HAMP (Hellenic Association in Medical Physics) Education Committee: Makridou Anna, Efstathopoulos Stathis, Malatara Georgia

Syllabus Group:

Malatara Georgia, Skouras Theodoros, Papatheodorou Spyridon

Translation from original:

Georgios Krokos

CLINICAL TRAINING OF MEDICAL PHYSICISTS – RADIATION PHYSICISTS IN PUBLIC HOSPITALS

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EFOMP ESTRO: CORE CURRICULUM FOR MEDICAL PHYSICISTS IN ADIOTHERAPY

16 February 2011

Introduction

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Objective

The objective of this document is to outline the minimum requirements for the education of Greek Medical Physicists in order to make the clinical training comparable across all authorised hospitals. The minimum clinical experience required by the candidate in order to be considered capable to act independently and the minimum qualifications required by the candidate in order to be characterised as specialised Radiation Physicist after the successful participation in the national exams for the acquisition of the professional license of Medical Physics - Radiation Physics.

The final recommendations are the result of consultations between the trainee Medical Physicists and their line-managers who are registered Medical Physicist - Radiation Physicists and bear the responsibility for the training.

Minimum available facilities for a hospital to be considered appropriate for clinical training:

- It must employ experienced Medical Physicist.
- It must have a radiotherapy, radiology and nuclear medicine department
- It must have appropriate equipment for measuring dosimetry in each department.
- It must have appropriate library with manuals and regulations for the specific department.

The role of the supervisor Medical Physicist

The supervisor of the trainee must be the principal medical physicist of each department. The supervisor must be experienced, specialised in the field of work of the relevant department and employed by the same Hospital. The supervisor is the link between the trainee and the other specialists in the departments. The supervisor has a pivotal role in ensuring the successful clinical training of the Trainee.

Namely:

- The supervisor is responsible for making the trainee familiar with the technological equipment of the department, encourages the trainee to use the equipment under his supervision until the trainee is deemed capable to work independently.
- The supervisor is responsible for organising and supervising the practical studies (description of the study, provision of protocols, forms, etc.) which must be completed by the trainee during the clinical training.
    - 4 in Nuclear Medicine
    - 4 in Clinical Radiology
    - 6 in Radiotherapy
    - 3 Studies in Radiation Protection (one in each sub-department)
    - 1 Practical in dealing with emergencies

The topic of the study will be chosen by the supervisors based on the available equipment in the hospital.

The role of the Trainee

- To comply with the timetable of each department and participate in all activities (quality assurance checks etc) that might also take place outside the scheduled timetable of the department.
- The trainee is obliged to deliver comprehensive reports of the practical studies. Such reports will be also kept electronically in the department. The reports will be evaluated in terms of quality and completeness.

In general, the collaboration between supervisor and trainee could be outlined as follows:

Step 1: The trainee must attend and observe multiple times a new procedure.

Step 2: The trainee studies the literature of the relevant procedure.

Step 3: The trainee performs the procedure under the supervision of the supervisor.

Step 4: The supervisor evaluates the trainee for the relevant procedure.

Step 5: The trainee performs the procedure unsupervised and the result of his work is evaluated.

Step 6: The trainee performs the procedure unsupervised as part of the clinical practice routine.

CLINICAL TRAINING OF MEDICAL PHYSICISTS IN RADIOTHERAPY

The fundamental theoretical background knowledge in the field has been acquired by the trainee during the postgraduate studying programme in Medical Physics. Additional skills must be developed by the trainee during the clinical training. By the end of the clinical training the trainee medical physicist must have developed at least the following knowledge/skills in the field of **Radiotherapy**:

- **Principles of interaction of photons and electrons with matter**
    - Photon interaction: photoelectric effect, Compton scattering, pair production etc.
    - Electron interaction: elastic and inelastic interactions. Breaking radiation etc.
    - Correlation of the above interactions in Radiotherapy (radiation detection, therapy, radiation protection etc.).
- **Physical properties of radioisotopes**
    - Principles of exponential decay of radioisotopes. Properties and characteristics of radiation emitted from radioisotopes.
    - Half-life and how to measure it.
    - Estimation of current radioisotope activity when its initial activity is given.
    - Energy sources (radioisotopes) currently used in radiotherapy and their physical properties.
- **Functional characteristics of equipment used in radiotherapy**
    - Physical characteristics and technological aspects of electron linear accelerators.
    - Physical characteristics and technological aspects of Cobalt units.
    - Physical characteristics and technological aspects of conventional radiotherapy simulators.
    - Physical characteristics and technological aspects of computer-tomography simulation for radiation therapy (CT-SIM).

