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Guidelines for education and training of medical physicists in radiotherapy Recommendations from an ESTRO/EFOMP working group

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Abstract

Purpose: To provide a guideline curriculum covering theoretical and practical aspects of education and training for medical physicists in radiotherapy within Europe.

Material and methods: Guidelines have been developed for the specialist theoretical knowledge and practical experience required to practice as a medical physicist in radiotherapy. It is assumed that the typical entrant into training will have a good initial degree in the physical sciences, therefore these guidelines also require that and are additional to it. National training programmes of medical physics, radiation physics and radiotherapy physics from a range of European countries and from North America were reviewed by an expert panel set up by the European Society of Therapeutic Radiology and Oncology (ESTRO) and the European Federation of Organisations for Medical Physics (EFOMP). A draft document prepared by this group was circulated, via the EFOMP infrastructure, among national professional medical physics societies in Europe for review and comment and was also discussed in an education session in the May 2003 EFOMP scientific meeting in Eindhoven.

Results: The resulting guideline curriculum for education and training of medical physicists in radiotherapy within Europe discusses the EFOMP terms, qualified medical physicist (QMP) and specialist medical physicist (SMP), and the group's view of the links to the EU (Directive 97/43) term, medical physics expert (MPE). The minimum level expected in each topic in the theoretical knowledge and practical experience sections is intended to bring trainees up to the requirements of a QMP. The responses from the circulation of the document to national societies and its discussion were either to agree its content, with no changes required, or to suggest changes, which were taken into account after consideration by the expert group. Following this the guidelines have been endorsed by the parent organisations.

Conclusions: This new joint ESTRO/EFOMP European guideline curriculum is a first step to harmonise specialist training of medical physicists in radiotherapy within Europe. It provides a common framework for national medical physics societies to develop or benchmark their own curricula, but is also flexible enough to suit different situations of initial physics qualifications, medical physics training programmes, accreditation structures, etc. The responsibility for the implementation of these standards and guidelines will lie with the national training bodies and authorities.

Keywords: Radiotherapy physics; Radiation oncology physics; Specialist training; Curriculum; Europe; European harmonisation; Quality assurance

1. Introduction

1.1. General

The medical physicist working in a clinical setting is a member of the clinical team responsible for diagnosis and treatment of patients. The qualified medical physicist (QMP) has a unique competence and carries a range of responsibilities in his/her area of practice, for example for equipment, techniques and methods used in the clinical routine, for the introduction, adaptation and optimisation of new methods, for calibration, accuracy, safety, quality

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assurance and quality control, and generally also for many areas of research and development.

Specifically in radiotherapy, medical physicists play a key role in the provision of the radiotherapy service as a whole. The specialist scientific training and expertise of radiotherapy physics staff makes them uniquely qualified to provide essential scientific input on physical processes and technology that underpins the whole radiotherapy process. Radiotherapy physicists design and develop the framework of radiation dosimetry, treatment planning algorithms, quality assurance of treatment and other equipment and of many aspects of the treatment process, radiation safety, etc. They provide expert advice on the development of new treatment techniques and on the optimisation of treatment processes and treatments for individual patients. They play a leading role in the implementation, development, safe utilisation and optimisation of advances in technology and techniques. Thereby they enable the multi-disciplinary team of radiation oncologists, radiotherapy physicists, radiotherapy technologists and others to practice 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. Whilst these Directives primarily deal with medical radiation physics, their consequences will also effectively set the standards for other branches of medical physics. They will gradually affect every European country, even though they are binding only on EU Member States.

1.2. EFOMP role

The European Federation of Organisations for Medical Physics (EFOMP) is an umbrella organisation for National Medical Physics Organisations, with one of its main objectives to harmonise and promote the best practice of medical physics within Europe. The federal structure allows EFOMP to represent the medical physics profession, without constraining the diversity of national opinions, which constitutes the essence of 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.

Policy Statement No 9, "Radiation Protection of the Patient in Europe: The Training of the Medical Physics Expert (MPE) in Radiation Physics or Radiation Technology" [3], is the EFOMP response to the Medical Exposure Directive, 97/43/Euratom [2], the MED. Here EFOMP presents its recommendations on the role and the competence requirements of the MPE, as defined in this Directive, together with recommendations on education, training and continuing professional development (CPD).

