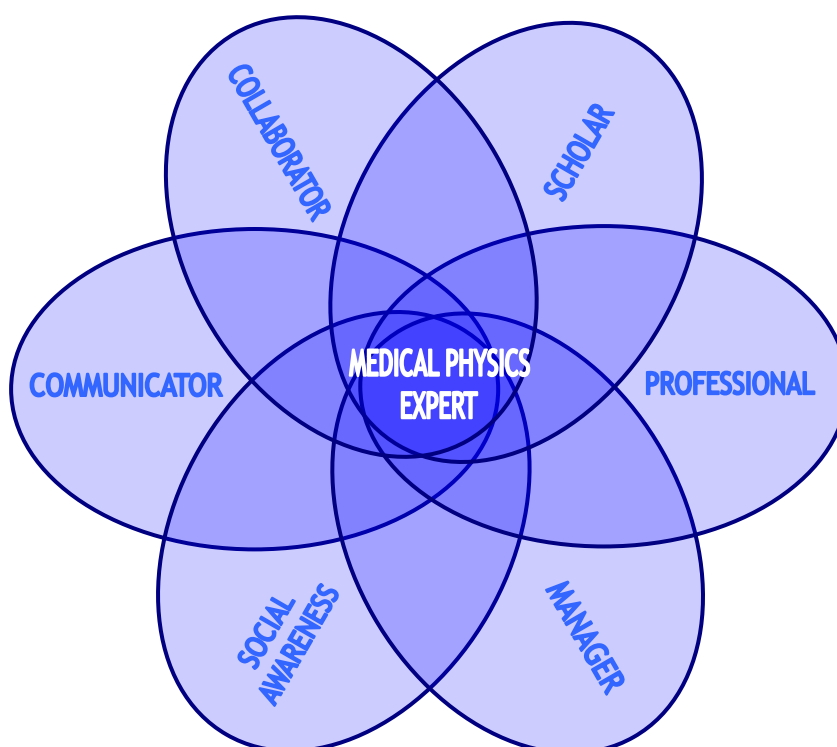# CORE CURRICULUM FOR MEDICAL PHYSICISTS

VOLUME 2 –RADIOLOGY AND NUCLEAR MEDICINE

Version 2.2
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1. Imaging Modalities

1.1.   General

Short description:
The medical physicist (MP) in radiology andnuclear medicine is reponsible for safe and effective operation of imaging equipment, is capable of optimizing image quality in relation to radiation dose, acquisition time and acquisiton parameters, has knowledge of state-of-the-art techniques, and is proactive in giving advise about new posibilities to the imaging department. In addition, the MP plays and important role in training, education, and research. All lifecycle phases of an imaging modality should be fully understood: selection, room design, acceptance, calibration, safety & quality assurance, optimization, and decommissioning.

Competences:
* understanding and applying the physics and principles of the whole 'imaging chain' for all modalities, that includes acquisition, reconstruction, processing, displaying and post-processing.
* understanding the hardware and software design of the imaging equipment
* understanding principles of projectionimaging
* understanding principles of tomographic imaging
* understanding clinical application of imaging modalities and its role in the patientcare
* understanding clinical decision making
* ability have technical discussions with engineers (e.g., concerning recalibration or replacement of parts);
* ability to perform all aspects of the introduction of new imaging equipment, i.e. able to:
    o advise ina business case
    o advise in a tender, write a technical program of demand
    o specify, justify and rank the criteria for specifying and selecting new imaging devices
    o negotiate with vendors
    o room design for imaging modality, taking into account shielding and technical considerations including power supply, safety and climat control demands
* ability to make risk analysis for use and operation of equipment
* ablity to translate technical specifications to clinical specifications and visa versa.
* ability to perform acceptance testing, commissioning and quality control of imaging equipment
* ability to operate imaging equipment safely for QA and QC purposes
* ability to optimize for image quality and radiation dose
* ability to understand and discuss the engineering and maintenance of the imaging equipment
* ability to interpret and recognize artefacts in images, and advise on the clinical impact and risks and how to avopid them.
* Ability to design, perform and supervise a QA and QC-program.
* ability to support clinical research and multicenter trials
* ability to communicate adequately with physicians, end users, technicians, radiographers and vendors