- Characteristics and technological aspects of treatment planning systems (TPS).
- Characteristics and technological aspects of transmission systems, recording, verification and saving of radiotherapy data and patient images (Record and verify, PACS).

- **Commissioning and acceptance of radiotherapy equipment:**
  - Room design and shielding calculation according to the existing legislation.
  - Acceptance checks and study of radiation protection and safe operation during the acceptance of radiotherapeutic equipment.
    - Checking of mechanical parameters.
    - Quality assurance of beam.
    - Checking of safe operation.
    - Estimation of dosimetric parameters for the treatment planning system.
- **Quality Assurance**
  - Protocols for quality assurance (daily, weekly, monthly and annually) for the following equipment:
    - Electron linear accelerators.
    - Cobalt units.
    - Conventional Therapy Simulator.
    - Computer Tomography based Therapy simulator (CT-SIM).
  - Quality assurance of treatment planning systems (TPS).
  - Quality assurance of transmission systems, recording, verification and saving of radiotherapy data and patient images (Record and verify, PACS).
- **Therapy using External Radiotherapy**
  - Localisation – Simulation
    - Patient positioning for treatment, immobilisation, construction of immobilisation devices (e.g. thermoplastic mask).
    - Imaging of patient when positioned for therapy.
    - Localisation of target/contour of patient (radiological/radioscopic localisation, localisation with computer tomography).
    - Planning of personalised protective equipment (blocks) or positioning of MLC (multiple leave collimators).
    - Patient marking (radiation field, Laser etc.).
  - **Treatment Planning**
    - Knowledge of beams' dosimetric characteristics and their role in treatment planning (e.g. contribution of primary and scattered radiation at point of interest, dose rate variation when changing the geometric parameters for therapy, etc.).
    - Selection of type of radiation, number of fields, irradiation geometry, components for shaping radiation magnitude (e.g. wedge filters) etc. for the optimisation of the dose distribution.
    - Knowledge of the algorithms used for dose estimation (photons, electrons) and their limitations for the estimation of dose distribution by the treatment planning system (TPS).
    - Knowledge of three-dimensional treatment planning (dose distribution in 3 dimensions, estimation of Dose-Volume histogram (DVH) etc.).
    - Estimation of Monitor Units (MU) for treatment planning with multiple radiation fields using various methods:
      - Non-isocentric irradiation technique (SSD).

- Isocentric irradiation technique (SAD).
- Extended source-to-surface distance technique (extended SSD).
- Dose estimation at points outside the primary axis.
- Heterogeneity corrections.
- Tissue compensators (tissue compensators).
- Asymmetric beam collimators.
- Application of Physical or dynamic wedge filter (physical or dynamic wedge).

▪ Quality assurance in therapy phase

- Check/verification of treatment plan.
- Check/verification of saved therapy parameters and their transfer to the therapy equipment. Electronic record and verify systems.
- Check of patient positioning – Therapy verification (film, EPID, digital radiography).
- Dose estimation in foetuses and pacemakers.
- In vivo patient dosimetry.
- Periodic review of estimation of MUs for each patient.

- **Dosimetry**
  - Electron and photon beam calibration.
    - Knowledge of the entire process for the calibration of a beam starting from a dosimeter calibrated at a standardising laboratory. (e.g. IAEA TRS 398 protocol, AAPM protocol).
    - Knowledge of the basic characteristics of ionising champers:
      - Cylindrical.
      - Parallel-plate.
  - Measurement of dosimetric characteristics of photon and electron beams:
    - Use of water tank and navigation system of the detector for measurement of depth dose, beam profile etc.
    - Use of detector arrangements (e.g. 2D Array) for the measurement of field homogeneity and symmetry.
  - Knowledge of all appropriate materials and their characteristics for dosimetry measurement.
  - In-vivo dosimetry: knowledge of available techniques and of the calibration procedures and quality assurance related with their use.
  - Thermoluminescent dosimeters.
  - Diode dosimeters.
  - Film dosimetry (radiographic, radiochromic, etc.).
  - Dosimetry with MOSFET detectors.