The MPE is defined in the MED as an expert in his/her own right with a well-defined professional role, requiring him/her to act, as well as give advice on all aspects of radiation protection of the patient. The training of the MPE and his/her competence to act and to give advice must be recognised by the competent national authorities. Member states are explicitly required to ensure that medical physicists have access to continuing education and training after qualification in addition to their basic theoretical and practical training.

General criteria for structured CPD have been laid down by EFOMP in Policy Statement No 8, "Continuing Professional Development for the Medical Physicist" [4]. CPD is the planned acquisition of knowledge, experience and skills, both technical and personal, required for professional practice throughout one's working life. EFOMP recommends that all medical physicists who have completed their basic education and training should be actively involved in CPD to maintain and increase competence and expertise after qualification.

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 Medical Physicists were established in 1995 [5]. EFOMP approval requires inter alia clear statements of theoretical and practical competencies, as well as training programmes consistent with the EFOMP policy on training, and a regular renewal mechanism. CPD is now being recommended as the best way to meet the requirement for a renewal mechanism, and Policy Statement No. 10 "Recommended Guidelines on National Schemes for Continuing Professional Development of Medical Physicists" [6], recommends National Member Organisations to set up their own detailed CPD Scheme. EFOMP approval also of the national CPD scheme will thus cover the whole structure of education and training for the medical physicist.

The EFOMP efforts, resulting in recommendations on a structured system for education, training, CPD and registration schemes as outlined above, have been recognised by the EC in the recent publication "Guidelines on education and training in radiation protection for medical exposures" [7].

In the EFOMP structured system, described in Policy Statement No 10 [6], two levels of competence are recognised for the medical physicist working in the clinical setting; the qualified medical physicist (QMP), and the specialised medical physicist (SMP). The QMP has reached the level of competence to start working independently and has the minimum qualifications required for enrolment in an

EFOMP approved national register for medical physicists. CPD activities should continue after qualification, enabling increasing competence and leading to higher levels of experience and responsibility. The QMP qualifies to become an SMP by gaining such advanced clinical experience and by undergoing specialist training within an EFOMP approved national CPD scheme. The SMP is thus competent also to give advice on all professional matters in his/her subspeciality. EFOMP expects all QMPs (including SMPs) to be enrolled in an EFOMP approved national register for medical physicists. In addition EFOMP expects the QMP to have formal recognition from a National Competent Authority. In some national systems the SMP may also have an additional recognition. While EFOMP recognises that it has no statutory authority in this area, it fully supports CPD undertaken on a voluntary basis at all levels of each individual's career as a practical contribution to enhancing patient care.

It may be noted that within the EU and 'in relation to medical exposures' as defined in the Medical Exposures Directive [2], EFOMP regards the MPE as equivalent to the SMP in the relevant disciplines involving ionising radiation.

1.3. ESTRO role

The European Society for Therapeutic Radiology and Oncology (ESTRO) is a multi-disciplinary society of individual radiation oncologists, radiotherapy physicists, radiobiologists and radiotherapy technologists. It is a partner member in the umbrella group, Federation of European Cancer Societies (FECS). ESTRO has developed, among other roles, a remit for improving standards and practice, for providing teaching and training tools and resources and for fostering research and development in radiotherapy in Europe. It actively co-operates with other international and national radiation oncology societies, medical physics organisations, etc. in these aims and activities. It has taken a multi-national European lead in developing and delivering guidance frameworks in various areas of radiation oncology, eg. in education [8,9] and quality assurance [9–11]. 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 guideline curricula recommendations for all the main specialities working directly in radiation oncology [12,13].

For radiotherapy physics, ESTRO has previously worked in conjunction and co-operation with EFOMP [14] where both organisations recognise that there is an overlap of 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" [7]. The current guideline curriculum for radiotherapy physics arises from an ESTRO initiative to develop various baseline standards and to support specific practical activities in education and training in radiotherapy. These are being carried out within an ESTRO project (ESQUIRE—Task 3 EDRO, EDucation for Radiation Oncology) supported by the EU [9,15].

