CORE CURRICULUM FOR MEDICAL PHYSICISTS IN RADIOLOGY

Recommendations from an EFOMP/ESR working group

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I. Introduction

The term 'Medical Physics Expert' refers to a physicist with an appropriate level of expertise. This term was introduced in 1997 in the European Council Directive 97/43/Euratom on health protection of individuals against the dangers of ionising radiation in relation to medical exposure [1]. It had to be transposed into the national legislation in all European countries, including the definition of the Medical Physics Expert. However, the requirements for the Medical Physics Expert were implemented differently across Europe.

A new directive, the Euratom Basic Safety Standards Directive from 2010 (version 24 February 2010), gives a more specific definition of the Medical Physics Expert [2]:

"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 recognised by the competent authorities".

The following guidelines with respect to competencies and core curriculum items can be used for the development of the local curriculum for medical physicists in radiology. The core curriculum aims at bringing the medical physicist in radiology up to the level of a qualified medical physicist. 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. To act as an expert further experience is required and an involvement in a programme for Continuing Professional Development is recommended [3]. Radiology involves many subspecialties, e.g. radiography, mammography, computed tomography, X-ray guided interventions, and paediatric radiology but also magnetic resonance imaging (MRI) and ultrasound imaging. The medical physicist in radiology who is recognised as a Medical Physics Expert must have a high level of expertise in X-ray imaging. In addition, but depending on local conditions, it may also be desirable or even required that the medical physicist in radiology acquires a certain level of expertise in MRI, ultrasound imaging, and nuclear medicine. Consequently, a trainee is not expected to cover all elements of this curriculum.

The medical physicist in radiology's role is essential for enabling the practice of safe, state-of-the-art medical imaging. Medical physicists in radiology are members of the multi-disciplinary clinical teams that are responsible for radiology services to patients. Their role is to provide critical scientific input on the physical processes and technology that underpin the whole radiology service. Generally, the medical physicists in radiology design and develop the framework of medical imaging, image processing, image distribution, image storage, radiation dosimetry, quality assurance of the imaging equipment, information and communication technology (ICT) aspects of the imaging process, and radiation protection of the patient and operator. Specifically, the medical physicists in radiology provide expert advice on the development, implementation and improvement of imaging techniques and processes. They also provide expert input for applications of medical imaging outside the radiology department.

Medical physicists in radiology have a leading role in the strategic planning, testing, safe use and optimisation of advances in medical imaging technologies and techniques. In order to acquire and maintain sufficient knowledge and an appropriate level of competence, both initial and continuing education and training are necessary. This core curriculum for medical physicists in radiology is issued jointly by the European Federation of Organisations for Medical Physics (EFOMP) and the European Society of Radiology (ESR). It provides guidelines for the education and training of medical physicist within medical imaging. These guidelines accommodate the contemporary requirements for the knowledge and competency needs in this rapidly evolving field of medicine.

The two organisations EFOMP and ESR have a long-standing commitment to improved clinical practice, science and development and to education and training. 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. 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 in Radiation Physics or Radiation Technology" [3], is the EFOMP response to the Medical Exposure Directive, 97/43/Euratom. Here, EFOMP presents its recommendations on the role and the competence requirements of the Medical Physics Expert (MPE), as defined in this Directive, 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" [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, including medical physicists in radiology, 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], and Policy Statement No. 12 "The present status of Medical Physics Education and Training in Europe. New perspectives and EFOMP recommendations" [7], recommend National Member Organisations to set up their own detailed CPD Scheme. In Policy Statement No.12 additional recommendations are published by EFOMP 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'', and with a view to facilitate the free movement of professionals within Europe. In Policy Statement No.11 Guidelines on Professional Conduct are published [8].

The European Society of Radiology (ESR) represents the medical specialty of Radiology throughout Europe. In the Statutes of the ESR the term 'radiology' means 'diagnostic and interventional radiology, biomedical and molecular imaging'. A radiologist is a qualified medical practitioner who has undergone appropriate postgraduate training in diagnostic and interventional radiology. The Society is dedicated to promoting and developing the highest standards of radiology and related sciences in Europe. Among other goals, the Society aims to (a) promote radiology and associated disciplines through education, research, quality of service, management skills, socio-economic responsibility and ethical principles in research and safe radiological practice, (b) provide radiologists with a broad range of high-quality educational materials and (c) harmonise and standardise teaching and examination programmes to provide equivalent training for radiologists and other staff working in radiology departments in European countries. ESR can be regarded as a prime provider for exquisite teaching and plays an ever increasing role in the education of radiologists in Europe and Worldwide. Medical physicists have always been at the forefront of the development of radiology. ESR and EFOMP are scientific organisations with a shared interest in and common goals for the advance of medical imaging. ESR seeks to foster greater cooperation among radiologists and members of EFOMP. Education and training should be recognised as the main process by which societies can reach their fullest potential. Establishing and promoting educational activities between radiologists and medical physicists will maximise technological progress and patient benefit.

[1] Council 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

[2] Draft Euratom Basic Safety Standards Directive Version 24 February 2010 (final)

[3] 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. Physica Medica 1999; XV (3): 149-153

[4] EFOMP Policy Statement No. 8: Continuing Professional Development for the Medical Physicist. Physica Medica 1998; XIV (2): 81-83

[5] EFOMP Policy Statement No. 6: Recommended guidelines of National Registration Schemes for Medical Physicists. Physica Medica 1995; XI (4): 157-159

[6] EFOMP Policy Statement No. 10: Recommended Guidelines on National Schemes for Continuing Professional Development of Medical Physicists. Physica Medica 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. Physica Medica 2010; (26) 1-5.

[8] EFOMP Policy Statement No. 11: Guidelines on Professional Conduct and Procedures to Be Implemented in the Event of Alleged Misconduct. Physica Medica 2003; (19) 227-229.

II. GENERAL COMPETENCIES

Organisation

Introduction

The medical physicist in radiology is a member of a multi-disciplinary team that includes radiologists, medical physicists in radiology, registered technologists in radiography (RTR's), computer scientists, assistant medical technicians, nurses, administrators, hospital management and other health care professionals. The medical physicist in radiology must be able to work together with the multi-disciplinary team in the clinical application of medical imaging and participates in the organising and structuring of the medical imaging process.

