-up or monitor treatment outcome.

More specifically the multi-disciplinary team heavily utilises imaging to determine the extent of disease and identification of the treatment targets and their spatial relationship with neighbouring healthy tissues. In modern radiotherapy it plays an indispensable role in patient positioning and ensuring the accuracy of treatment delivery. Functional and 3D molecular-imaging modalities (e.g. PET, SPECT, PET, MRI, MRI spectroscopy and fMRI) provide non-invasive information about biological and physiological processes of relevance to treatment design and assessment of treatment response. Within the multi-disciplinary team it is the role of the medical physicist in radiotherapy to ensure that imaging equipment in the radiotherapy process is used appropriately, effectively and safely.

### Competences

- demonstrate an understanding of the physics and principles of imaging in the radiotherapy process, the sources of image errors, the uncertainties and the resolution limits;
- ability to understand and interpret the images from the various modalities (CT, MRI, PET and US)
- appreciate the effect of contrast media in different modalities and the limits of the imaging signal for appropriate application;
- demonstrate an understanding of the different acquisition protocols in CT and MR imaging and the effect of the adjustable parameters to the appearance and the properties of the image;
- demonstrate an understanding of functional imaging techniques fMRI and spectroscopy;
- ability to set the requirements of PET studies specifically for radiation oncology planning;
- ability to perform acceptance and commissioning tests and set up a QA programme for all imaging modalities used in radiation therapy to evaluate performance, image quality and geometric accuracy and dose to the patient;
- ability to evaluate the imaging modalities, conduct specifications and select imaging systems;
- ability to assess and evaluate discrepancies of the images acquired during the radiotherapy process;
- ability to observe and assess the engineering maintenance of the imaging equipment.

### Core curriculum items

- physics of image formation;
- image handling, digital image processing, reconstruction algorithms;
- noise and measurements of image quality;
- physics and principles, equipment, and practical applications in radiotherapy of the imaging modalities (radiography & fluoroscopy, CT, conventional and CT simulators, MRI, US, PET, PET/CT, SPECT);
- physics and principles of the different imaging systems on treatment units (portal imaging devices, flat panels, kV and MV CBCT, US);
- anatomical and functional imaging using different modalities and techniques;
- effect and management of patient organ motion;

- geometrical accuracy, reproducibility and methods of assessment;
- QA programmes.

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

**Recommended literature:**

- Webb S, The physics of medical imaging, IoP 1992
- Buschberg JT et al. The essential physics of medical imaging, 2002
- Mutic S et al. Quality assurance for computed-tomography simulators and the computed-tomography-simulation process: report of the AAPM Radiation Therapy Committee Task Group No. 66, Med Phys 2003; 2762-2792.
- IPEM, Report 80: Quality control in magnetic resonance imaging, IPEM, York (1995).
- American Association of Physicists in Medicine, Quality Assurance. Methods and Phantoms for Magnetic Resonance Imaging, AAPM, Maryland (1990).
- 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.
- Xing L. Quality assurance of PET/CT for radiation therapy. Int J Radiat Oncol Biol Phys 2008; 71(Suppl.):S38-S42.

## 14. External beam radiotherapy

### 14.1 Treatment equipment

#### Short description:

The medical physicist in radiotherapy is responsible for the maintenance of safe and effective operation of radiotherapy equipment. External beam radiotherapy devices include all treatment units used to irradiate the patient with kV and MV X-ray beams, gamma rays or electron beams. Most contemporary treatment machines have integrated imaging systems to localise the target on-line before the treatment or even to track its motion during treatment (image-guided radiotherapy, IGRT).

#### Competences

- demonstrate an understanding of the physics and principles of all treatment units and in-room imaging equipment, the sources of interlocks, and the sources of deviations in dosimetric or mechanical parameters;
- ability to understand and have technical discussions with engineers (e.g., concerning recalibration or replacement of parts);
- ability to perform acceptance testing, commissioning and quality control of treatment units and in-room imaging equipment;
- ability to operate treatment units and in-room imaging equipment safely;
- ability to specify, justify and rank the criteria for specifying and selecting treatment units and in-room imaging devices.

#### Core curriculum Items

- kV X-ray units;
- cobalt units;
- linear accelerators and other systems for MV X-ray and electron beams (tomotherapy unit, robotic linacs, mobile linacs for intra-operative radiation therapy);
- stereotactic irradiation devices;
- imaging systems on treatment units: electronic portal imaging devices, kV-MV cone beam CT;
- imaging systems at treatment units: opto-electronic systems, stereoscopic X-ray imaging systems, in-room CT, radiofrequency-based and ultrasound devices;

Time to be spent on this topic: 5 ECTS

## 14.2 Clinical dosimetry of conventional treatment beams

### Short description

The medical physicist in radiotherapy performs an essential role to ensure that radiotherapy is delivered as expected by characterising the beams produced by the treatment machines. Basic dosimetry of conventional photon and electron beams, in isocentric and fixed-SSD approaches, is the first step for the implementation of the treatment planning system and of any manual dose calculation. Ongoing quality control using similar methodologies ensures that assumed treatment beam models remain valid.