1.4. Aims and structure of the document

This guideline curriculum aims to provide both theoretical (Section 3) and practical (Section 4) requirements for the specific education and training of radiotherapy physicists. It has been drawn up with the aim of giving an outline of the underlying knowledge and experience required to fulfil the expectations (Section 2) for such specialists. The guideline assumes that the typical entrant into training as a medical physicist specialising in radiotherapy (radiotherapy physicist) will have been educated initially as a physicist, by obtaining a good first degree in the physical sciences, giving a comprehensive initial physics training to underpin the specialist training laid out here. It is recognised that different countries may have different structures to provide this, for example in some systems the academic requirements may be obtained during the same course, whilst in others the first degree and the specialist radiotherapy physics education may be separate; also that specific entry requirements into medical physics are different in different national systems.

The document is intended to provide a framework which can be used by national societies to guide their own curriculum development, or to compare to their existing documents. It is intended to provide a baseline standard in the radiotherapy physics speciality. However its structure and application are intended to be flexible to suit different national situations, recognising national differences in initial physics qualifications, and in existing radiotherapy physics education and training programmes, structures and accreditation.

The level of knowledge and training in each topic area listed in this curriculum should bring trainees in radiotherapy physics up to the requirements of a QMP according to the EFOMP structured system [3,6], i.e. able to act independently without supervision and to gain formal recognition from a National Competent Authority. It should be noted that different national healthcare, accreditation and legal systems may have varying criteria for recognition, depending on the overall length of graduate and postgraduate education and training, on the level and content of structured training and also on the different policies that different national governments apply to recognition of professional qualifications and competence. In some systems, one level only is defined. and recognised by the National Competent Authority. In some countries this is set at the level of QMP, according to the EFOMP structure, whilst in others (in the European Union) it is equated to the level of MPE, meeting the requirements of the Medical Exposures Directive. In other systems, two levels are recognised, the first being equivalent to that of QMP, in the

EFOMP structured system and the second requiring a few years additional experience and responsibility (demonstrated via structured CPD) after initial recognition by the national authority. This latter corresponds to the SMP, in the EFOMP structured system. In European Union countries which have the latter two-level system, the second level is taken to be that of MPE.

2. Expectations

After having completed theoretical and practical training a QMP as defined in the 9th EFOMP policy statement [3], is expected to be competent to act independently. To satisfy this in radiotherapy physics the QMP is expected to have the following skills:

1. **General skills in medical physics comprising**:
   a. Attitude to work according to rules of professional conduct, amongst others:
      – Ensure that the well-being, interests and dignity of patients are promoted and safeguarded at all times, taking care that their work and its products do not constitute an unnecessary hazard to any person.
      – Work effectively in a team, in a hospital environment with other professional health care workers.
   b. Appropriate knowledge and understanding of the following:
      – Physics and engineering principles underlying therapy, patient function support and patient surveillance techniques.
      – Principles of function examination for at least one organ system.
      – Principles of medical imaging and image handling.
      – Health and safety in the medical environment including radiation protection.
      – Anatomy, physiology, pathology and biology.
      – Principles of medical instrumentation and medical signal analysis.
      – Principles of quality management applied to medical systems.
      – Information science in the medical environment.
      – Medical statistics.
      – Principles of hospital, department and project management.
      – Organisation, funding and legislation for health care.
      – Principles and national regulations in medical ethics.
   c. Scientific skills:
      – Ability to understand and apply mathematical and natural science methods;
      – Skills in innovation, implementation and optimisation of technology and methods. The ability to report on that appropriately;
      – Communication and teaching skills.