Competences:

- Demonstrate an understanding of the organisation of local and national health care
- Demonstrate an awareness of trends in health care
- Ability to work effectively, in terms of time and equipment, as a staff member in a medical team
- Ability to manage workload and to provide effective input to a team
- Demonstrate an understanding of the required technological infrastructure for a radiology department and an awareness of how to establish the necessary interactions with other disciplines within the hospital (e.g. nuclear medicine; radiotherapy; cardiology; surgery; and other medical specialties that apply medical imaging)
- Ability to organise specified aspects of the routine radiology physics service
- Ability to participate in networks for research and development

Professionalism

Introduction

The medical physicist in radiology should ensure that the well-being, interests and dignity of patients are promoted and safeguarded at all times. The medical physicist in radiology takes care that practices in the hospital do not constitute an unnecessary hazard to any person. The medical physicist in radiology 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 health care services. This includes the accurate communication of information within the radiology department and with other hospital staff. Incidentally it may also be necessary to give information to patients and answer their questions. As a health care professional the role of the medical physicist in radiology implies certain social actions that have consequences for the patient, the health care organisation and society.

Competences:

- Know their own limitations of knowledge and competency
- Demonstrate an understanding of the role of the medical physicists in radiology within the health care system
- Understand relevant national professional codes and the need to work within them
- Demonstrate an understanding of, and be able to act within, relevant national legislation and international regulations and guidelines
- Demonstrate an understanding and correct use of medical terminology
- Discuss technical and clinical aspects of medical imaging with medical staff
- Discuss general aspects of medical imaging with patients and the general public
- Ability to prepare written material in the form of notes, reports and scientific papers
- Demonstrate the ability to work in multidisciplinary team
- Ability to participate in the process of site planning and room design
- Ability to participate in the tender process for medical imaging systems, and to participate in selection procedures
- Ability to work within the framework of cross-disciplinary research collaboration to improve the routine clinical service
- 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 in response to incidents
- Show consideration for another person’s ethical, cultural or moral issues

III. RADIOLOGY PHYSICS KNOWLEDGE, SKILLS AND COMPETENCIES

The field of medical imaging is a dynamic, fast evolving discipline with constant development, introduction and implementation of new advanced imaging and minimal invasive treatment technologies. Because of their key role in this process, medical physicists in radiology require broad scientific interests and need to constantly learn and acquire new knowledge. An excellent knowledge of radiation physics, X-ray imaging, dosimetry, and radiation protection remains the central competence, but competences may also be required with regard to magnetic resonance imaging (MRI), ultrasound imaging (US), and nuclear medicine (NM). Interdisciplinary knowledge is needed for involvement in application and development of new hybrid imaging technologies.

The medical physicists in radiology have to demonstrate and apply their knowledge in clinical practice through skills and appropriate attitude. The following sections provide more detail on the required areas of core knowledge and required competencies for the medical physicist in radiology.

Fundamental knowledge (sections 1 to 10) should be acquired by all medical physicists that are trained in radiology physics. Applied knowledge with regard to dosimetry, medical X-ray imaging, and radiation protection should also be acquired by all medical physicists (section 11 (dosimetry), 12 (Medical X-ray imaging), and 15 (Radiation protection for ionising radiation)). The requirement to acquire applied knowledge in the field of magnetic resonance imaging, ultrasound imaging, or nuclear medicine imaging may depend on local conditions.

FUNDAMENTAL KNOWLEDGE

1. Fundamentals of human anatomy, physiology, and pathology

Short description

Basic understanding and knowledge of human anatomy, physiology and pathology is required to understand the clinical aspects of medical imaging. It is also a pre-requsite for communication and exchange of patient-, diagnosis-, and disease-related information. Likewise, basic knowledge of human anatomy, physiology and pathology is essential to understand the advantages and drawbacks of different imaging modalities and is,as such, a prerequisit for optimization of imaging and radiation protection.

Competences

- Ability to participate, at a basic level, in discussions on clinical aspects of medical imaging in a multidisciplinary clinical environment
- Ability to recognise basic anatomical and pathological structures of the human body in medical images, with an emphasis on static and dynamic 2D and 3D visualization of anatomical and pathological structures
- Demonstrate an understanding of how physiology interacts with medical imaging

Core curriculum items

- General knowledge of nomenclature in anatomy
- Knowledge of human anatomy
- General knowledge of pathology
- General knowledge of physiology
- Appearance of anatomy and pathology in medical images
- The effect of physiology on medical images

2. Fundamentals of clinical care

Short description

Medical physicists in radiology work as a part of a interdisciplinary team of referring physicians, radiologists, and radiographers. A basic understanding of clinical care, including the fundamentals of diseases and trauma; of diagnosis and treatment; of screening and follow up, is required.

The medical physicist in radiology should understand the structure of the management of both the hospital and the radiology department to be able to participate in it. The medical physicist in radiology should acquire basic knowledge of the organisation and management of the health care system and of the relevant guidelines and recommendations from national or international organisations. The medical physicist in radiology should be familiar with ethical issues in health care and with the role of the medical ethics committee.

Competences

- Demonstrate a basic understanding of trauma and the development of diseases, as well as their diagnosis and follow up
- Demonstrate a basic understanding of screening programs
- Demonstrate knowledge of various options for diagnosis and treatment
- Demonstrate an understanding of the position of the medical physicist in radiology's own institution as part of the local and national health care systems,
- Demonstrate knowledge of the development of medical physics and the applications of medical physics in health care
- Apply ethical considerations in medical practice

Core curriculum items:

- Basic introduction to major diseases including their signs and symptoms
- Basic introduction to trauma
- General principles of diagnosis
- General principles of image guided treatment, for example in surgery, interventional radiology, radiotherapy and cardiology
- General principles of population screening
- General principles of follow up
- General overview of the application of medical physics in clinical care
- Overview of medical uses of ionising radiation in medical imaging (X-ray, nuclear medicine)
- Overview of medical uses of non-ionising radiation in medical imaging (MRI, ultrasound imaging)
- National and local health care system, global view of other European systems
- Guidelines and recommendations related to clinical care from national and international organisations
- General ethical considerations in medical practice and in biomedical research
- Principles of management as applied to hospital departments and research projects

3. Principles of radiobiology

Short description

Activities of medical physicists in radiology require basic knowledge in the field of radiobiology. Principles of radiobiology are the basis for risk assessment in radiology. Special knowledge of radiobiology is required to assess the effect of radiation exposure for special groups like children and pregnant women. Special knowledge on deterministic radiobiological effects (tissue reactions) is required for risk assessment in patients that develop such effects. For proper risk management with regard to patients, staff, and general public expertise should thus be acquired both for late and acute radiation effects.