### Competences

- demonstrate a working knowledge of the terminology used in clinical dosimetry;
- ability to perform absolute and relative dose measurements (output factors, PDD, beam profiles, etc.) in air, in water and solid phantoms for photon and electron beams using different equipment (ionisation chambers, diodes, film, TLD);
- ability to select the most appropriate detector to measure absolute and relative dose in different irradiation conditions for photons and electrons beams;
- demonstrate understanding of the influence of relative dosimetry on treatment parameters;
- demonstrate understanding of the influence of beam modifiers on the beam characteristics;
- ability to acquire beam data for the treatment planning system;
- demonstrate knowledge of dosimetric standards and traceability.

### Core curriculum items

- terminology used in clinical dosimetry (e.g.: PDD, TMR, TPR, OAR);
- definition of “reference conditions” in fixed-SSD and isocentric approaches;
- beam quality specification (quality index for photons, range and energy parameters for electron beams);
- in-air and in-phantom characteristics of clinical beams;
- absolute and reference dosimetry. Absorbed dose in reference conditions: national and international protocols (e.g. IAEA);
- relative dosimetry:
  - central axis dose distribution in water
  - output factors: effects of head scatter and phantom scatter, dependence on treatment parameters
  - 3D dose distribution: 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;
- basic dosimetry in non-reference conditions (e.g. extended SSD, off-axis);

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

### 14.3 Treatment techniques

#### Short description

Radiotherapy during the last decades has developed from simple 2D techniques to 3D conformal radiotherapy and intensity-modulated radiotherapy (IMRT). It has also developed a closer reliance on imaging during each stage of the process (Image Guided Radiotherapy (IGRT)). The recent technological developments allowed a more efficient and sophisticated method to deliver IMRT using rotational techniques. Special techniques are used in particular clinical situations.

#### Competences:

- demonstrate understanding of the capabilities and limitations of all different irradiation techniques;
- demonstrate understanding of current and state-of-the-art treatment techniques for all relevant treatment sites;
- ability to implement all treatment techniques, from commissioning to treatment simulation, planning, verification and quality assurance;
- ability to choose the most appropriate technique according to the tumor site and intent of the treatment;
- ability to compare national and international treatment protocols for different irradiation techniques with those used at the institution.

#### Core Curriculum Items

- conventional techniques: wedges, bolus, compensators, beam shaping, beam combinations, weighting and normalization, field matching;
- more advanced techniques: 3D conformal radiotherapy, rotational techniques (conformal arcs, conformal dynamic arcs), non coplanar techniques;
- IMRT: fixed-gantry IMRT: MLC-based static or dynamic delivery, compensator based IMRT rotating-gantry IMRT: serial and helical tomotherapy, intensity-modulated arc therapy (IMAT);
- special techniques: stereotactic radiosurgery (SRS) and radiotherapy (SRT), intraoperative radiation therapy (IORT), total body irradiation (TBI), total skin electron irradiation (TSEI), gated irradiation of mobile targets;
- corresponding knowledge and skills will need to be acquired for new upcoming techniques.

Assessment of the amount of time to be spent in this topic      10 ECTS

## 14.4 Treatment simulation and planning

### Short description

Treatment simulation and planning consist of all procedures used to determine the optimal irradiation plan for a patient. The first step is the immobilisation and simulation of the patient. Except for simple cases, treatment planning is now performed with computerised treatment planning systems (TPS), which rely on computer hardware, software and networking. Using dosimetric data of the treatment beams obtained with phantom measurements, 3D patient anatomical model created with multimodality imaging, and applying dose calculation algorithms, dose distributions of different irradiation techniques can be calculated. Detailed knowledge of the effect of beam arrangements, modification devices, beam weights, normalisation, optimisation techniques and dose prescription is necessary to produce a good treatment plan. Plan evaluation methods are essential to clinically accept the treatment plan. The medical physicist in radiotherapy plays a key role and is responsible in all the treatment planning procedure, i.e. in the optimization and evaluation of dose distribution. They are also responsible for ensuring the effective use and operation of the devices used to simulate the treatment which include conventional and virtual (CT) simulators.