- **Radiation protection of patient**
  - Protective equipment (blocks).
    - Selection of appropriate materials for the attenuation of radiation depending on the type of radiation.
    - Methods for calculating the block width as a function of the required attenuation field.
    - Manufacture and verification of customised blocks.

- Knowledge of the necessary (from the radiation protection point of view) systems for therapy monitoring.
- Relevant knowledge of room design and use of materials for prevention of radio-contamination.

- **Radiation protection of staff**
  - Monitoring methods, radiation detectors used and requirements in order for them to be given to employees exposed to radiation.
  - Knowledge of dose limits for radiation workers..
  - Record keeping of radiation the radiation workers received.
  - Designation and categorisation of areas (supervised area, controlled areas).
  - To draw up emergency plans (e.g. in case of malfunction of the Cobalt unit).

- **Brachytherapy**
  - Characteristics and handling of radioactive sources
    - Physical characteristics of radioactive sources (shape/size/manufacture).
    - Licensing, safety, storing, handling, withdrawal of sources.
    - Check of radiation leakage.
    - Appropriate equipment for measuring radiation in the room.
    - Activity measurement and calibration of sources.
    - Knowledge of source afterloading systems and their operation.
    - Manufacture / check of equipment essential for performing brachytherapy treatment (molds, protection systems, blocks, etc.).
  - Clinical Applications of Brachytherapy
    - Selection of radioisotope.
    - Selection of applicator.
      - For low dose rate brachytherapy (LDR).
      - For high dose rate brachytherapy (HDR).
    - Estimation of activity.
    - Documentation of procedures.
  - Planning of Therapy using Brachytherapy
    - Positioning and arrangement of sources.
    - Activity.
    - Dose rate and models for calculating dose.
    - Source localisation.
    - Computation of therapy planning.
      - Calculation of dose distribution.
      - Calculation of treatment time given the actual position of the sources.
  - Protocols for quality assurance in Brachytherapy.
  - Radiation Protection in Brachytherapy.
    - Room designing.
    - Radiation protection survey.
    - Radiation protection of staff and visitors.
    - Staff dosimetry.
    - Sending and Receiving radioactive sources.

- Registering radioactive sources (day of purchase, calibration certificates, information on delivery, withdrawal or disposal of sources in waste, etc.).
- Knowledge of procedures that must be followed in case of source loss.
- Drawing up emergency plans (e.g. in case of malfunction of the source withdrawal/securing system).
- Instructions to patients with radioactive seed implants.

- **Knowledge of legislation**
  - Knowledge of the relevant legislation for the medical use of ionising radiation (e.g. radiation protection directive).
  - Knowledge of the responsibilities and obligations of the different specialties involved in the Radiotherapy department (technologists, medical physicists, clinicians, radiotherapists, etc.).
  - Knowledge of the hierarchy, report and control procedures by the supervising authority (GAEC – Greek Atomic Energy Commission).

- **Medicotechnical skills**
  - In External Radiotherapy

    For the following clinical cases:
    - Breast.
    - Central nervous system (CNS).
    - Gynaecologic cancer (GYN).
    - Gastrointestinal cancer (GI).
    - Brain and cervical cancer.
    - Lymphoma.
    - Melanoma.
    - Sarcoma.
    - Thoracic cancer.

    The trainee must have at least elementary knowledge of the following:
    - the medical indication (justification) for the application of external radiotherapy,
    - the dose levels and fractionation of therapy,
    - the basic anatomy of the region which undergoes therapy,
    - the role of the specialties involved in the therapy,
    - the appropriate positioning of the patient and the necessary immobilisation devices,
    - the appropriate imaging method,
    - the usual treatment plan for the relevant clinical case:
      - number of fields and irradiation geometry,
      - criteria for selecting the treatment plan,
      - selection of reference levels for the calculation of the dose distribution,
      - selection of field weights,
      - normalisation,
      - dose and monitor units (MU) calculation
    - monitoring and quality assurance of therapy.