2. **Specific skills in medical physics for the radiotherapy field comprising**:
   a. Attitude to work effectively as a staff member in a radiotherapy team.
   b. Ability to create the scientific framework and infrastructure for other professionals to work in (e.g. radiation oncologists, radiotherapy technologists).
   c. Appropriate knowledge, skills and experience in the following aspects to a level to be able to carry the responsibility as a QMP in radiotherapy:
      ○ Radiation physics.
      ○ Mathematical methods underpinning radiotherapy physics.
      ○ Imaging for radiotherapy.
      ○ Fundamentals of oncology.
      ○ Radiotherapy.
      ○ Clinical radiobiology.
      ○ Equipment, facilities and systems for the treatment of patients with radiotherapy.
      ○ Specification, purchase, acceptance, commissioning, maintenance and quality control of the equipment and systems in a radiotherapy department.
      ○ Radiation dosimetry.
      ○ Treatment planning, preparation and delivery.
      ○ Radiation protection for staff, patients, public and environment
      ○ Information and communication systems.
      ○ Quality management.
      ○ Development and/or introduction of new radiation techniques.
      ○ The supervision and instruction of radiation oncologists, radiotherapy technologists and others in the use of (new) equipment and/or methods and the ability to provide physical-technical guidelines.
      ○ Provision of advice to radiation oncologists and radiotherapy technologists on optimisation and safety of individual patient treatments and treatment protocols.
      ○ To interact with and to explain appropriate details of treatments to patients.
      ○ Design and testing of physical and technical aids and methods for both the treatment of patients and physical measurements.
      ○ Clinical issues and the ability to participate in clinical research.
   d. Scientific skills:
      ○ Up to date knowledge of the radiotherapy physics literature, scientific reports and national and international recommendations.
      ○ Up to date knowledge of radiotherapy, its role and methods to evaluate treatments.
      ○ Ability to conduct scientific research and development in radiotherapy physics, independently as well as supervising, evaluating and reporting on such research. In addition, ability to participate in

research projects in collaboration with radiation oncologists and others.

3. Theoretical part—curriculum items

3.1. Part I. General topics on medical physics

1. **Fundamentals of human anatomy and physiology**
   Medical terminology.
   General structure and organisation of the body.
   Basic anatomy: structure, position and nomenclature.
   Elements of physiology.
   Human organs and systems.
   Identification of anatomical structures in clinical imaging modalities.
   Introduction to the nature and effects of disease and trauma.
   Principles of function examination for at least one organ system.

2. **General safety principles in the medical environment**
   Principles of safety and risk management.
   Electrical, electro-magnetic, and magnetic safety.
   Principles of Radiation Protection, ionising radiation and non-ionising radiation, e.g. microwave, RF and magnetic fields, ultraviolet, lasers, ultrasound.

3. **Principles of quality management**
   Meaning of quality, quality assurance and quality control.
   Quality standards.
   Assessment of quality.
   Quality management systems, records, audit and improvement of quality.

4. **Information science in the medical environment**
   Current computer architecture.
   Operating systems.
   Networks and communication protocols, including DICOM, PACS,….
   Programming principles and practice.
   Use of applications software, including scientific reference systems.
   Overview of the applications in the medical environment.
   Data security, data management and legal aspects, e.g. data protection legislation, professional responsibilities and good practice.
   Hospital information systems.
   Database management.

5. **Principles of medical instrumentation and medical signal analysis**

6. **Principles of medical imaging and image handling**
   Physics of image formation.
   Principles of clinical imaging modalities.
   Image handling and processing.
   Noise and measurements of image quality.
   Picture, archiving and communication systems.
   Multi-registration of images from different modalities.
   Image format standards, including DICOM: interconnectivity and interoperability.
   Principles, equipment, and practical applications in radiotherapy of the following imaging modalities: X-rays, radiography and fluoroscopy, CT, PET, SPECT, ultrasound, MRI.
   Developments in medical imaging.

7. **Statistical methods**
   Descriptive statistics.
   Probability distributions.
   Test of significance-general principles and choice of test for comparing continuous and categorical data.
   Relation between variables.
   Uncertainty analysis.
   Clinical study design and analysis of outcomes (application to evidence-based medicine approaches).

8. **Organisation and management in health care**
   National and local system, global view on other European systems.
   National regulations and EU directives.
   Guidelines and recommendations from national and international organisations.
   Ethical considerations in medical practice.
   Principles of management as applied to hospital departments and projects, etc.
   Principles of personnel management.

3.2. Part II. Specific topics on medical physics for the radiotherapy field

9. **Review of radiation physics**
   Ionising radiation.
   Structure of matter.
   Radiation interaction processes (photons and particles).
   Energy transfer. Scattering and attenuation.
   Radioactivity.
   Applications of statistics to radioactivity.
   Principles of X-ray production.
   Other radiation sources.
   Overview of medical uses of radiation.
   Specification of radiation beams.

10. **Review of mathematics underpinning radiotherapy physics**
    In radioactivity.
    In radiation transport (e.g. Boltzman equations and Monte-Carlo methods).