### Competences

- demonstrate an understanding of the use of the conventional and CT simulator devices;
- demonstrate an understanding of immobilisation devices and their application;
- demonstrate familiarity with steps of conventional and CT simulator;
- demonstrate knowledge of the hardware and software components of a TPS and networking;
- ability to import measured beam data into the TPS;
- ability to perform the commissioning of the TPS;
- ability to acquire multimodality imaging data and perform image fusion for target volume delineation and planning;
- demonstrate working knowledge of the ICRU terminology regarding the target volumes and organ at risks;
- demonstrate awareness of the limitations of dose calculation algorithms for heterogeneity corrections in low density tissue and tissue interface where electronic equilibrium is not fully established;
- demonstrate knowledge of algorithms / models to calculate the dose distribution for photon and electron beams;
- ability to manually create a number of plans for a variety of different irradiation techniques;
- ability to produce computer-supported plans for simple techniques, using appropriate beam modifiers such as wedges, blocks, MLCs, compensators and bolus;
- ability to create a number of computer-supported plans for sophisticated and special techniques (e.g. IMRT, stereotactic radiosurgery, etc.);
- ability to perform manual monitor unit or time calculations for MV and kV X-ray beams, gamma rays and electron beams for a variety of clinical situations;
- ability to check computer calculations of monitor units on treatment plans using the institution's charts or independent monitor unit calculation program, taking into account field-size factors, wedge factors and other relevant factors;
- ability to compare different levels of treatment planning complexity in relation to clinical requirements and the uncertainties involved;
- ability to perform plan optimisation and evaluation using uniformity criteria, constraints, DVHs and biological parameters (TCP, NTCP);
- ability to record and report dosimetric parameters according to international recommendations;

- ability to specify, justify and rank the criteria for specifying and selecting TPS.

### Core Curriculum Items

- immobilisation devices and their application;
- principles of CT simulation;
- multimodality image registration and fusion for target volume delineation and planning;
- hardware and software components of a treatment planning system (TPS) and networking (dicom, dicom RT etc.);
- specification of dose and volumes, margin decisions, including international recommendations (ICRU 50, 62, 83);
- ICRU terminology regarding target volumes and organ at risks (GTV, CTV, PTV, PRV, etc);
- principles of treatment planning: manual and computer supported;
- Dose calculation algorithms (correction-based, model-based and Monte Carlo) for photon and electron beams;
- monitor unit calculation for fixed-SSD and isocentric approaches;
- computer-supported plans for all different irradiation techniques;
- virtual simulation and tools: BEV, DRR; DCR (Digitally composited radiographs)
- effect of various beam arrangements, beam modification devices (wedges, compensators, blocks, MLCs, bolus) and beam weights on dose distribution;
- IMRT planning: forward vs. inverse planning, fluence optimisation;
- plan optimisation and evaluation methods: uniformity criteria, constraints, DVHs and biological parameters (TCP, NTCP);
- 4D TPS;
- recording and reporting dosimetric parameters according to international recommendations;
- 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.

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

## 14.5 Treatment verification

### Short description

Treatment verification includes all procedures to verify the different steps of the treatment: patient positioning, target localisation, data transfer from the treatment planning system to the treatment unit through the record and verify system and dosimetric verification of the irradiation plan. Patient set-up and target localisation before treatment can be verified with different IGRT techniques with on-line or off-line correction protocols. Techniques have been developed to minimise the effects of organ motion due to breathing during treatment.

The dosimetric verification of the irradiation plan 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, like transit dosimetry with portal imaging.

### Competences

- ability to implement different IGRT techniques;
- ability to implement the techniques to control respiratory motion;
- ability to assess intra and inter-fraction set-up errors and target motion;
- ability to apply different set-up and IGRT correction protocols;
- ability to perform pre-treatment dosimetric verification of standard and sophisticated RT technique's plans in a phantom;
- demonstrate knowledge of different approaches and appropriate detectors to perform in-vivo dosimetry;
- ability to use a record and verify system.

### Core Curriculum Items

- patient alignment and set-up on the simulator and on treatment units;
- IGRT techniques at the treatment unit to optimise the set-up and target localisation;
- techniques to control breathing motion during treatment (respiratory gating, breath hold and tumor tracking);
- basic dosimetry source data;
- dosimetric verification of standard 3D-CRT plans;
- dosimetric verification of special technique plans;
- dosimetric verification of IMRT plans;
- in-vivo dosimetry;
- record and verify systems;
- geometric setup protocols based on bony anatomy and based on tumor position.