Core curriculum items:
* Ability to operate image acquisition systems
* Knowledge of:
    o Principles of interaction between radiation/waves and matter/tissue.
    o X-ray tubes
    o Photon detectors, coilsand transducers used in medical imaging;
    o Signal processing and data acquisition techniques (hard and software)
    o Image reconstruction algorithms
    o Effect of imaging parameters on image quality, dose and acquisition time

- o Revelant laws, reports and guidelines
- o protocols and phantoms for quality control
- Ability to participate in:
  - o Purchase and installation of new equipment
  - o A tender for imaging equipment
  - o The building design process for new imaging equipment
  - o Artifact identifcation and solving
  - o Image protocol optimization
  - o Measurement of image quality (homogeneity, contrast, detail, MTF, DQE, SNR, CNR, NPS etc)

Time to be spent on this topic: ≥ 3ECT

1.1.1. Computed Tomography

Competences:
- Global understanding of hardware and software design of CT scanners.
- Ability to assess and monitor diagnostic reference levels
- Ability to optimize patient protocols with respect to image quality and patient dose
- Ability to create a safe working environment including for CT guide punctions and biopsies.
- Global knowlegde of clinical application of CT

Core curriculum Items:
- CT detector technology
- CT system architecture
- Acquisition techniques: helical, axial, triggered, gated, dynamic
- Cone beam CT, flat panel CT
- Reconstruction algorithms: FBP, variousIterative reconstruction techniques
- Influence of reconstruction algorithms on (diagnostic) image quality
- Dose parameters: DLP, CTDI
- Dose reduction techniques
- Dual energy and spectral CT
- Functional CT
- Dual source CT, high pitch CT, volume CT
- Quality criteria
- CT-cardiology (calcium score, coronary angiography, rest and stress myocardial imaging, cardiac function)
- CT-colonoscopy
- CT-intervention
- CT-perfusion and -substraction.
- 3D-postprocessingtechniques (VRT, MIP, MPR)
- CT guided punctions
- Short clinical internship at the CT; acquisition and reporting
- Principles and use of contrast agents
- Relation between tube voltage, tube current, contrast and noise

Time to be spent on this topic: ≥ 3 ECTS

1.1.2. Magnetic Resonance Imaging

Competences:
- Understanding of the physics of MRI signal transmission and reception

- Have an overview and understanding of acquisition parameters and their effect on the MR image
- Ability to design and validate an MRI-room, including magnetic field containment and Faraday cage
- Ability to advise on optimal acquisition and reconstruction settings for a specific diagnostic task
- Ability to design and supervise a MR safe working environment
- Ability to judge MR safety for patient contraindications and third company devices brought into the MR suite.
- Ability to advise on MR physics aspects in building an MR suite.
- Be at the level of the MR safety expert
- Global knowlegde of clinical application of MRI

Core curriculum Items:
- Contrast effects by: T1, T2, T2*, PD ,DWI, velocity, flow,susceptibility and diffusion
- Thorough knowledge of the principles, techniques and applications of MRI
- Magnet and gradient systems
- RF-coils
- Acquisition methods and techniques
- Principle of k-space and k-space sampling
- Reconstruction methods
- Factors of influence on SNR
- Safety aspects of MRI: heating, perpheral nerve stimulation and protectiles.
- Quality control
- Advanced MRI applications, including MR angiography, functional MRI, diffusion MRI, MR spectroscopy, Dynamic Contrast Enhancement,(ASL) and diffusion tensor imaging.
- Parallel imaging
- Influence of magnetic field on image quality and SNR
- Potential interaction aspects of MRI: EM interference (due to not 100% closed Faraday cage, mechanical vibrations, influence of magnetic field on medical devices (pacemakers),
- Buiding considerations for MRI systems
- Short clinical internship at the MRI; acquisition and reporting
- Principles of RF transmission and reception
- Surface, volume, quadrature, phased array and parallel imaging coils
- Safety aspects of MRI regarding workers, patients (e.g. implants and devices) and environment (e.g. housing)
- Principles, classification, safety/risks and use of MR contrast agents