In medical statistics.
In medical imaging: Fourier-transform, signal analysis (e.g. PSF, MTF and Wiener-spectrum).
In treatment planning algorithms (e.g. convolution, superposition, multiparametrical optimisation, IMRT optimisation, e.g. simulated annealing, gradient techniques).
Computer packages for statistics and mathematics.

11. **Dosimetry**

11.1 **Principles of dosimetry**

Concept of dose and kerma.
The Bragg-Gray cavity theory.
Dosimetric quantities and units: exposure, kerma and absorbed dose; relationships.

11.2 **Physics, techniques and instrumentation of radiation detectors systems, e.g**:

Calorimetry.
Chemical dosimetry.
Gas detectors, including ionisation chambers.
Scintillation detectors.
TLD.
Semiconductors.
Film dosimetry.
Portal dosimeters.
Gel dosimetry.

11.3 **Practical dosimetry systems**

Radiation beam analyser systems.
Phantoms.
Quality control systems.
Choice of dosimetry systems.
Technical specification, acceptance testing, calibration and quality control of practical systems.

12. **Fundamentals of oncology**

Principles of oncology: epidemiology, etiology, biology of cancers, localisation of primary tumours, dissemination pathways, and treatment modalities.
Tumour classification.
Evidence based practice in oncology.
Developments in oncology.

13. **Principles and applications of clinical radiobiology**

Introduction to molecular and cellular biology.
The response to radiation at the molecular and cellular level. Cellular injury and cell survival curves.
The macroscopic response of tissue to radiation.
The response of tumours and normal tissue to therapeutic levels of radiation; Dependence on fractionation, dose rate, radiosensitisation, reoxygenation.
Radiobiological models, including linear-quadratic model.
The therapeutic ratio and its role in optimising dose delivered to patients.
Tolerance dose. Radiation dose and tumour cure probability.
Dose-volume effects. TCP and NTCP models.
Radiation effects—early and late.
Developments in radiobiology.
Practical clinical applications.

14. **Quality management in radiotherapy**

Quality management systems (e.g. ESTRO, AAPM and ISO publications).
Quality audit, analysis and improvements.

15. **Radiation therapy. External beam radiotherapy**

15.1 **Treatment and imaging equipment**

kV X-ray units.
Cobalt units.
Linear accelerators and other systems for MV X-ray and electron beams.
Practical designs for production and control of static and dynamic clinical beams.
Imaging systems on treatment units.
Hadrontherapy units.
Simulators: conventional and CT simulators; virtual simulators.
Standard CT and other imaging systems for localisation (MRI, PET,…).

15.2 **Clinical dosimetry of conventional treatment beams**

In air and in phantom characteristics of clinical beams.
Definition of ‘reference conditions’ in fixed SSD and isocentric approaches.
Definition of terminology (e.g. PDD, TMR, TPR…).
Beam quality specification.
Absolute and reference dosimetry. Absorbed dose in reference conditions: national and international protocols, including IAEA protocols.
Dosimetric standards and treacebility.
Relative dosimetry:
Central axis dose distribution in water.
Electron beam characteristics, range and energy parameters
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, etc.
Requirements and methods of data acquisition for treatment planning.

15.3 **Patient data acquisition**

Patient position and immobilisation.
Imaging acquisition, image registration and image fusion.
Multiple image sets: handling and analysis.
Quality assurance of imaging processes.
Target volume and critical organ localisation.
Volume growing and margin evaluation.

15.4 **Treatment planning**

Specification of dose and volumes, margin decisions, including international recommendations, (for example ICRU 50, 62); GTV, CTV, PTV, etc.

Principles of treatment planning: manual and computer supported.

Monitor units calculation and systems: SSD and isocentric approaches.

Treatment planning systems, including hardware, implementation, input, output and networking.

Virtual simulation and tools: BEV, DRR.

Treatment planning algorithms: 1D, 2D and 3D algorithms.

Treatment planning optimisation and evaluation: uniformity criteria and constraints, DVH, biological indices (TCP, NTCP).

IMRT planning.

Recording and reporting according to international recommendations.

Archiving and back-up.

15.5 **Radiotherapy techniques**

Conventional techniques:

Use of wedges, bolus, compensators; beam shaping; beam combinations: weighting and normalisation; field matching; rotational techniques.

More advanced techniques:

3D conformal radiotherapy, non coplanar techniques; IMRT methods: static and dynamic.