Assessment of the amount of time to be spent in this topic      5 ECTS

Total: 45 ECTS for External beam radiotherapy (Chapter 14)

## Recommended literature

- Greene D and Williams PC. Linear accelerators for radiation therapy. IOP 1997
- Williams JR, Thwaites DI (Eds.). Radiotherapy physics in practice, Oxford University Press, Oxford, 2nd Edition 2000.
- Smith AR (Ed). Radiation Therapy Physics. Springer-Verlag, New York, 1995.
- IPEM Report No 94. Commissioning and quality assurance of linear accelerators, IPEM, York, 2006.
- 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.
- ESTRO booklet series (Booklets 1 (1994), 3 (1998), 6 (2001) and 9(2008))
- Determination and use of scatter correction factors of megavoltage photon beams. Report 12 of the Netherlands Commission on Radiation Dosimetry.
- Webb S. Contemporary IMRT Developing Physics and Clinical Implementation. IOP Publishing Ltd. Bristol, UK, 2005.
- Webb S. The physics of conformal radiotherapy / advances in technology. IOP Publishing Ltd., 1997.
- 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.
- AAPM Report series (report 54 (1995), 55 (1995), 85 (2004))
- Ezzell G et al. Guidance document on delivery, treatment planning, and clinical implementation of IMRT: report of the IMRT subcommittee of the AAPM radiation committee. Med Phys 2003; 30: 2089-2115.
- ICRU report series (reports 50(1993) and 62(1999))
- Kahn FM. Treatment planning in radiation oncology. Lippincott Williams & Wilkins 2007.
- Photon treatment planning collaborative working group. Three-dimensional dose
- Calculations for radiation treatment planning. Int J Radiat Oncol Biol Phys 1991; 21:25-36.
- Wong JW, Purdy JA. On methods of inhomogeneity corrections for photon transport. Med Phys 1990; 17:807-814.
- Hogstrom KR. Treatment planning in electron beam therapy. In: Frontiers of radiation therapy and oncology. 25
- The role of high energy electrons in the treatment of cancer, 30-52. Eds: J.M. Vaeth, J.L. Meyn. Karger, Basel, 1991.
- Coia L, Schultheiss T, Hanks G (Eds.). A practical guide to CT-simulation. Advanced Medical Publishing, Madison, WI, 1995.
- Purdy JA, Starkschall G (Eds). A Practical Guide to 3-D Planning and Conformal Radiation Therapy. Advanced Medical Publishing, Madison, WI, 1999.
- Dobbs J, Barrett A, Ash D. Practical radiotherapy planning, 4th Edition. Edward Arnold, London, 2009.
- 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.
- 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. IAEA, Vienna, 2005.

## 15. Brachytherapy

### Short description

Brachytherapy (BT) is a technique that uses sealed radioactive sources which are placed inside the tumour or in close proximity to it. It has been used widely for many years to treat a large variety of tumours. Due to the nature of the modality, specialist dosimetry protocols and procedures have to be applied, measurement systems and treatment planning systems are specifically designed. BT physics is often considered a specific subdivision of radiotherapy physics.

In recent years, Brachytherapy has undergone important changes due to different factors.

- a) New isotopes have been introduced, expanding the scope of possible procedures
- b) Developments allowing changes to source geometry and “activities” have allowed wider utilisation of automatic afterloading systems.
- c) Image Guided Brachytherapy has become a common technique in most of the applications (utilising CT, MR, US)

### Competences

- demonstrate an understanding of the basic operation of the commercially available afterloading systems;
- ability to assess the advantages and limitations of the locally available afterloading systems and BT sources;
- ability to apply calibration protocols for the BT sources used locally, and to determine the uncertainties of the measurement;
- ability to assess the functional characteristics of the source calibration equipment, and to perform quality control of this equipment;
- ability to participate in the overall clinical process of brachytherapy from operating theatre through simulator localisation, treatment planning and treatment delivery;
- ability to discuss the use of the different closed/sealed brachytherapy sources;
- demonstrate an understanding of the dosimetry systems for intracavitary brachytherapy and interstitial brachytherapy (GEC—ESTRO, Manchester, Paris, image based dosimetry);
- ability to assist in the preparation of brachytherapy sources for clinical use;
- demonstrate an understanding of the basic principles of imaging systems for brachytherapy
- demonstrate an understanding of the TG 43 dose calculation algorithm and modern model based algorithms;
- demonstrate understanding of the use and limitations of optimisation techniques in brachytherapy treatment planning;
- ability to perform independent verifications of the calculated treatment times of intracavity insertions and interstitial implants using manual methods;
- ability to setup a quality control program of the brachytherapy sources, applicators and equipment, including the TPS;
- ability to handle basic radiation safety procedures, such as leakage tests on the sources, disposal of sources, prevention and actions in case of source loss;
- ability to discuss national and international regulations for the use and transport of radioactive materials;

### Core curriculum items

## Equipment

- sources: radionuclide types and source design;
- applicators;
- after-loading systems: low dose rate (LDR), high dose rate (HDR), pulsed dose rate (PDR);
- source calibration equipment;
- imaging systems for brachytherapy.