Time to be spent on this topic: ≥ 6 ECTS

1.1.3. Positron Emission Tomography (PET/CT and PET/MRI)

Competences:
- Understanding the hardware and software design of PET system
- Knowledge on positron emitters, electron capture, beta and beta+ decay
- Knowledge about PET tracers
- Ability to perform acceptance testing, set up quality control, and optimize scanning protocols.
- Understanding of specific PET image reconstruction algorithms.
- Ability to make shielding calculations and design for PET-facilities
- Knowledge about the clinical indications and protocols for PET: oncology, cardiac, neurology, radiotherapy.
- Understanding quantification and image analysis

- Ability to interpret image artifacts
- Knowledge about and able to recognize image artefacts and scanner malfunctions, and take appropriate action.
- Understand the hardware and software and the specific challenges for different designs of PET/MR systems
- Knowlegde of PET detectors for MR environment
- Understand the specific application, indications, benefits and pitfalls of PET/MR imaging
- Knowledge of PET-tracer modeling.

Core curriculum Items:
- Hardware and software architecture of PET system
- Quality testing and assurance guidelines:
    - PET: NEMA-NU2, NEMA-NU4, Aanbevelingen Nucleaire Geneeskunde
    - CT: Impact, Catphan, CTDI, Guidelines of NVKF
- Data acquisition: Noise Equivalent Countrate, List mode, sinogram mode.
- Corrections and pre processing: geometry correction, normalization, attenuation correction, scatter correction, random correction, dead time correction, decay correction.
- Image reconstruction: FBP, iterative methods (ML-EM), LOR-reconstruction, Time-of-Flight, Point Spread Function.
- Quantification in PET: SUVs, Patlak analysis, input function, tumortracking software.
- Quantitative PET
- Respiratorygating techniques
- Monte Carlo simulations
- Calculation of PET-radiopharmaceutical models.
- Short clinical internship at the PET;acquisition and reporting
- System designs PET/MR: Split, split bore, fully integrated
- PET detectors in PET/MR: APD, SiPM
- Attenuation correction methods for PET/MR

Time to be spent on this topic: ≥ 3 ECTS

1.1.4. Gamma camera: planar and SPECT/CT

Competences:
- Understand the hardware and software design of the gamma camera
- Have thorough knowledge of single emission tracers
- Have overview and understanding of the whole range of acquisition protocols available
- Understand the processing techniques of planar nuclear imaging
- Understand the reconstruction techniques applied for SPECT
- Understand quantification methods in planar and SPECT imaging
- Able to operate scanner and processing software
- Understand the added value of the CT
- Global knowlegde of clinical application of gamma cameras

Core curriculum Items:
- Hard and software architecture of gamma camera
- Coregistration, attenuation correction, scatter correction
- Short clinical internship SPECT; acquisition and reporting

Time to be spent on this topic: ≥3ECTS

1.1.5. Radiography, conventional and chest

Competences:
- Thorough knowledge of conventional and chest x-ray imaging, system design, the components in the imaging chain, and the different parameters which influence the image quality
- Understand the specific application, indications, benefits and pitfalls of radiography imaging
- Ability to interpret and avoid image artifacts
- Global knowlegde of clinical application of conventional radiography

Core curriculum Items:
- X-ray tube
- X-ray spectra
- Iteraction of x-rays with tissue: Compton, Rayleigh and photoelectric effect
- Heel effect
- Projections, image magnification
- Scatter and scatter rejection
- Conventional radiography
- Chest radiography
- Different type of detectors and their specifications
- Understand differences between conventional, mammography, chest radiography
- To be able to define, based on clinical question, the required diagnostic image quality and patient dose
- Radiation safety and shielding
- Short clinical internship Bucky, Trauma, Thorax; acquisition and reporting