- **Radiobiology knowledge**
    - Carcinogenicity.
    - Radio-physiology of human tissues.
    - Factors that affect cellular response to dose.
    - Linear energy transfer (LET).
    - Relative biological effectiveness (RBE).
    - Tissue radiosensitivity.
    - Time-Dose and fractionation.
    - Calculation of equivalent dose (EQD2) using the Linear-Quadratic model.
    - Other types of radiation (protons, neutrons, heavy particles).

It is encouraged, depending on the available equipment and the capability of the trainee to visit more laboratories in order to acquire skills and knowledge in specialised procedures and state-of-the-art systems.

- **Intensity-modulated radiation therapy (IMRT)**
    - Inverse planning.
        - Object-oriented functions.
        - Optimisation models.
    - Therapy using IMRT
        - Functionality of multi-leave collimators (MLC).
        - IMRT using the step-and-shoot technique.
        - IMRT using the sliding window technique.
        - Intensity modulated arc therapy (IMAT).
        - Tomotherapy.
    - Quality Assurance in IMRT
        - Check of accuracy of movement of collimator leaves.
        - Check of accuracy of the generated fluence maps.
        - Check of accuracy of the treatment plan using a phantom.
        - Accuracy check of the isodose curves.
        - Check of accuracy of the therapy applied to the patient.
    - Safety
        - Check of radiation leak.
        - Radiation protection check in the therapy room for the application of IMRT.

- **Special Radiotherapy Techniques**
    - Total body irradiation with a photon beam (TBI).
    - Total skin electron therapy (TSET).
    - Intraoperative radiation therapy with electron beams (IORT).
    - Irradiation with small diameter beams.
    - Stereotactic radiosurgery (SRS).
    - Stereotactic radiotherapy (SRT).
    - Electron arc therapy.
    - Tissue compensators for electron and photon beams.
    - Respiratory gated radiotherapy.

CLINICAL TRAINING OF MEDICAL PHYSICISTS IN RADIOLOGY

The fundamental theoretical background knowledge in the field has been acquired by the trainee medical physicist during the postgraduate studying programme in Medical Physics. Additional skills must be developed by the trainee during the clinical training. By the end of the clinical training the trainee medical physicist must have developed at least the following knowledge/skills in the field of **Radiology** and therefore, the participating centres must be equipped with:

- Conventional radiographic equipment with film or flat panel detector.
- Radioscopic equipment with image intensifier or flat panel detector.
- Single or Multislice computer tomograph.
- Magnetic Resonance Imaging (MRI) scanner.
- Mammographic equipment.
- Dental radiographic equipment.
- Orthopantotomograph.
- Bone densitometer.
- Dosimetric equipment.

The trainee must cover the following fields:

Field 1: Clinical experience / familiarisation

Field 2: Radiation protection and safety

Field 3: Quality assurance

Field 4: Dosimetry, equipment and calibration

Field 5: Patient dosimetry

1. FAMILIARISATION WITH CLINICAL ENVIRONMENT

The trainee must attend the clinical examinations in the radiology department in order to better comprehend the field and understand the work flow for the various diagnostic examinations.

- Film or/and digital radiography/radioscopy.
- Surgical and cardiac imaging.
  (To also include the dose received by patients and staff during a typical examination).
- Mammography.
- CT and MRI tomography.
- Ultrasound examinations.
  Attend the various ultrasound examinations (whenever possible) including Doppler imaging.
  To try to understand the differences and the advantages of ultrasounds and X-rays.
- Dental radiology.

2. RADIATION PROTECTION AND SAFETY

- **Staff Dosimetry**

- Records of radiation workers
  - Dosimeter type.
  - Method for collecting dosimeters.

- Collection of dosimeters from radiation workers.
- Interpretation of the different levels of recorded dose.
- Conclusions regarding which staff and which departments need to be regularly monitored.
- Investigation of potential overexposures to radiation.
- Estimation of effective dose using the recorded dose from the dosimeter.