## Source specification

- quantities and units: activity, reference air kerma rate (RAKR), exposure rate, etc.;
- “source strength” determination according to national and international protocols, including IAEA recommendations;
- interpretation of the source calibration certificate from the manufacturer
- dosimetry measurement methods.

## Treatment techniques and methods

- permanent and temporal implants;
- standard applications;
- classical implantation and dose calculation systems (LDR), e.g: interstitial, the “Paris System” and intracavitary, the “Manchester System”;
- extension to other dose rate categories: HDR, PDR;
- special brachytherapy techniques, e.g.: permanent prostate seeds, stereotactic brain implants, eye plaques, partial breast irradiation.

## Treatment planning and dose calculation

- dose calculation algorithms, TG 43, model based algorithms;
- general structure of brachytherapy planning systems;
- source and points position reconstruction algorithms: radiographic films, CT and other image based algorithms;
- optimisation algorithms for HDR, PDR;
- dose-Volume Histograms in BT, DVH-related planning evaluation parameters
- treatment planning optimisation and evaluation; Uniformity criteria and constraints.

## Specification of dose and volumes

- according to national and international protocols, including ICRU 38 and ICRU 58, GEC ESTRO and ABS recommendations.

## Quality Assurance

- equipment specifications, commissioning and QC of after-loading equipment (LDR, 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 patients treatment plans;
  - in-vivo dosimetry in brachytherapy.
- 
- **Radiation Protection and Radioactive substances regulation;**

Assessment of the amount of time to be spent in this topic: 15 ECTS

### Recommended literature

- The Physics of Modern Brachytherapy for Oncology. *Series in medical physics and biomedical engineering*. Baltas D, Sakelliou L, Zamboglou N. CRC Press. ISBN: 0750307080, 9780750307086. 2007.
- The GEC ESTRO Handbook of Brachytherapy. Gerbaulet A, Pötter R, Mazon 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
- Dutreix A, Marinello G, Wambersie A. Dosimétrie en Curiothérapie. Ed.Masson, Paris, 1982
- ICRU Report series (reports 38(1985) and 58 (1997)).
- IAEA. International Atomic Energy Agency. "Calibration of photon and beta ray sources used in brachytherapy". Guidelines on standardized procedures at SSDs and Hospitals. IAEA-TECDOC-1274.March, 2002.
- ICRP. International Commission on Radiological Protection "Radionuclide Transformations. Energy and Intensity of Emissions" ICRP Report 38, 1983.
- ESTRO Booklet series (Booklet 8 (2004))
- Haie-Meder C, Pötter R, Van Limbergen E, et al. Recommendations from Gynaecological (GYN) GEC ESTRO Working Group (I): concepts and terms in 3D image-based 3D treatment planning in cervix cancer brachytherapy with emphasis on MRI assessment of GTV and CTV. *Radiother Oncol* 2005; 74:235-45.
- Pötter R, Haie-Meder C, Van Limbergen E, et al. Recommendations from Gynaecological (GYN) GEC ESTRO Working Group (II): concepts and terms in 3D image-based treatment planning in cervix cancer brachytherapy - 3D dose volume parameters and aspects of 3D image-based anatomy, radiation physics, radiobiology. *Radiother Oncol* 2006; 78:67-77.
- AAPM Report series (report 43 (1995), 56 (1997), 59 (1998), 64 (1999), 43 Updated (2004), 43 Supplement (2007), 128 (2008), 98 (2008), 137 (2009))
- 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.
- Kovacs G, Potter R, Loch T, Hammer J, Kolkman-Deurloo I, de la Rosette J, Bertermann H. GEC/ESTRO-EAU recommendations on temporary brachytherapy using stepping sources for localised prostate cancer. *Radiother and Oncol* 2005; 74:137-148.
- Mazon JJ, Ardiet JM, Haie-Méder C. GEC-ESTRO recommendations for brachytherapy for head and neck squamous cell carcinomas. *Radiother Oncol* 2009; 91: 150-156.
- Pötter R. Image-guided brachytherapy sets benchmarks in advanced radiotherapy. Editorial. *Radiother Oncol* 2009; 91:141-146.
- Arthur D.W, Vicini F.A, Kuske R.R, Wazer D.E and Nag S. Accelerated partial breast irradiation: an updated report from the American Brachytherapy Society. *Brachytherapy* 2003; 2(2):124-130.
- Major T, Frohlich G, Lovey K, Fodor J, Polgar C. Dosimetric experience with accelerated partial breast irradiation using image-guided interstitial brachytherapy. *Radiother Oncol* 2009; 90:48-55.