Competences

- Ability to apply radiobiological knowledge for achieving proper risk assessment in diagnostic imaging and in image guided interventions
- Ability to use radiobiology to stimulate optimisation of the application of ionising radiation in diagnostic radiology
- Contribute appropriate radiobiological knowledge for the assessment of possible harm in case incidents with relatively high exposures that may occur for occupational exposures as well as for clinical exposures of patients

Core curriculum items

- Fundamentals of cellular and molecular biology
- The physical and biological background to the effect of ionising radiation on living cells
- The response of tissues to radiation at a molecular, cellular and macroscopic level
- Radiobiology for humans in general, and for children and the fetus in particular
- Models of radiation induced cancer and heriditary risks

4. Overview of radiation physics

Short description

The medical physicist in radiology should have a high expertise in fundamental radiation physics in order to understand how ionising radiation is applied in medical imaging. Good knowledge of radiation physics is also essential for achieving optimal radiation protection of patients, staff, and general public. Relevant descriptions of the different sources of ionising radiation as applied in different imaging modalities, including X-ray imaging and nuclear medicine, should be included. Of great importance is the knowledge of the physics of interaction of different types of radiation with matter and tissues, as it forms the basis for understanding the advantages and limits of various imaging techniques. Knowledge of the response of various detector materials to different varieties of ionising radiation provides insight in the (potential) performance of detectors. Finally, good knowledge of radiation physics is required for proper application of radiation dosimetry.

Competences and skills

- Ability to specify the different mechanisms of generation of ionizing radiation, including radioactive decay
- Ability to recognise the difference between the physical interactions of indirectly and directly ionising radiation
- Ability to describe different mechanisms of energy loss of various type of radiation through various media
- Ability to describe quantitatively radiation fields applied in radiology

Core curriculum items

- Atomic structure
- Electromagnetic and particulate radiation
- Ionising and non-ionising radiation
- Quantum nature of electromagnetic radiation
- Principles of X-ray generation and the X-ray spectrum
- Radioactivity and radiation sources
- Interaction of photons (X-rays, gamma-rays) with matter and tissues
- Scattering and attenuation of a photon beam in matter and tissues
- Interaction of charged particles with matter and tissues

5. Fundamentals of medical imaging

Short description

As a specialist in the application of medical physics in radiology, the medical physicist in radiology must acquire a high degree of knowledge about the fundamental models and mechanisms of medical image formation and image display, of reconstruction and postprocessing; and about fundamental aspects of observer performance and human image perception.

Competences and skills

- Ability to apply the theory of image formation to advice on the selection of the most appropriate imaging modality
- Ability to apply the theory of image formation to achieve the most optimal image acquisition protocol
- Ability to apply theory of image reconstruction and postprocessing to achieve optimal image quality for a specific clinical task
- Ability to apply the theory of observer performance to the optimization of medical imaging
- Ability to apply the theory of human image perception to the optimization of image reading
- Ability to advise on the implementation and application of systems for computer aided diagnosis

Core curriculum items

- Fourier analysis
- Image formation and image quality
- Reconstruction algorithms
- Vision and perception
- Visualisation of medical images
- Image display
- Image processing
- Quantitative image analysis
- Statistics of the imaging process
- Image registration and image fusion
- Computer aided diagnosis

6. Statistical methods

Short description

Routine work in a radiology department often requires the use of statistics in medicine, including radiology. Medical physicists are frequently involved in technical and clinical studies; in particular in designing, analyzing and interpreting the experimental approach and processing the data. Therefore, medical physicists have to be trained in the fundamentals of statistical methods.

Competences

- Ability to demonstrate the understanding of the fundamentals of biostatistics
- Abilty to perform common statistical tests
- Ability to estimate measurement uncertainties and their categories
- Ability to apply computational techniques and dedicated software packages for statistical data analysis
- Ability to analyse and interprete statistical results
- Ability to set tolerances and action levels

Core curriculum items

- Descriptive statistics
- Probability distributions
- General principles and application of statistical tests
- Study design and power analysis
- Random and systematic errors
- Error propagation
- Uncertainty analysis
- Regression and correlation
- Tolerance and action levels
- Receiver operating characteristic curves

7. Principles of quality management in health care

Short description

Quality management requires an organisational structure where responsibilities, procedures, processes and resources are clearly defined. It should be supported by the radiology 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 radiology team. The quality system must incorporate compliance with all the requirements of national legislation, accreditation and requires the development of a formal written quality assurance program that details the quality assurance policies and procedures, quality control tests, frequencies, tolerances, action criteria, required records and personnel.

The Quality Assurance (QA) process in radiology involves all steps of the diagnostic process from image request and justification of the examination to equipment performance, and image reading and strorage.