Time to be spent on this topic: ≥ 3 ECTS

1.1.6. Mammography

Competences:
- Thorough knowledge of x-ray imaging techniques is required in order to fully understand the imaging of the breast with different, low-energy x-ray spectra and optimal use of high image quality
- Global knowlegde of clinical application of Mammography

Core curriculum Items:
- Conventional and digital mammography
- Digital tomosynthesis
- Contrast enhanced mammography
- Stereotactic punction
- Quality control (protocols, LRCB, Euref)
- Breast cancer screening
- Dose assessment
- Diagnostic reference levels
- Influence of breast density on image quality
- Short clinical internship at the Mammography; acquisition and reporting
- Positron emission mammography (PEM)
- MR mammography
- CT mammography
- Ultrasound breast imaging

Time to be spent on this topic: ≥ 3 ECTS

1.1.7. Fluoroscopy

Competences:
- Thorough knowledge of fluoroscopy imaging, system design, the components in the imaging chain, and the different parameters which influence the image quality
- Understand the specific application, indications, benefits and pitfalls of fluorscopy imaging
- Knowledge about the different fluorscopy suites, their specific demands and advantages
- Knowledge about different fluoroscopy configurations (floor, ceiling mounted, mobile, bi-plane C-arms)
- Knowlegde on the different operation modes of fluoroscopy and its software applications
- Global knowlegde of clinical application of fluoroscopy

Core curriculum Items:
- Fluoroscopic image chain components
- Fluoroscopic detector systems, that is::
  - Image intensifiers
  - Flat panel fluoroscopy
- CT fluoroscopy
- MR-fluoroscopy.
- Different modes of operation (continuous, pulsed, averaging, last frame hold, road mapping, CT-mode)
- Image quality aspects (spatial and temporal resolution, image contrast)
- To be able to define, based on clinical question, the required diagnostic image quality and patient dose
- Geometric distortion
- Digital Subtraction Angiography
- 3D (angiographic) imaging
- Short clinical internship at the lab; acquisition and interventions
- Different labs: genitourinary, geniurinary, peripherical vascular and cardiac angiography, cardiac electrophysiology, neurovascular imaging and interventions

Time to be spent on this topic: ≥ 3 ECTS

1.1.8. Ultrasound

Competences:
- Thorough knowledge of principle, working mechanism and application of ultrasound
- Ability to interpret image artifacts
- Ability to perform QA and QC
- Global knowlegde of clinical application of ultrasound

Core curriculum Items:
- Ultrasound system architecture
- Transducer techniques and systems
- Doppler, color Doppler
- Quality control
- (Differential) harmonic imaging
- Contrast agents
- IVUS

- Applications and specific demands
- 3D ultrasound
- Short clinical internship at the echo; acquisition and reporting

Time to be spent on this topic: ≥ 3ECTS

1.1.9. Bone densitometry

Competences:
- An understanding of the theory and operation of DXA equipment and the
- Importance of QC and calibration in the accurate use of normal ranges
- Ability to perform QA and QC.
- Understanding of other techniques for bone density estimation: quantitative CT
- Global knowlegde of clinical application of bone densitometry
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Core curriculum Items:
- Dual energy x-ray absorptiometry principles.
- Bone mineral densitometry concepts
- DXA equipment components
- Basic introduction to osteoporosis, bone physiology and risk factors
- Scan acquisition modes
- Phantom calibration
- Normal range, precision and reproducibility
- Procedures for AP Spine, Femur/Dual Femur, Total Body, Forearm and LVA/Lateral spine.
- Quantitative CT for bone densitometry.

Time to be spent on this topic: ≥ 0.5ECTS

1.2. *Image reconstruction and postprocessing*

Competences:
- Understanding principles and methodologies of image reconstruction, pre and post processing.
- Knowledge of mathematical algorithms used tomographic image reconstruction.
- Able to advise on optimization of reconstruction and post-processing parameters
- Able to recognize and advise on artefacts created by image reconstructions algorithms
- General knowledge of Computer Aided Diagnoses (CAD).
- Able to perform software validation (image processing) to understand the underlying principles of image processing techniques applied to medical images and be able to write and test the image processing routines in interactive programming environment and effectively apply them to selected clinical problems.