## 16. Particle therapy

### Short description

Due to their favourable physical and radiobiological properties, beams of ions (protons and heavier ions) are expected to have an increasing role in radiotherapy for certain indications. Medical physicists in radiotherapy will 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 technological, physical, biological and clinical research on the further development of particle therapy. Therefore, they should be familiar with the physical and technological aspects of particle therapy.

### Competences

- ability to demonstrate a deep understanding of the electronic and nuclear interactions of ions with matter;
- ability to derive from the physical characteristics of ion beams, implications on the technical equipment for accelerating and delivering ion beams, radiation protection of patients, staff and equipment, dosimetric measurements, quality assurance, treatment planning, radiobiology and therapeutic strategies;
- ability to evaluate the performance parameters of ion therapy equipment;
- ability to demonstrate an understanding of the operation of ion accelerators and beam transport components;
- ability to demonstrate an understanding of the techniques of field formation with ion beams including intensity modulation and organ motion compensation;
- ability to discuss the concepts of treatment planning for therapeutic ion beam irradiation including biological optimisation;
- ability to discuss the concepts of dosimetry and quality assurance at ion beams;

### Core curriculum items

- electronic and nuclear interactions of ion beams with matter;
- particular biological effects of ion beams;
- accelerators for ion beams;
- therapeutic ion beam deliveries;
- field formation (passive, active) and intensity modulation;
- motion compensation techniques in ion therapy;
- dosimetry of ion beams;
- quality assurance for therapeutic ion beam deliveries;
- range measurements and in-vivo dosimetry by positron emission tomography;
- treatment planning for ion therapy including biological optimisation.

**Assessment of the amount of time to be spent in this topic - 3 ECTS**

### Recommended literature

- Linz U (Ed.), Ion beams in tumor therapy, Chapman and Hall, 1995
- Scharf WH, Biomedical particle accelerators, American Institute of Physics, 1994

- Kraft G. Tumor therapy with charged particles, Progr Part Nucl Phys 2000; 45:473-544.
- Scholz M, Kraft G. Track structure and the calculation of biological effects of heavy charged particles, Adv Space Res 1996; (1-2): 5-14.
- Krämer M et al. Treatment planning for heavy-ion radiotherapy: physical beam model and dose optimization, Phys Med Biol 2000; 45:3299-3317.
- Jäkel O et al. Treatment planning for heavy-ion radiotherapy: clinical implementation and application, Phys Med Biol 2001; 46:1101-1116.

## 17.Principles of Unsealed source therapy

### Short description

The absorbed radiation dose from internally deposited radionuclides is a major 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. From this the therapeutic response (effectiveness) and related toxicities can be assessed.

It is recognised that this type of treatment is not necessarily within the remit of the radiotherapy physics groups and may reside with nuclear medicine departments.

### Competences

- demonstrate an understanding of the principles of radionuclide therapy and the radionuclide selection criteria;
- demonstrate an appreciation of the issues in managing and measuring the unsealed sources;
- be able to discuss organ dose calculations;
- ability to compose safety procedures for the personnel and the patients treated with radionuclide therapy - perform waste management.

### Core Curriculum items

- choice of radionuclide; physical properties, imaging properties, labelling compound properties;
- radiobiological considerations, Dosimetric protocols;
- dosimetry models (standard man - MIRD, MIRDOSE);
- use and safety of unsealed sources - radionuclides;
- management of unsealed sources, waste and patient wastes;
- therapy procedures;
- safety procedures and dose evaluation of the personnel and family.

**Assessment of the amount of time to be spent in this topic - 3 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.
- Radiation Dose to Patients from Radiopharmaceuticals. ICRP Publication 80 Dec2008; (Addendum 2 to ICRP Publication 53). ICRP Publication 106 (Addendum 3 to ICRP Publication 53).
- Snyder WS, Ford MR, and Warner GG, MIRD Pamphlet No.5, "Estimates of Specific Absorbed Fractions for Photon Sources Uniformly Distributed in Various Organs of a Heterogeneous Phantom," Revised, Medical International Dose Committee, New York. Society of Nuclear Medicine, 1978.