Competences:

- Ability to participate in quality management and facilitate quality improvement
- Ability to define quality objectives and to measure and improve effective quality performance
- Ability to define and apply control tests, frequencies, tolerances, and action criteria
- Ability to demonstrate knowledge of national and international legislation and recommendations for quality assurance
- Ability to perform quality control on diagnostic imaging modalities
- Ability to participate in clinical audits in radiology departments
- Ability to set specifications, measure performance, compare with specifications, and, as required, adjust the process to meet specifications in accordance with the recommendations and standards (including documentation and training of other professionals)
- Demonstrate knowledge of national and international recommendations and local protocols for quality management
- Ability to implement EU Directives, national regulations and guidelines and recommendations from national and international organisations
- Demonstrate knowledge of equipment management
- Demonstrate understanding of written procedures of a departmental quality management system

Core curriculum items

- Basic aspects of planning and management
- Quality, quality assurance and quality control
- Quality standards
- Assessment of quality

- Quality management systems, records, and improvement of quality
- National and international recommendations and local protocols for quality management
- Quality procedures and tests on imaging modalities
- Clinical audit processes

8. General principles of risk management and safety in health care

Short description

Medical imaging is essential in clinical care and involves advanced and complex instruments that require a high level of safety and constant quality improvement. Ensuring safety in medical imaging is a dynamic process that should continuously be improved and modified to meet the evolving needs and demands of the hospital environment. The medical physicist will provide specific information with regard to risk management and safety in radiological-, electromagnetic-, and ultrasound imaging. Medical physicists must be familiar with such hazards and necessary precautions. They should have a sufficient appreciation of best practice concerned with safety and risk management to be able to contribute, facilitate, implement and improve safety management systems.

Competences:

- Ability to use risk assessment and incident investigation to improve the quality program
- Ability to evaluate and prevent the risks of a given procedure or protocol
- Ability to prevent investigate, and evaluate incidents in a radiology department and implement corrective actions
- Ability to evaluate whether service agreements and software updates of radiology equipment are adequate to ensure patient safety
- Ability to evaluate effective safety performance
- Ability to manage and plan for emergency situations
- Ability to assess human factors and safety-related behaviour
- Ability to increase the safety aspects that are related to medical physics for the patient undergoing diagnostic and (minimal) invasive image guided treatment procedures
- Ability to identify and manage the risks associated with medical imaging

Core curriculum items

- Definition and measurement of risk
- Assessment and quantification of risk
- Risk management
- Human risk perception
- Electrical, electro-magnetic, magnetic, and ultrasound safety
- Mechanical safety
- Principles of radiation protection for ionising radiation and non-ionising radiation
- Tools for risk assessment such as Failure Mode Analysis; Effect Analysis; and Root Cause Analysis

9. Evidence based medicine

Short description

Evidence based medicine generally requires a multidisciplinary effort that integrates medical, social, economic and ethical issues related to the use of clinical care and medical technology in a systematic, transparent, unbiased and robust manner. Its aim is the formulation of safe, effective health policies that are patient focused but that also seek optimal economical and societal value.

Competences:

- Demonstrate an understanding of the basic methodology employed in health technology assessment
- Ability to perform a systematic review of the literature to evaluate the clinical effectiveness of a new technology or technique
- Ability to assess the efficacy of a new technology/technique
- To be familiar with the standards for reporting of diagnostic accuracy (STARD, Quadas)
- To be familiar with the goal and principles of the Cochrane Collaboration
- Ability to apply experimental outcomes to evidence based medicine approaches

Core Curriculum items

- General aspects of health technology assessment
- Design and implementation of clinical trials
- International classification of diseases (ICD)
- Principles of systematic review

10. Information and communication technology

Short description

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

Competencies

- Ability to understand and discuss ICT concepts with other healthcare professionals
- Ability to understand and discuss healthcare data connectivity standards with colleagues from other disciplines to facilitate the integration of general systems within radiology departments
- Demonstrate a understanding of hardware configuration, operating systems and typical software applications
- To understand the basic concepts in health informatics such as the unique patient indentifier, the medical record and disease coding such as ICD10
- To understand basic principles of communication standards in medicine such as HL7, SNOMED, IHE
- To understand the DICOM standard for medical image communication
- To understand basic concepts of Patient Administration Systems, the Electronic Patient Record and Order Communication Systems
- To be aware of privacy issues related to electronic patient information systems
- To understand ICT infrastructure for a radiology department (RIS, PACS)
- To understand safety and risk related issues associated to ICT

Core Curriculum items

- Operation of the major components of computers,
- The principles of computer networks (LAN, WAN)
- Data exchange formats and standards (DICOM, PACS, and others as required)
- Hardware that is required to support health informatics systems
- Risk issues associated with ICT

APPLIED KNOWLEDGE

11. Dosimetry

Short description

Dose assessment is an important task of the medical physicist in radiology. The concept of absorbed dose and kerma in particular, and dosimetric quantities and units in general should be well understood. The medical physicist in radiology should be familiar with the principle of the calibration chain from primary standard to field instrument, and understand the physics and technologies of the different dosimetry detectors. Determination of the absorbed dose in the primary and scattered X-ray beam is an important issue.

The medical physicist in radiology should be familiar with the different practical measurements or computational systems that can be used for patient, occupational, and environmental dosimetry of X-rays and understand their advantages and limitations in order to be able to select the most appropriate system for each dosimetric problem.

Competences:

- Demonstrate a good understanding of the basic dosimetric quantities and units and fundamental concepts
- Demostrate knowledge of the dosimetric systems (systems based on ionisations in air, thermo luminescence dosimetry (TLD); semi-conductor; film, optical stimulated luminescence (OSL), scintillation)
- Ability to identify and select the appropiate dosimetry system for various applications
- Ability to perform measurements with several dosimetry system
- Demonstrate knowledge of dosimetric standards and traceability
- Demonstarte an understanding of the calibration systems and methods used in radiology
- Ability to select appropiate phantoms for the dosimetry of diagnostic X-ray beams
- Abilty to identify and properly apply the dosimetric techniques specific for radiology equipment
- Ability to perform patient dosimetry in radiology, including dose assessment for the fetus

Core curriculum items

- Basic quantities, i.e. photon fluence and photon fluence rate, energy fluence and energy fluence rate, kerma and absorbed dose
- Primary measurements, i.e. ionisation in air as the primary radiation standard, mean energy required to create an ion pair, cavity theory, the Bragg-Gray principle, conversion of charge to absorbed dose