Core curriculum Items:
- Image pre and postprocessing
  - Spatial domain and frequency domain
  - Filters for noise and contrast improvement; principles and presentation in both image domains
- Algorithms for image reconstruction and linear-system and non-linear-system theory for imaging technologies
  - Fast Fourier Transform
  - Filtered Back Projection

- - Central slice theorem
  - Iterative reconstruction (2D and 3D)
    - Maximum likelihood (MLEM)
    - OSEM
    - Bayesian
    - Model based
  - Transfer Functions, like MTF, PSF
  - Pre- and Postprocessing in CR and DR
- Quantification of biomarkers
  - Determination of stenose grade by angiography, ultrasound and CT
  - Cardiac function by ultrasound, DSA, cardio angiography, cardio CT and MRA
  - Dynamic contrast enhancement by MRI, CT and ultrasound
- Computer Aided Diagnosis
  - Mammography
  - Lung cancer
  - Colonoscopy
- Postprocessing techniques
  - Multi Planar Reformats
  - Maximum Intensity Projection
  - Volume en surface rendering
  - Virtual endoscopy

Time to be spent on this topic: ≥ 3 ECTS

1.3.   Quality assurance

Short description:

The imaging modalities that use x-ray, radionuclides, MRI and ultrasound are categorized as high risk medical equipment because of the potential direct physical risks (mechanical, radiation, heating) for patients and employees andthe risks of incorrect diagnosis in case of malfunctions and artefacts. Therefore it is important to implement, maintain and (to) perform a quality assurance program.The medical physicist Radiology and Nuclear Medicine plays a central role as a specialist in this field.

Competences:
- Ability to set up quality assurance program for the whole imaging department
- Ability to communicate adequately with technicians, technologists and physicians on quality assurance and maintanance, and to supervise qualty control control testing.
- Ability to make correct decisions of clinical relevance of artefacts and surpassed quality criteria.

Core curriculum Items:
- Optimization of patient safety, quality and cost
- Calibration and use of equipment and phantoms
- Knowledge of relevant legislation in the field of quality in general:
  - Good LabatoryPractice (GLP),ISO certification, Quality Act, Nuclear Energy Act
- Knowledge of specific procedures and protocols in the field of acceptance, and status tests (IEC, AAPM, IPEM, QC Light, WAD protocols)
- DRN
- Setting up and monitoring of QC and QA-program
- Perform acceptance testing of a large image modality

Time to be spent on this topic: ≥ 3 ECTS

1.4.   Other equipment

Numereous medical devices are involved inthe workflow of the departments of radiology and nuclear medicine. The medical physicist should have enough knowledge and skills to take responsibility for the save utilization of these devices.

Competences:

- Global knowledge of the system designs
- Understand the specific application, benefits and pitfalls
- Able to set up a quality assurance program
- Global knowledge on how to operate theequipment.

Core curriculum Items:

- Contrast Injectors (DSA, CT, MR).
- Monitoring: ECG, heart rate (triggering CT, MR, SPECT), respiration, apnea, (non) invasive blood pressure, cardiac output, capnography, O2-CO2 saturation (eg sedation and anesthesia by MR imaging), temperature monitoring (MR), arrhythmia and telemetry (MR)
- Gamma probes
- Dose calibrator

Time to be spent on this topic: ≥ 0.5 ECTS

2. Medical fundamentals of diagnostics and treatment

Short description:
In order to effectively communicate and operate within a multi-disciplinary team a basic understanding of the medical fundamentals of human physiology and pathology in relation to diagnostics and treatment in the department of radiology or nuclear medicine is required.Therefore the medical physicist should be able to recognize basic anatomy, physiology and pathology in images created on a radiologic or nuclear imaging modality. A basal understanding of the pathologies which can be diagnosed and treated in the departments of radiology or nuclear medicine should be acquired, but also a general understanding of other treatment options of pathologies which can be detected on radiologic or nuclear images.