- **Radiation risk assessment**

In departments where exposure to staff and patients is relatively high (invasive radiology, surgeries etc.).

- List of potential risks in the corresponding departments.
- List of all vulnerable staff and how could potential overexposure be avoided.
- Record the guidelines for radiation protection.
- Checking of radioprotective equipment (lab coats, screens, googles, shielding).
- Methods to limit exposure of staff and patients.
- Shielding calculation.
- Protection in MRI.

3. QUALITY ASSURANCE

- **Radiographic cassettes**
  - Measurement of film's optical density.
  - Film's characteristic curve using sensitometer and densitometer.
  - Check of contact between film and cassette.
  - Visual check for artefacts and for ensuring that the cassette is light proof.

- Dark room / Film processor
  - Film processor
    - Measurement of temperature.
    - Processing speed.
    - Measurement of base+fog level.
    - Inspection of the efficiency of the radiographic fixer and of the developer.
    - Visual inspection of cleanliness.
    - Inspection of artefacts on film.
  - Dark room
    - Visual inspection of light leaks and security light.
    - Measurement of the fog on the film due to the light in the dark room.

- **Conventional radiology**
  - Quality assurance according to the GAEC protocol
    - Alignment of radiological/radiographic field.
    - Measurement of X-ray tube leakage.
    - kVp accuracy.
    - Timer accuracy.
    - Linearity of time-exposure product.

        - Reproducibility of time-exposure product.
        - Measurement of HVL.
        - Bucky movement.
        - Tomograph checks (optional)
            - Height of the field of view.
            - Width of the field of view.
            - Homogeneity of exposure.

- **Digital and conventional radioscopy**
    - Quality assurance according to the GAEC protocol
        - Agreement between X-ray beam and imaged area.
        - X-ray tube radiation leakage.
        - kVp accuracy.
        - Check of timer.
        - Check of collimators.
        - Calculation of entrance skin dose both for the patient and at the image intensifier at the AEC.
        - HVL measurement.
        - Quality assurance checks of the image.

- **Digital radiography using detector or digital cassette**
    - Quality assurance according to the GAEC protocol
        - Homogeneity check.
        - Dark noise – pseudo-images check.
        - Residual image.
        - Measurement of spatial resolution.
        - Noise and low contrast checks.
        - Dose linearity and DDI.
        - Deletion efficiency (CR).

- **Automatic exposure control (AEC)**
    - Quality assurance according to the GAEC protocol
        - Clinical use of AEC.
        - Reproducibility of AEC.
        - Ion chamber stability.
        - Effect of voltage variations on optical density.
        - Effect of phantom thickness on optical density.

- **Mammograph**
    - Quality assurance according to the GAEC protocol.

- **Dental radiology**
    - Conventional/digital dental radiology
        - Quality assurance according to the GAEC protocol.
    - Orthopantotomograph
        - Quality assurance according to the GAEC protocol.

- **Computed tomography**
    - Quality assurance according to the GAEC protocol.

- **Magnetic Tomography**
    - Measurement of homogeneity.
    - Measurement of SNR.
    - Geometric distortion.
    - Low contrast detectability.
    - High contrast detectability.
    - Measurement of slice thickness.
    - Positioning of slice.

- **Bone densitometer**
    - Quality assurance according to the GAEC protocol.

- **Dosimetry, equipment and calibration**
    - Study of the dosimetry protocol applied in the laboratory.
    - Familiarisation with dosimetric equipment (ionisation champers, electrometer, survey meter).
    - Definition of the dosimetric equipment which should be used in each circumstance.
    - Study of the calibration documentation.
    - Organisation and performance of the cross-calibration process for the ionisation champers using a recently calibrated chamber.

- **Patient dosimetry**
    - Calculation of surface entrance dose with and without the use of back scatter factor.
    - Calculation of DAP.
    - Calculation of CDTI.
    - Estimation of average dose in mammary gland in mammography.
    - Description and/or performance of the process of calculating the diagnostic reference levels for a clinical examination.