- Secondary measurements, i.e. chemical effects (oxidation of ferrous to ferric ions), biochemical changes, biological changes
- The ionisation chamber
- Relationship between exposure and absorbed dose
- Conversion of absorbed dose in air to absorbed dose in another medium
- Other detectors, i.e. scintillation detectors, thermoluminescent dosemeters, optical stimulated luminescence, semiconductor detectors, photographic film and radiochromic film
- Phantoms and phantom materials for dosimetry in diagnostic X-ray beams
- Principles of dose measurement for specific imaging modalities and implications for patients
- Basic clinical patient dose indicators (dose area product, entrance skin dose)
- Dose indicators for the detector (absorbed dose and absorbed dose rate on the detector)
- Detector dose requirement in projection radiography (speed class (film-screen), speed index (CR and DR)
- Dose im mammography, absorbed dose in glandular tissue
- Patient dose in diagnostic fluoroscopy and in interventional radiology (entrance dose, dose in the interventional reference point)
- Patient dose in computed tomography (computed tomography dose index, dose length product)
- Dose assessment for the foetus
- Dose measurements in quality assessment of equipment

12. Medical X-ray imaging

Short description

X-ray imaging is the most widespread application of medical imaging. It can be performed in many ways, for different clinical applications, and by various medical professionals. X-ray imaging is essential in the health care system, but necessitates certain radiation exposure of the patient, and sometimes exposure of workers and general public. The application of X-rays in medical imaging is strictly regulated; this is to ensure that appropriate measures for radiation protection are implemented. Medical X-ray imaging varies from general projection radiography, to 3D visualisations; from static imaging to dynamic imaging; from dental applications to whole body CT. Medical X-ray imaging is often associated with the radiology department, but is also routinely applied in departments such as cardiology, radiotherapy and urology. Sytems for medical X-ray imaging are installed in emergency rooms, and mobile systems for X-ray imaging are often used in operating rooms.

This chapter lists competencies and core curriculum items for medical X-ray imaging, the first section lists generic competencies and curriculum items for X-ray equipment and X-ray imaging; the following sections provide specific additional competencies and curriculum items for the hardware and the image acquisition in general projection radiography, mammography, fluoroscopy, and computed tomography.

12.1 General principles of X-ray equipment and X-ray imaging

Competences

Basic principles

- To become acquainted with the physical components of X-ray imaging equipment (high voltage generator, X-ray tube, tube cooling, flat filters and shaped filters, collimator, detector, anti scatter grids, operator console, patient support, computer, display, workstation)
- Understand the physical principles underlying X-ray imaging systems

Image acquisition, image processing and image reconstruction

- Understand the effect on image formation of basic X-ray interaction processes in the body
- Understand the modes of operation of different image receptors
- Understand the image acquisition protocols, preprocessing of image data, image reconstruction principles, and postprocessing of images
- Ability to operate the X-ray units at a basic level, primarily for quality control, but also for image quality assessment and dosimetry
- Acquire general knowledge about the different image acquisition protocols used to perform the most common types of clinical examinations

Image quality (including artefacts)

- Ability to assess image quality from measurements with test objects and with human observers
- Demonstrate awareness that different requirements for image quality apply to specific clinical tasks
- To be familiar with the effect on image quality when changing imaging and reconstruction parameters
- The know how to optimise protocols for X-ray imaging
- Ability to recognise and analyse image artefacts

Safety and standards

- Ablity to evaluate the local applications of laws, regulations, recommendations and standards related to X-ray safety
- To provide practical safety-related guidelines, incident-reporting routines and educational material for all personnel

Clinical aspects

- To understand the patient's perspective in the entire process of X-ray examinations
- To become familiar with images from routine X-ray examinations (projection radiography, mammography, fluoroscopy, X-ray guided interventions, computed tomography, tomosynthesis)
- To recognise basic normal anatomy as well as pathology in the images

Core curriculum items

Basic principles

- X-ray tubes for different applications
- Components of the X-ray tube
- X-ray generators and timing of the X-ray exposure
- Optimisation of the design of the X-ray tube and generator for different applications in medical imaging
- X-ray imaging geometry
- Beam limiting devices
- Relative importance of photoelectric and Compton effect at different X-ray energies in different tissues
- Reduction of scattered radiation
- K-shell energies and absorption edges in radiology
- Performance requirements of imaging receptors – especially resolution and sensitivity
- Critical comparison of different analogue and digital receptors
- Operation of X-ray imaging systems

Image acquisition, image processing and image reconstruction

- Image acquisition protocols
- Pre- and postprocessing of digital images
- Image reconstruction principles

Image quality (including artefacts)

- Basic aspects of image quality (spatial resolution and contrast, contrast to noise ratio, point spread function, modulation transfer function, noise power spectrum, detective quantum efficiency, noise equivalent quanta, contrast-detail curve)
- Physical measurement of image quality
- Assessment of image quality using human observers
- Differences in image quality for different X-ray imaging systems
- Optimisation of clinical protocols for X-ray imaging
- Image artefacts for X-ray imaging systems

Safety and standards

- Laws, regulations, recommendations and standards related to X-ray imaging
- Acceptance and constancy tests of X-ray imaging systems

Clinical aspects

- General overview of clinical applications of X-ray imaging
- General understanding of clinical images
- General understanding of clinical requirements with regard to image quality in X-ray imaging

12.2 General projection radiography

Competences

Hardware

- To demonstrate awareness of different designs of general projection radiography systems, like table- and wall-bucky systems, general radiography outside the bucky system, mobile systems for general radiography, chest radiography systems, radiography systems for children
- To demonstrate awareness of detector systems for general radiography, i.e. screen film radiography, computed radiography, and digital radiography
- To be able to advice on the purchase and use of the most appropriate general projection radiography unit for a specific clinical application

Image acquisition

- To understand common image acquisition parameters for X-ray imaging
- To understand principles of projection radiography
- To demonstrate familiarity with special requirements for pediatric projection radiography
- To demonstrate awareness of the application of radiostereometric analysis imaging
- Dual energy imaging, including dual energy X-ray absorptiometry (DXA)

Core curriculum items

Hardware

- Projection radiography imaging systems (general system, chest system, paediatric system, mobile system, table system, wall stand)
- Detector design for projection radiography imaging systems

Image acquisition and postprocessing

- Modes of operation of projection radiography imaging systems
- Acquisition parameters (tube voltage, filtration, tube current, exposure time, automatic exposure control, collimation)
- Digital image pre- and post-processing