Special techniques:

TBI, TSEI, radiosurgery, stereotactic radiotherapy, intraoperative treatments, image guided treatments.

Other treatment modalities, e.g. particle beam treatments.

15.6 **Treatment verification**

Patient alignment and set-up on the simulator for verification and on treatment machines.

Set-up and movement tracking systems.

Imaging at the treatment unit. e.g. portal imaging.

Optimisation of set-up and use of systems.

Geometrical accuracy, reproducibility and methods of assessment.

In vivo dosimetry.

IMRT verification.

Record and verify systems.

15.7 **Quality assurance**

Equipment specifications, commissioning and QC of treatments units, treatment planning systems, imaging systems in RT, dosimetry systems, networks.

National and international recommendations and local protocols.

QA of treatment processes.

Verification, checking and QA of individual patients treatment plans and MU calculations.

16. **Radiation therapy. Brachytherapy**

16.1 **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.

16.2 **Source specification**

Quantities and units: activity, reference air kerma rate (RAKR), exposure rate, etc.

'Source strength' specification according to national and international protocols, including IAEA recommendations.

Dosimetry measurement methods.

16.3 **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, intravascular.

16.4 **Treatment planning and dose calculation**

General formalisms, including TG 43 (AAPM).

General and points structure of brachytherapy planning systems.

Data configuration and TPS set-up.

Source and points position reconstruction algorithms: radiographic films, CT and other image based algorithms.

Dose calculation algorithms; optimisation algorithms for HDR, PDR.

Treatment planning optimisation and evaluation; Uniformity criteria and constraints.

16.5 **Specification of dose and volumes**

According to national and international protocols, including ICRU 38 and ICRU 58 recommendations.

16.6 **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.

Q.A. of the whole treatment brachytherapy process.

Verification, checking and QA of individual patients treatment plans.

17. **Radiation therapy. Unsealed source therapy**

Choice of radionuclide; physical properties.

Radiobiological considerations.
Dosimetry techniques. MIRD.
Targeted therapies: dosimetric protocols.
General procedures in the management of unsealed source therapy.
Specific therapy procedures.

18. **Radiation protection for ionising radiation**
Radiation risk assessment.
Biological basis of radiological risk.
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.

19. **Uncertainty in radiotherapy**
Measurement theory.
Sources of uncertainty.
Management of uncertainty.
Tolerance and action levels.

4. Practical training

The following section headings are those used in the theoretical part of the curriculum, for ease of comparison.

No practical training guidelines are provided here for headings 1–10. This is in part because some of them are largely theoretical in nature. However, in addition, most are of wide applicability to many areas of medical physics and not specific to radiotherapy physics only.

Therefore they may be provided differently in different national approaches, in terms of the level of practical training and also whether in a university course or in a hospital-based training. Hence this leaves flexibility for different national approaches to be applied.

Actions required for practical training:

11 **Dosimetry**

11.2 **Physics, techniques and instrumentation of radiation detector systems**
To use a range of dose measuring equipment to understand the scope, limitations and problems.
To evaluate the use of different dosemeters in different clinical situations.
To specify and justify the infrastructure required to provide a dosimetry service in a radiotherapy department.
To assess the uncertainties in dose measurement.

13. **Principles and applications of clinical radiobiology**
To investigate the use of radiobiological models, such as the LQ model, TCP and NTCP models, in the local radiotherapy centre.
To find out what parameters are used for these models by the oncologist.
To find out what models and parameters are used in the local treatment planning system.
To calculate practical examples of LQ problems including accounting for gaps in treatment.

15. **Radiation therapy—external-beam radiotherapy**
15.1 **Treatment and imaging equipment**
To observe the construction and layout of treatment and imaging equipment and the interdependence of parameters and the factors affecting them (e.g. energy, flatness, dose rate, dose per monitor unit).
To observe and assess the engineering maintenance of radiotherapy equipment.
To justify the criteria for specifying and selecting linear accelerators.
To observe acceptance tests and/or commissioning tests.
To perform quality control of treatment and imaging systems.
15.2 **Clinical dosimetry of conventional treatment beams**
To investigate and apply dosimetry protocols including the national code of practice.
To assist with the calibration of dose measuring equipment including ionisation chambers and diodes.
To perform constancy checks (e.g. strontium-90 based) on ionisation chamber dosemeters.
To make absolute and relative dose measurements (output factors, PDDs, beam profiles, etc) of photon and electron beams using different equipment (ionisation chambers, diodes, film, TLD).
To use the radiation beam analyser (water phantom) and perform quality control checks.
To be involved in acquiring beam data for the treatment planning system.
15.3 **Patient data acquisition**
To verify the transfer of images and other data