This knowledge enables better application of the medical physicist's function in contemporary radiology and nuclear medicine.

Competences:
- Ability to communicate effectively with the medical staff and exchange of relevant patient information
- Understanding the questions and challenges facing medical staff and able to translate those questions in medical physical terms
- Demonstrate a basic understanding of anatomy, physiology and the development of different pathologies in oncology, cardiology, neurology and orthopaedics
- Demonstrate knowledge of the various treatment options

Core curriculum items:
- Joining the patient discussions in which nuclear physicians and radiologists participate
- Observing physicians while making their diagnosis
- Neurology
- Cardiology
- Orthopaedics
- Surgery
- Oncology
    - Carcinogenesis and angiogenesis
    - Major signalling pathways of importance for response to radiation
    - Principles of diagostics and staging of cancer
    - Principles of surgical, medicaland radiation oncology.
- Medical aspects
    - Fundamentals of anatomy and physiology
    - Orientation, planes and directions
    - Anatomy at the biochemical, cellular and tissue level
    - Nervous system
    - Blood and the cardiovascular system
    - Lymphatic system and Immunity
    - Respiratory system
    - Hepatobiliary system
    - Digestive system
    - Kidneys and urinary tract
    - Reproductive system and embryological development
    - Endocrine system
    - Immune system
    - Musculo-skeletal system and the skin
- Further fundamentals of physiology
    - Metabolic function
    - Sensory function

- Neurophysiology and cerebral function
- Regulation of fluids, electrolytes and temperature
- Fundamentals of pathology
- Normal tissue and cell function
- Infectious processes and disorders of the immune system
- Oncogenesis
- Fundamentals of radiobiology
  - Cell cycle
  - Genes and mutations
  - Biochemical damage and radiosensitivity; radioprotectors
  - Cell survival curves
  - Dose rate response
  - Acute radiation sickness
  - Chronic radiation effect
  - Radiation-induced cancers
  - Radiation-embryology
  - Justification

Time to be spent on this topic: ≥3 ECTS

3. Isotopes, tracers and the radionuclide laboratory

Short description:
At the basis of molecular imaging lie the radiolabeled molecules that mark a specific physiological process of the body. The medical physicist should be an expert in the physical properties of the different radioactive isotopes and tracer-molecules affecting imaging, the dosimetry and the possibilities for quantification.
Knowledge of production and synthesis of tracers is also a necessity. In addition the medical physicist should be an expert in the design, work processes and regulations surrounding radionuclide laboraties.

Competences:
- Understanding isotope production in nuclear reactors and cyclotrons
- Have knowledge about the synthesis of tracers
- Ability to design a hotlab
- Have knowledge about all regulatory laws and guidelines applicable to production and handling of radioactive tracers in the hospital.
- Have extensive knowledge about the different gamma- and positron emitting tracers:
    - Understanding PET-tracer pharmacokinetic and pharmacodynamics modelling
    - Understanding the properties and applications of the different tracers

Core curriculum items:
- Overview of cyclotron principles, configurations and operation
- Production of positron emitters (F-18 targetry, C-11, O-15, N-13, Ga-68, Rb-82, Cu-61/62/64)
- Synthesis of tracers (+ quality control)
- Physiological and molecular mechanisms describing tracer biodistribution.
- Pharmacokinetic and pharmacodynamic modelling
- Dose calibrators: quality control, calibration
- Concepts of vascular input function and blood sampling

Time to be spent on this topic: ≥ 6 ECTS

4. Dosimetry and detection

Short description:
The medical physicist in radiology and nuclear medicine should be an authority on dosimetry of personnel and patients, be familiar with the different measurement systems of software tools that are available for dosimetry and quality control, have a critical understanding of their advantages and limitations to be able to select the most appropriate system for each dosimetric problem. This appreciation should include acceptance testing, calibration and quality control of these measurement systems as well as estimation of the (statistical) uncertainty of measurements.