12.3 Mammography

Competences

Hardware

- To demonstrate awareness of the designs of mammography systems, including systems for image guided stereotactic biopsy
- To demonstrate awareness of different detector systems for mammography, i.e. screen film mammography, mammography with computed radiography plates, and digital mammography with flat panel detectors
- To be able to advice on the purchase and use of a mammography unit

Image acquisition and postprocessing

- To understand common image acquisition parameters for mammography
- To demonstrate familiarity with special requirements for mammography compared to general projection radiography
- To understand the effect of compression in mammography
- To demonstrate familiarity with computer aided diagnosis in mammography
- To demonstrate familiarity with image guided biopsies
- To demonstrate familiarity with tomosynthesis in mammography

Core curriculum items

Hardware

- Mammography imaging systems (mammography, tomosynthesis)
- Detector design for mammography imaging systems

Image acquisition and postprocessing

- Modes of operation of projection radiography imaging systems
- Acquisition parameters (tube voltage, filtration, tube current, exposure time, automatic exposure control, collimation, magnification, projection mammography and tomosynthesis)
- Digital image pre- and post-processing, reconstruction of tomosynthesis acquisitions
- Stereotactic biopsy

12.4 Fluoroscopy

Competences

Hardware

- Demonstrate awareness of different designs of fluoroscopy systems, like fluoroscopy units with one or two C arms, with under- or over-table X-ray tubes, or mobile C arms
- To demonstrate awareness of different detector systems that can be incorporated in fluoroscopy systems, like an image intensifier, or different types of flat panel detector
- To be able to advice on the purchase and use of the most appropriate fluoroscopy unit for a specific clinical application

Image acquisition and postprocessing

- To understand common acquisition parameters for imaging with a fluoroscopy unit
- Demonstrate awareness that different acquisition parameters should be used for different clinical tasks
- To understand the different acquisition modes of a fluoroscopy unit
- To understand static and dynamic 2D imaging
- To understand static 3D imaging with a fluoroscopy unit (cone beam CT)
- To demonstrate familiarity with special requirements for fluoroscopy of children
- To become familiar with contrast enhanced fluoroscopy studies
- To be aware of special requirements with regard to radiation protection in fluoroscopy, and particularly in X-ray guided interventions
- To be aware of the possible occurrence of skin effects at high skin doses

Core curriculum items

Hardware

- Fluoroscopy imaging systems (diagnostic fluoroscopy, fluoroscopy guided interventions, mobile flluoroscopy systems, bi-plane systems)
- Detector design for fluoroscopy imaging systems

Image acquisition and postprocessing

- Modes of operation of fluoroscopy systems (continuous and pulsed fluoroscopy, automatic brightness control, high dose rate fluoroscopy, digital spot imaging, digital subtraction angiography, cine runs, last image hold, cone beam CT with fluoroscopy units)
- Image acquisition parameters (tube voltage, filtration, tube current, exposure time, collimation (field size), magnification)
- Contrast enhancement in fluoroscopy
- Digital image pre- and post-processing
- Overview of practices with possible high skin dose

12.5 Computed tomography (CT)

Competences

Hardware

- To demonstrate awareness of different designs of computed tomography systems, like multislice CT, dual source CT, and volumetric CT scanners; CT scanners for diagnostic imaging and for radiotherapy planning, cone beam CT scanners
- To demonstrate awareness of different modes of operation of CT scanners
- To be able to advice on the purchase and use of the most appropriate computed tomography systeem for a specific clinical application

Image acquisition and reconstruction

- To understand common acquisition parameters for CT imaging
- To understand CT image reconstruction
- To understand static 2D and 3D acquisitions in CT
- To understand dynamic 2D and 3D acquisitions in CT
- To demonstrate familiarity with special requirements for pediatric CT imaging
- To demonstrate familiarity with special requirements for quantitative imaging in CT
- To become acquainted with contrast enhanced studies in CT
- To be aware of special requirements with regard to radiation protection in CT, particularly in peadiatric CT and CT guided interventions
- Dual energy imaging

Core curriculum items

Hardware

- Computed tomography imaging systems (general CT scanner, radiotherapy planning CT scanner, cone beam CT scanner)
- Detector design for computed tomography imaging systems (curved CT detector, flat panel detector)

Image acquisition and reconstruction

- Basic principles of computed tomography reconstruction (filtered back projection, iterative reconstruction, beam hardening correction, noise reduction, correction for photon starvation)
- Modes of operation of CT systems (axial, helical, and volumetric acquisition and reconstruction, dynamic acquisition and reconstruction (CT fluoroscopy), CT radiograph, bolus tracking, prospective triggering (ECG), retrospective gating (ECG, respiratory), CT perfusion)
- Acquisition parameters (tube voltage, bow tie filter, tube current, rotation time, tube current modulation, scanned field of view, slice thickness, beam collimation, over beaming, over scanning)
- Contrast enhancement in computed tomography
- CT guided interventions
- CT in hybrid imaging systems

13. Magnetic resonance imaging

Short description

Magnetic resonance imaging (MRI) is an advanced medical imaging technique which has shown rapid technical development during the last decades. MRI has proven particularly useful for morphological imaging of the brain and spine, due to excellent soft tissue contrast, but is becoming increasingly important also in cardiac, abdominal, musculoskeletal and neurofunctional imaging applications. In addition, magnetic resonance spectroscopy (MRS) is a promising tool for in vivo studies of metabolic changes. The image acquisition is based on the combined use of a static magnetic field, with superimposed time-varying magnetic field gradients, and pulsed radiofrequency (RF) electromagnetic fields. MRI is characterised by the ability to provide a multitude of image contrast features, implying that each clinical application requires careful optimisation of the employed imaging protocol. Identification and reduction of image artefacts is also of considerable importance for optimal image quality. MRI safety issues include practical hazards, such as ferromagnetic objects acting as projectiles, awareness of biophysical aspects of electromagnetic fields, assessment of associated physiological effects and appropriate risk assessment for staff and patients. In this section, competencies and core curriculum items for MRI and MRS are listed, including hardware, image acquisition, post-processing procedures, image quality, clinical applications and safety issues.