- Snyder WS, Ford MR, Warner GG, Watson SB. , MIRD Pamphlet No. 11, "'S" Absorbed Dose per Unit Cumulated Activity for Selected Radionuclides and Organs," New York, NY: Society of Nuclear Medicine, 1975.
- Siegel JA, Thomas SR, Stubbs JB, et al. MIRD pamphlet no. 16. Techniques for quantitative radiopharmaceutical biodistribution data acquisition and analysis for use in human radiation dose estimates," J Nucl Med 1999, 40(suppl):37S-61S.
- Zaidi H, Sgouros G, eds. Therapeutic Applications of Monte Carlo Calculations in Nuclear Medicine. Bristol, U.K.: IOP Publishing Ltd., 2003: 95-102.
- International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources. Vienna, Austria: IAEA, 1996, no.51, Safety series no. IAEA 115.

## 18 Radiation Protection for ionising radiation

### Short description

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 protected against by the application of radiation safety standards.

The medical physicists in radiotherapy must have a broad scientific knowledge of radiation protection. They have to be prepared to address the needs of protecting the patient, personnel and the general public in the radiotherapy department. They have to know 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.

### Competences

- demonstrate an understanding of the principles of radiation safety procedures;
- ability to measure effective performance of radiation safety procedures;
- ability to improve effective performance of radiation safety procedures;
- ability to investigate and assess risk factors of radiation;
- ability to optimise medical exposures;
- ability to verify that the clinical physics program is in compliance with applicable national radiation safety regulations (e.g., radioactive materials licenses, occupational dose limits, and review of radiation surveys for any new construction);
- ability to perform radiation surveys of an area using appropriate dose-rate meters
- ability to perform design calculations for a linac room, simulator/CT room, brachytherapy source room;
- ability to discuss the use of personal dosimeters;
- ability to prepare the documentation needed for audits by the radiation protection authorities;

### Core curriculum items

- the effects of radiation on the embryo and foetus, leukaemogenesis and carcinogenesis, genetic and somatic hazards for exposed individuals and populations;
- scientific basis of radiation protection;
- quantities and units in radiation protection;
- basic principles of dose limitation. Deterministic and stochastic effects;
- justification. Optimisation: ALARA principle. Dose limits (workers, population);
- radiation monitoring: classification of areas, Personal monitoring;
- administration and organisation of radiation protection. National and international rules and organisations;
- national and international legislation;
- design and facilities including: treatment rooms, imaging rooms, sealed and non-sealed source storage;
- management of radiation safety, including hazard assessment, contingency plans;
- accidents in radiotherapy;
- radioactive material management, transport and waste disposal;

- patient protection.

Assessment of the amount of 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 (1984), 82(1985), 84(1985), 112(1991), 116(1993), 122(1995), 128(1998), 151 (2005))
- 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

## 19. Mathematical modelling of treatment outcomes

### Short description

Mathematical modelling plays an ever increasing role in radiation oncology, and is frequently implemented in commercially available treatment planning systems, in altered fractionation regimens and out-come analysis. Given their strong mathematical background the medical physicist in radiotherapy often undertakes such activities. To safely utilise the existing models a comprehensive understanding of radiobiological modelling is required.

### Competences and skills:

- ability to critically perform fractionation calculations, response calculations (NTCP/TCP), effective dose calculations and volume effect corrections using established models;
- ability to critically assess radiobiological calculations performed by commercial treatment planning systems;
- demonstrate an understanding of the limitations in existing models and the parameters established from published data as well as the underlying biological rationale and limitation of the model;
- ability to perform detailed dose-response analysis from clinical data and patient series;
- ability to critically make use of novel modeling and statistical strategies.

### Core curriculum items

- models for DNA damage;
- cell survival, repair and fractionation models;
- NTCP and TCP- models;
- $P_+$ , utility function and other relevant models used in optimisation;

Assessment of the amount of time to be spent in this topic - 3 ECTS

### Recommended literature

- Dale R and Jones B (eds.), Radiobiological Modelling in Radiation Oncology, The British Institute of Radiology, 2007

## 20. Uncertainties in radiotherapy

### Short description

The Radiotherapy pathway comprises of many steps from its preparation until its completion. At all steps, data is acquired, measured and/or calculated with more or less accuracy and precision. This will always lead to differences between the dose prescribed and that effectively delivered to the patient. The magnitudes, sources, and implications of day-to-day treatment variability need to be assessed in order to minimise these differences. The medical physicist in radiotherapy plays a key role in the evaluation of uncertainties and the definition of tolerances and action levels.

### Competences and skills:

- ability to discuss measurement theory and manage sources of uncertainties;
- ability to evaluate the magnitudes, sources, and implications of day-to-day treatment variability;
- ability to design experiments and/or surveys;
- ability to manage the acquisition, editing, analysis, interpretation, presentation, and reporting of data;
- ability to set tolerances and action levels.