Competences:
- Demonstrate a working knowledge of the terminology;
- Demonstrate a good understanding of the fundamental theoretical and practical aspects of all dosimetry.
- Understand physics, techniques and instrumentation of radiation detector systems
- Demonstrate knowledge of dosimetric standards;
- Ability to understand and apply the relevant national or international Codes of Practice
- Ability to select the most appropriate detector to use to measure absolute dose and relative dose distributions in different irradiation conditions;
- Ability to set up a program for acceptance testing, calibration and quality control of the measurement systems.
- Ability to estimate measurement uncertainties and their categories;
- Understand and be able to apply principles of patient dosimetry with radiological x-ray sources
- Understand and be able to apply principles of patient internal dosimetry with radioactive tracers (MIRD)
- Understand and be able to apply principles of dosimetry for workers
- Ability to use software tools to calculate patient dose for both external x-ray sources and internal and external radioactive tracers.

Core curriculum items:
- Principles of dosimetry
- Concept of absorbed dose and kerma
- The cavity theory
- MIRD
- Different detectors and detection techniques: pulse mode , scinitillation, germanium detectors, ionisation chamber, Geiger-Muller, liquid scintillation counters, thermoluminescence dosemeters.
- Calibration chain for dosimetry detectors;
- Dosimetric standards and traceability;

Time to be spent on this topic: ≥3 ECTS

5. Therapy

Short description:
Therapy is increasingly becoming an important part of the departments of radiology and nuclear medicine. In nuclear medicine radioactive isotopes and tracers are used to target specific regions, organs or cells in the body. These radiopharmacons are used for curing diseases and for palliative therapy. The medical physicist must have a full understanding of the techniques and equipment that are being used and be able to calculate the patient dose.
Increasingly, ablation techniques are used that are not based on ionizing radiation. Examples of such techniques are High-Intensity Focused Ultrasound (HIFU), Radio Frequency Ablation (RFA) and Photo-Dynamic Therapy (PDT). These ablative treatments are used to achieve optimal coverage of the tumor, while minimizing involvement of surrounding tissue. Image guidance, target definition and dose monitoring are common features of all techniques. An understanding of the relation between tumor cell kill and the probability of achieving local control is essential.

Competences:
- Extensive knowledge about the principles, methodology, techniques and different radionuclides used in radionuclide therapy
- Understanding the principles and practical implications of MR-HIFU.
- Understand the use of image information in therapeutic treatment planning by other departments.
- Understand the relation between tumour cell kill and the probability of achieving local control.

Core curriculum items:
- Radionuclide therapy:
    - Radiopharmaceuticals uptake and retention
    - Uptake measurements
    - Calculation of therapeutic dose
    - Radiation safety: patients and employees
    - Relevant legislation and guidelines
- Interventional radiology / cardiology
    - Stenting
    - PCI
- Internship departments of radiotherapy and surgery
- Use of image information for therapeutic treatment planning
    - Neuronavigation
    - Stereotactic neurosurgery
    - Radiotherapeutic treatment planning
    - 3D presentation for surgery
    - Radio Frequency Ablation (RFA)
    - Photo-Dynamic Therapy (PDT).

Time to be spent on this topic: ≥6 ECTS

6.   Diagnostic monitors

Short description:
The 'imaging chain' starts with data acquisition and ends with displaying the image on a diagnostic monitor and the image perception of the observer. This crucial final step needs also to be fully understood by the medical physicist.

Competences:
- Understanding the factors influencing the visual perception of an image on a medical display.
- Understanding technical components of display influencing image quality, calibration, gray- and color-scaling.
- Able to make recommendations concerning selection of displays during puchasing proces.
- Able to make recommendations for optimal setting of Lmin and Lmax.
- Able to perform quality control measurements and calibrations.
- Able to make recommendations regarding optimal setting of viewing conditions.
- Able to make specific recommendations for images of different modalities (MRI, CT, Mammography, PET, etc)
- Able to setup quality control program for diagnostic displays
- Able to recognize and act in case of suboptimal performance, malfunction or artefacts on diagnostic displays