across the network system from CT and simulator to treatment planning system to linear accelerator and between linear accelerators, and to perform appropriate quality control on the transfer system.
To specify, justify and rank the criteria for specifying and selecting imaging systems in radiotherapy (e.g. simulator, CT, MRI).
To participate in using these imaging systems for localisation and treatment design in clinical practice.
To produce and/or verify outlines and contours and other patient data for treatment planning.
To evaluate the uncertainties in this patient data.

15.4 **Treatment planning**

Assess and compare the process of delineating GTV, CTV, PTV and OR for different sites.
Attend discussions within multidisciplinary teams.
To verify the process of transfer of localisation images to the treatment planning system.
To assess the limitations of treatment planning algorithms using available information (user groups, manuals, etc).
Investigate the effects of changing parameters on a treatment plan using the treatment planning system.
To investigate the methods used to account for inhomogeneities and missing tissue in photon irradiation, for example, equivalent path lengths, ETAR, convolution-superposition.
To perform manual monitor unit or time calculations for megavoltage and kV X-ray beams and electron beams for a variety of clinical situations.
To produce simple manual plans for different photon beam configurations and calculate the required number of monitor units.
To produce dose distributions for extended field treatment.
To specify, justify and rank the criteria for specifying and selecting treatment planning systems.
To practise choosing the energy of photons or electrons for clinical applications.
To produce computer plans showing the effect of obliquity and heterogeneities.
To produce computer plans for a variety of image sources and a representative set of target sites, using appropriate beam modifiers such as wedges, blocks, MLCs, compensators and bolus.
To investigate locally available IMRT protocols and dose constraints.
To produce computer plans with matching fields.
To perform quality control of the treatment planning system and the data in it.
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.
To check individual patient treatment plans and charts.

15.5 **Radiotherapy techniques**

To compare different levels of treatment planning complexity in relation to clinical requirement and the uncertainties involved.
Observe and evaluate the treatment of a representative set of patients.
Observe and evaluate planning and treatment using special techniques such as stereotactic radiotherapy, total-body irradiation and total skin irradiation where available.
To compare national and international treatment protocols with those used at the institution.

15.6 **Treatment verification**

To accompany a physicist and interact with patients as permitted by local clinical practice.
To observe and evaluate activities in the mould room and the production of treatment aids such as immobilisation devices and shielding blocks.
To check the use of these devices by following the process through from simulator to treatment planning system, linear accelerator and megavoltage image.
Observe the use of a simulator to verify plans before treatment.
To verify treatment plans by planning locally available phantoms and then measuring the dose delivered using the plan (this tests the treatment planning algorithm in some situations).
To evaluate discrepancies between portal images, simulator verification images and DRRs.
To use a record and verify system.

15.7 **Quality assurance in radiotherapy**

(See also 'Treatment and Imaging Equipment')
To assess sources and levels of uncertainty in geometry and dose delivery and the methods for monitoring and controlling them.
To evaluate incident reports in a department, and the actions ensuing.

16 Radiation therapy—brachytherapy

16.1 **Equipment**

To justify the choice of closed/sealed brachytherapy sources and the reasons for their choice in a particular clinical situation.
Assess the advantages and limitations of locally available sources.
To observe the safe use and custody of small radioactive sealed sources, and to practise action to be taken if a source is lost and formal disposal of such sources.
To perform leakage tests on brachytherapy sources.
To assist in the preparation of brachytherapy sources for clinical use.

16.2 **Source specification**

To measure the source strength or calibration of brachytherapy sources in local use, using available methods and to determine the uncertainties of the measurement.

16.3 **Treatment techniques and methods**

To investigate dosimetry systems for intracavitary brachytherapy and interstitial brachytherapy (Manchester and Paris).

To plan the distribution of sources for a required dose.

To observe and participate in the complete clinical process of brachytherapy, (preferably both manual and afterloading) from operating theatre through simulator localisation, treatment planning and radiation treatment.