### Core curriculum items

- measurement theory;
- sources of uncertainty;
- management of uncertainty;
- tolerance and action levels.

Assessment of the amount of time to be spent in this topic - 1 ECTS

### Recommended literature

- Prins J. "Process or product monitoring and control," NIST/SEMATECH e-Handbook of Statistical Methods. National Institute of Standards & Technology, Gaithersburg, 2007.
- Wheeler DJ and Chambers DS, Understanding Statistical Process Control, 2nd ed. SPC, Knoxville, TN, 1992.
- Dutreix A. When and how can we improve precision in radiotherapy? Radiother Oncol 1984;2: 275-292.
- Mijnheer B, Batterman J, Wambersie A. What degree of accuracy is required and can be achieved in photon and neutron therapy, Radiother Oncol 1987; 8: 237-252.
- ISO Guide to Expression of Uncertainty in Measurement (1992).
- Geometrical Uncertainties in Radiotherapy = British Institute of Radiology, 2003

# RESEARCH PROJECT

## Short description

The medical physicist in radiotherapy often has a central role in the development and advancement of the field of radiotherapy and in the strengthening of research activities in the international community.

To prepare the medical physicist in radiotherapy for this responsibility, a short, focused research project should be undertaken at some stage during the training programme, either as a full-time activity within a well-defined period or on part-time basis over a prolonged time period (e.g. part of the practical training period).

The project should be performed under supervision of a trained medical physicist in radiotherapy. It should be well structured and limited in scope, in order to fit within the given time frame. The topic of the research project should be relevant for radiotherapy physics and practice, typically it would lie within the clinical and applied side of the span of radiotherapy physics research.

The project should result in a written report, preferably in the form of a manuscript suitable for submission to a medical physics/radiotherapy journal.

## Competencies and skills

- ability to plan, prepare and perform different phases of a research project;
- ability to acquire first-hand experience in proper scientific evaluation, of both own and published data;
- ability to prepare a scientific manuscript for publication.

**Assessment of the amount of time to be spent on this topic - 30 ECTS.**

## Reccommended 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

## Estimated time to be spent on the topics of the Core Curriculum - general overview

<b>FUNDAMENTAL KNOWLEDGE, SKILLS AND COMPETENCES</b>	<b>23</b>	
1. FUNDAMENTALS OF HUMAN ANATOMY AND PHYSIOLOGY	2	
2. FUNDAMENTALS OF ONCOLOGY	2	
3. PRINCIPLES AND APPLICATIONS OF RADIOBIOLOGY AND MOLECULAR BIOLOGY	3	
4. REVIEW OF RADIATION PHYSICS	7	
5. PRINCIPLES OF QUALITY MANAGEMENT	1	
6. STATISTICAL METHODS	1	
7. ORGANISATION, MANAGEMENT AND ETHICAL ISSUES IN HEALTH CARE	1	
8. QUALITY AND RISK MANAGEMENT IN RADIOTHERAPY	1	
9. GENERAL SAFETY PRINCIPLES IN THE MEDICAL ENVIRONMENT	1	
10. HEALTH TECHNOLOGY ASSESSMENT	1	
11. INFORMATION AND COMMUNICATION TECHNOLOGY	3	
<b>KNOWLEDGE AND SKILLS AND COMPETENCES SPECIFIC FOR RADIOTHERAPY</b>	<b>107</b>	
12. DOSIMETRY	15	
13. PRINCIPLES OF MEDICAL IMAGING AND IMAGE HANDLING	15	
14. EXTERNAL BEAM RADIOTHERAPY	45	
15. BRACHYTHERAPY	15	
16. PARTICLE THERAPY	3	
17. PRINCIPLES OF UNSEALED SOURCE THERAPY	3	
18. RADIATION PROTECTION FOR IONISING RADIATION	5	
19. MATHEMATICAL MODELLING OF TREATMENT OUTCOMES	3	
20. UNCERTAINTIES IN RADIOTHERAPY	3	
<b>RESEARCH PROJECT</b>	<b>30</b>	<b>30</b>
	<b>160</b>	<b>160</b>

## 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 a written exam, the complete set of competencies needed to safely act in a healthcare setting is substantially more complicated to assess. In the following different components of a possible assessment scheme is described. The different components must, however, be adopted according to the national education and training programme. It is recommended that the assessment of competencies includes more than one of the assessment modules listed below.

### 1. WRITTEN TESTS

#### 1.1. 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.

#### 1.2. Constructed-response format (essays)

Essays pose questions that 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.

#### 1.3. 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 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 cases (situations), 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 (360-DEGREE EVALUATION) (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 physicians (e.g., resident peers), allied health professionals (e.g., 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 an extremely flexible educational technology 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