Core curriculum items:
- Storage of image in digital archive (Dicom, PACS)
- Differences between images and display criteria of different modalities (MRI, CT etc).
- Characteristics of images: compression, post processing, matrix- and pixel- size, bit depth.
- Display calibration
- Test patterns used for display testing and calibration
- Physiology of perception: working of eye (anatomic and functional) and cognitive processing:
  - Contrast sensitivity- spatial resolution-temporal resolution

- - - Dynamic range
- Gray scale display
    - Different types: LCD, LED, TFT
    - Pixel-, matrix- , screen- size of image and monitor: influence on noise and resolution in image.
    - Maximal and minimal luminance
    - Lmax, Lmin
    - Calibration (GSDF)
- Color scale display
    - Influence of GSDF calibration color display
    - Color calibration: influence on gray scale display
    - Measuring of color display (color temperature)
- Video card and GPU
    - Conversion of stored digital images to display on monitor
- Quality control protocols: QClight, WAD-protocols etc.
- Viewing conditions
    - Ambient light
    - Viewing angle and distance
    - Contrast display-background
    - Influence of viewing conditions of luminance settings/calibrations
    - Heat dissipation
    - Sterile environment (OR)

Time to be spent on this topic: ≥2 ECTS

7. Clinical IT

Digital image communication, storage and distribution is increasingly relevant for the medical physicist. Images need to be transferred stored and accessed, but also connected with an patient individual electronic health record (the 'EPD': Electronic Patient Dossier)

Competences:
- Understanding the digitization proces and workflow within imaging departments
- Understanding architecture of different types of IT networks.
- Understand design of picture archive databases, including redundancy and data security.
- Having general knowlegde about short- and long-term image storage (capacity): hardware and software.
- Understanding data-compression techniques (lossless and lossy) and their potential image degradation effects.
- Understand different types of program/script languages, standards and protocols.
- Understanding of DICOM:
  - interpret and manipulate DICOM headerinformation
  - basis of DICOM communication
  - interpret DICOM conformance statements
- Basic knowledge of Hospital Information Systems
- Knowledge of the 'Integrating the Healthcase Enterprise' (IHE):
  - Knowledge of basic IHE terminology.
  - Specific knowledge of integration profiles for Radiology domain.
  - Knowledge where IHE standard workflow fits in between communication standards like DICOM and HL7.
- Knowledge of teleradiology and cross enterprise document sharing (IHE-XDS).
- Able to advise during purchase proces of new PACS.
- Able to test DICOM functionality during system acceptance,

Core curriculum items:

- HIS/RIS/PACS
- Dicom:
  - header information, nodes, AE-title, storage class user (SCU, Storage class provider (SCP),
  - DICOM worklist
  - DICOM Service classes: DICOM echo, Storage, Query / retrieve, MPPS, Storage commitment.
  - DICOM display (GSDF)
  - DICOM conformance statements
- HL7.
- IT and data security
- Data storage: NAS, SAN, databases
- IHE:Domains, technical framework, integration profiles, actors and transactions.
- Teleradiology and cross enterprise document sharing (IHE-XDS).
- Software validation: dedicated workstations, server-client, different combinations of modalities and processing software.
- Image processing/ analysis

Time to be spent on this topic: ≥ 3 ECTS

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

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	Minimal ECTS	Total ECTS
FUNDAMENTAL KNOWLEDGE, SKILLS AND COMPETENCES (VOL I)		90
RESEARCH PROJECT		60
KNOWLEDGE, SKILLS AND COMPETENCES, RADIOLOGY AND NUCLEAR MEDICINE (VOL II)	60	90
Imaging modalities	37	
General	3	
CT	3	
MRI	6	
PET	3	
Gamma camera	3	
Radiography	3	
Mammography	3	
Fluoroscopy	3	
Ultrasound	3	
Bone densitometry	0,5	
Image reconstruction and post processing	3	
Quality Assurance	3	
Other equipment	0,5	
Others	23	
Medical fundamentals of diagnostics and treatment	3	
Isotopes, tracers and the radionuclide laboratory	6	
Dosimetry	3	
Therapy	6	
Medical Monitors	2	
Clinical IT	3	
Total over 4 years		240