16.4 **Treatment planning and dose calculation in brachytherapy**

To investigate locally used calculation and optimisation algorithms.

To calculate treatment times of intracavitary insertions using manual methods.

To calculate treatment times of interstitial implants using manual methods.

To produce dose distributions of brachytherapy treatments using a computer system.

16.6 **Quality management in brachytherapy**

To perform quality control of brachytherapy sources, applicators and equipment (e.g. constancy of activity along an iridium wire).

17 **Radiation therapy—unsealed source therapy**

(In some countries and/or departments, unsealed source therapy is carried out within Nuclear Medicine departments, in others within Radiation Oncology Departments: practical training in this area may depend on the local situation).

Check activities of radionuclides in a well counter.

To perform organ dose calculations.

To observe the clinical process of administering open/liquid radionuclides to a patient and the subsequent management of the patient.

18 **Radiation protection for ionising radiation**

To discuss the principles of radiation safety.

To evaluate the application of current laws, regulations and recommendations as applied locally.

To perform radiation survey of an area using appropriate dose-rate equipment.

To discuss the use of personal dosemeters (TLD etc).

To investigate risk factors of radiation (effective dose).

To discuss emergency plans.

To carry out risk assessments.

To practice design calculations for a linac room, simulator room, brachytherapy source room.

To assess the design of the local radionuclide preparation laboratory (barriers, etc).

To perform radiation protection area surveys of radiation facilities.

To investigate how principles of waste disposal operate locally.

To plan and practice contingency measures, e.g. lost source, spill.

To discuss decontamination procedures after a spill of liquid radionuclide.

19 **Uncertainty in radiotherapy**

Estimate the size of discrepancies from different sources of uncertainty in radiotherapy.

Investigate the management of uncertainty in the local centre.

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Glossary

AAPM:, American Association of Physicists in Medicine; ALARA:, As Low As Reasonably Achievable; BEV:, Beam's Eye View; BSF:, Backscatter Factor; BT:, Brachytherapy; CPD:, Continuing Professional Development; CT:, Computed Tomography; CTV:, Clinical Target Volume; DICOM:, Digital Imaging and Communication in Medicine; DRR:, Digitally Reconstructed Radiograph; DVH:, Dose Volume Histogram; EDRO:, Education for Radiation Oncology; EFOMP:, European Federation of Organisations for Medical Physics; ESQUIRE:, Education Science and Quality Assurance in Radiotherapy in Europe; ESTRO:, European Society for Therapeutic Radiology and Oncology; ETAR:, Equivalent Tissue Air Ratio; EU:, European Union; FECS:, Federation of European Cancer Societies; GTV:, Gross Tumour Volume; HDR:, High Dose Rate; IAEA:, International Atomic Energy Agency; ICRU:, International Commission on Radiation Units and Measurements; IMRT:, Intensity Modulated Radiation Therapy; ISO:, International Organisation for Standardisation; LDR:, Low Dose Rate; LQ model:, Linear-Quadratic model; MED:, Medical Exposure Directive 97/43 Euratom; MIRD:, Medical Internal Radiation Dose; MLC:, Multileaf Collimator; MPE:, Medical Physics Expert; MRI:, Magnetic Resonance Imaging; MTF:, Modulation Transfer Function; MV:, Megavoltage; MU:, Monitor Unit; NTCP:, Normal Tissue Complication Probability; OR:, Organs at Risk; PACS:, Picture Archive and Communication Systems; PDD:, Percentage Depth Dose; PDR:, Pulsed Dose Rate; PET:, Positron Emission Tomography; PSF:, Point Spread Function; PTV:, Planning Target Volume; QA:, Quality Assurance; QC:, Quality Control; QMP:, Qualified Medical Physicist; RAKR:, Reference Air Kerma Rate; RF:, Radio Frequency; RT:, Radiotherapy; SMP:, Specialised Medical Physicist; SPECT:, Single Photon Emission Computed Tomography; SSD:, Source Surface Distance; TBI:, Total Body Irradiation; TCP:, Tumour Control Probability; TLD:, Thermoluminescent Dosimetry; TMR:, Tissue Maximum Ratio; TPR:, Tissue Phantom Ratio; TPS:, Treatment Planning System; TSEI:, Total Skin Electron Irradiation.