Competences and skills

Basic principles

- To become acquainted with the operation of MRI units, the software user interface and surrounding equipment
- Substantial expertise in all aspects of the quality assurance (QA) of MRI units

Hardware

- To demonstrate awareness of commercially available magnet designs and field strengths, radiofrequency (RF) systems and gradient systems
- To measure static-field levels in the vicinity of the MR unit (e.g., to map and delineate the 0.5 mT contour)
- To be able to select appropriate RF coils

Image acquisition

- To perform basic imaging, including positioning, pulse-sequence selection and image display
- To understand the importance of basic scanner parameters (echo time, repetition time, inversion time, flip angle, field of view, matrix size etc.) for image quality, acquisition time and contrast behaviour using spin-echo, gradient-echo and inversion-recovery pulse sequences
- To demonstrate familiarity with fast and advanced pulse sequences, with respect to image quality and contrast features
- To demonstrate familiarity with parallel imaging techniques
- To understand flow effects and become acquainted with MR angiography (MRA)

- To become acquainted with pulse sequences, protocols and post-processing tools for perfusion and diffusion MRI, functional MRI and MR spectroscopy (MRS)
- To be aware of special requirements associated with MRI-guided interventions

Image quality (including artefacts)
- To determine signal to noise ratio (SNR) from phantom measurements, demonstrating awareness of relevant noise distributions, and to predict the effect on SNR when changing various imaging parameters
- To be able to identify and reduce common MRI artefacts

Safety and standards
- To evaluate the local applications of laws, regulations, recommendations and standards related to MR safety
- To maintain relevant emergency routines and basic MR compatibility assessment
- To provide practical safety-related guidelines, incident-reporting routines and educational material for all personnel

Clinical aspects
- To understand the patient's perspective in the entire process of an MRI examination
- To become familiar with the employed imaging protocol and the resulting images for routine MRI examinations (normal anatomy as well as pathology)

Core curriculum items

Basic nuclear magnetic resonance principles
- Electro-magnetic
- Spins in the static magnetic field (B_0) (proton, phosphor)
- Larmor frequency
- Excitation radiofrequency field (B_1)
- The formation of the spin/gradient echo
- Intrinsic and extrinsic MRI contrast parameters
- Relaxation mechanisms (T1, T2, T2*)

Hardware
- The static magnetic field subsystem
- The radiofrequency field subsystem (coil design and RF shielding)
- The gradient field subsystem (amplitudes, rise times, slew rate and eddy current effects)

Basic image formation
- Spatial encoding in three dimensions using linear magnetic field gradients and the properties of k-space
- Conventional pulse sequences (spin echo, gradient echo, inversion recovery)
- Fast imaging techniques (echo-planar imaging, fast spin-echo)

Introduction to special techniques, sequences and applications
- Parallel imaging
- Steady-state free precession sequences

- Motion compensation
- Flow quantification
- MR angiography (MRA), perfusion and diffusion imaging
- Functional MR imaging (BOLD-fMRI)
- MR spectroscopy (MRS)

Image quality, factors influencing image contrast
- Signal-to-noise ratio (SNR)
- Spatial resolution
- Acquisition time

Image quality, common artefacts
- Motion artefact
- Aliasing
- Metal and susceptibility artefact
- Chemical shift artefact
- Truncation artefact

Image quality, system-related issues
- B_0 inhomogeneity
- B_1 inhomogeneity
- RF distortions and coil problems
- Ghosting (not ascribed to motion)

Contrast agents
- Basic mechanisms
- Image contrast effects of paramagnetic and ferromagnetic contrast agents
- Hyperpolarised substances

Safety and standards
- Guidelines
- Practical hazards (projectiles, implants, heating, acoustic noise)
- Physiological effects related to electromagnetic fields
- Safe use of contrast agents

Introduction to clinical applications of MR

14. Ultrasound imaging

Short description

Ultrasound imaging is a modality that provides essential information in the detection and differentiation of disease using non-ionizing radiation. Ultrasonography is routinely used not only in radiology but also in departments such as gynecology, obstetrics, cardiology and emergency medicine. Medical physicists in radiology must have a broad scientific knowledge of physics and technology related to medical ultrasound. They have to be familiar with the performance evaluation methods of ultrasound systems including acceptance testing and routine quality control testing. Moreover, they must know the principles of ultrasound safety and the relevant regulations. This knowledge will allow them to design and perform a quality assurance program of ultrasound equipment, optimise performance and apply the ALARA principles in clinical practice.

Competences and skills

Basic principles

- Substantial expertise in all aspects of the operation and quality assurance (QA) of ultrasound imaging units
- Familiarity with all principal modes of operation i.e. A-mode, B-mode, M-mode, Pulsed Doppler, Colour Doppler
- Ability to select the appropriate transducers for gray-scale or Doppler imaging and understand the effect of ultrasound imaging parameters such as frequency, overall gain, time gain compensation, focusing on image quality
- Ability to measure or compute distance, area and volume computations is important and the trainee must become familiar with images from routine examinations.

Image quality

- Ability to optimise image quality in clinical images
- Ability to identify and explain image artefacts. A pictorial record containing an illustrated description of different artefacts should be collected and is a useful confirmation of experience

Safety

- The trainee must understand and recognise general aspects of safety in ultrasound imaging
- Ability to interpret and use the acoustical output indices i.e. thermal index and mechanical index

Core curriculum items

Basic principles

- Wave equation, harmonic solution and non-linear solutions.
- Basic parameters (pressure, displacement, density, particle velocity; Intensity and power; speed of sound in soft tissue, gas and bone; acoustic impedance)

Interactions of ultrasound with tissue

- Absorption, frequency dependence
- Scatter – single and multiple scattering and relationship to wavelength
- Reflection, behaviour at interfaces – angular dependence
- Refraction

Single element transducers

- Piezo-electric effect
- Transducers –resonance, bandwidth, backing and matching
- Near and far field beam patterns
- Pulsed operation, duty factor
- Focusing – aperture

Arrays

- Linear arrays (design principles, side lobes; electronic focusing; transmit beam forming; receive focusing; apodisation and dynamic aperture; curvi-linear arrays)
- Phased array (off axis focusing; multi-frequency imaging; 1.5 and 2D arrays)

Gray scale imaging

- Pulse-echo principle: pulse repetition frequency; gain, time gain compensation
- mode operation
- mode operation
- M-mode
- Demodulation
- Compression
- Frame rate
- Display and archiving
- Pre- and post processing
- Harmonic Imaging
- 3D and 4D techniques

Doppler techniques;

- Doppler equation
- Continuous Wave principle –detection and origin of spectrum
- Spectral analysis and display
- Pulsed Doppler – aliasing
- Colour Doppler
- Power Doppler
- Spectral indices e.g. Pulsatility Index, Resistance Index

Image Quality

- Spatial resolution (axial , lateral, slice thickness)
- Contrast resolution and dynamic range;
- Artefacts (propagation artefacts e.g. shadowing, reverberation, flaring)
- Mirror image, beam width artefacts
- Side lobe

Contrast Agents

- Blood pool contrast agents
- Microbubbles, resonance, non-linear behaviour
- Inert gas bubbles

Safety

- Mechanisms of interaction (thermal, cavitations, micro-streaming)
- Biological effects (molecular, cellular, animal, human)
- Waveform indices (thermal index, mechanical index)
- Safe operating levels
- Legislation (national and international)

Quality Assurance

- Tissue mimicking phantoms
- Measurement protocols
- Output measurement (hydrophones and power balances)
- Doppler performance assessment
- Recording and file archiving

Clinical applications

- Obstetrics and gynaecology
- Cardiac
- Abdominal
- small body parts (breast, testes, thyroid)
- Musculo-skeletal
- Paediatric
- Vascular

15. 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 the use of radiation. Nonetheless, the risks must be minimised by the application of radiation safety standards.
Medical physicists in radiology should 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 radiology 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 medical exposures. They will apply the ALARA and dose limitation principles in the design of radiology facilities and imaging protocols.

Competences and skills:

- Apply general principles of radiation protection and risk management
- Implement radiation protection principles and risk management in radiology
- Assess the effectiveness of radiation protection measures
- Apply the concept of justification to medical exposures
- Optimise medical exposures in radiology
- Assessment of radiation effects on humans in general, and on children and the fetus in particular
- Implement the concept of diagnostic reference levels in radiology
- Verify that radiation protection and risk management is in compliance with guidelines, directives, and legislation (including dose limits where applicable)
- Perform radiation surveys of areas by using models and dose measurements
- Perform shielding calculations for planned or modified X-ray rooms (radiography; mammography; CT; fluoroscopy; operation rooms; and emergency rooms)
- Design and perform suitable experiments to check shielding calculations
- Supervise occupational dosimetry and the use of personal dosimeters
- Optimise radiation protection in high dose or high risk practices (Interventional radiology; CT; Health screening programmes; Irradiation of children, neonates or the fetus; Genetic predisposition for detrimental radiation effects)
- Conduct critical examinations (interlocks, warning systems, safety design features and barriers)
- Advise on personal protective equipment, including protective garments, and fixed and mobile shielding devices
- Demonstrate familiarity with ethical aspects of biomedical research with regard to aspects of radiation protection of patients and volunteers in biomedical research

Core curriculum items

- Scientific basis of radiation protection
- Quantities and units in radiation protection
- Basic principles of dose limitation

- Justification, optimisation, and the ALARA principle
- Dose limits (workers, population)
- International and national recommendations standards and regulations
- Safety design of medical X-ray installations
- Radiation effects in radiology on the embryo and foetus, leukaemogenesis and carcinogenesis, genetic and somatic hazards for exposed individuals and populations;
- Genetic risk factors
- Radiation monitoring
- Classification of areas
- Personal dose monitoring
- Administration and organisation of radiation protection. National and international rules and organisations
- Management of radiation safety, including hazard assessment, contingency plans;
- Accidents in radiology, actions to take in the event of a radiation accident
- Responsibilities and duties of all workers that are involved in radiation protection
- Occupational exposure and occupational dosimetry quantities and methods
- Medical exposure and patient dosimetry quantities and methods
- Diagnostic reference levels
- Operational parameters affecting patient dose and image quality
- Public exposure
- High entrance skin dose applications
- Potential exposure and emergency plans
- Shielding calculations and assessment of shielding (general radiology, CT, fluoroscopy, interventional radiology, mammography)
- Optimization of radiation protection (patients, staff and general public) by optimisation of practices, procedures and acquisition protocols

16. Diagnostic image display and image processing

Short description

For the purpose of image reading and image review, the medical images are predominantly displayed on monitors. The systems for image reading, and the image reading itself, are often integrated in the radiology and hospital information and communication technology (ICT) systems. The quality and quality control of these monitors is essential for ensuring good performance of a radiology department. The medical physicist in radiology should be able to advise on the application of clinical images, both for visualization and quantification purposes.

Competences and skills

- Give advise on the selection of a system for image display and image processing
- Discuss different types of processing of clinical images
- Ablity to explain methods of image processing on clinical images
- Ablity to distinguish between different applications of image display systems
- Ablity to coordinate the acceptance and constancy testing of image display systems

Core curriculum items

- Knowledge of the hardware for image display and image processing
- Knowledge of the software for image display and image processing
- Requirements for image display and image processing systems for different clinical applications
- Measurement of the performance of image displays
- Integration of systems for image display and image processing
- Clinical applications of image processing
- Acceptance and constancy tests of diagnostic image display systems

IV RESEARCH PROJECT

Short description

The medical physicist plays a key role in the development and advancement of the field of radiology and in strengthening of the research activities in the medical physics community. To prepare the medical physicist for this responsibility, one or more short, focused research projects 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). Such projects will also result in the trainee acquiring advanced competencies for from different parts of the syllabus.

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

The project should result in a written report, ideally in the form of a manuscript suitable for submission to a medical physics or radiology journal. Alternatively, it could result in one or more shorter reports, based on specific problems arising in the trainee's department.

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