CLINICAL TRAINING OF MEDICAL PHYSICISTS IN NUCLEAR MEDICINE

The fundamental theoretical background knowledge in the field of nuclear medicine has been acquired by the trainee medical physicist during the postgraduate studying programme in Medical Physics. Additional skills must be developed by the trainee during his clinical training in an authorised-certified hospital which is equipped with the necessary facilities and staff (specialised Medical Physicists).

By the end of the clinical training the trainee medical physicist must have developed at least the following knowledge/skills in the field of **Nuclear Medicine:**

1: BASIC PRINCIPLES OF NUCLEAR MEDICINE IN CLINICAL PRACTICE

The purpose is for the trainee to acquire the clinical knowledge and experience related with the field of Nuclear Medicine

- **Anatomy and physiology for Physicists in Medicine**

- Understanding of the anatomy and physiology when performing imaging using Nuclear Medicine (static, dynamic scintigraphy, SPECT tomography) and comparison with other imaging techniques (radiography, computed tomography, magnetic tomography etc.).
- Development of basic anatomy and physiology knowledge in order to be able to interact with clinical staff.

- **Basic principles of radiobiology and epidemiology**
  - Understanding of radiobiological and epidemiological phenomena when performing imaging using Nuclear Medicine.

- **Clinical requirements and management of patients – examinees**
  - This refers to the capability of the trainee to discuss and understand the special requirements in order to give instructions to the patients – examinees who are admitted to hospital for administration of radiopharmaceuticals and imaging in the Nuclear Medicine department.

2: RADIATION PROTECTION IN NUCLEAR MEDICINE

The trainee develops special skills in the radiation protection techniques-measurements related to Nuclear Medicine.

- **Measurements of the radiation levels including staff dosimetry**
  - Understanding of the operating principles of the equipment used in Nuclear Medicine for measuring radiation levels.
  - Understanding of the requirement and the method for performing personalised staff dosimetry. – Types of personal dosimeters.
  - To develop the skill to perform quantitative measurements of the dispersion of radioactive materials.

- **Exposure to open or closed sources and radioactive contamination hazard**
  - Understanding of the methods for reducing exposure.
  - Ability to handle open sources.
  - Ability to assess and act upon potential radioactive surface contamination.

- **ALARA principle and basic guidelines for radiation protection in diagnostic and therapeutic applications of Nuclear Medicine**
  - Understanding of how to apply the ALARA principle.
  - Understanding of how to apply the radiation protection guidelines in routine clinical practice in Nuclear Medicine (time, distance shielding, etc.).

- **Evaluation of hazards and supply of instructions-advice to staff, patients and their relatives with regard to radiation hazards**
  - Understanding of the methods for the evaluation of the effective dose according to the diagnostic applications of Nuclear Medicine.
  - Justified knowledge of the hazards from the exposure to radioisotope radiation.
  - Understanding of the procedures for the evaluation of the hazards from the perspective of radiation protection.

- **Definition of areas-rooms in which radioactive materials will be used**
    - Familiarisation with the areas where radioactive materials will be used and measures for radiation protection need to be taken.
    - Knowledge of the different types of radioactive decay.
    - Ability to handle and store radioactive waste from radioactive sources used in the nuclear medicine laboratory.

- **Design – arrangement of a Nuclear Medicine laboratory – Calculation of the required shield thickness according to the radiation protection guidelines**
    - Understanding of the principles, the requirements and the assumptions that are taken into account for the design of the areas and the calculation of the required shield thickness depending on the type, the quantity, and the energy of the radioisotopes used in the Nuclear Medicine laboratory.
    - Familiarisation with the shielding requirements in case a SPECT or/and a PET system is/are to be installed when such systems are combined with other radiodiagnostic modalities e.g. CT.
    - Ability to calculate the approriate shielding thickness and design every room for each equipment in the Nuclear Medicine department.

- **Legislation. Radiation protection regulations and other standardised guidelines related with the safe working with ionising radiation in the applications of Nuclear Medicine**
    - Understanding of the regional, national, European and other regulations for radiation protection related to Nuclear Medicine.
    - Licensing process for nuclear medicine laboratories.
    - Classification of laboratories.

3: ORDERING AND ACCEPTANCE TESTS OF NUCLEAR MEDICINE EQUIPMENT

The purpose is the familiarisation of the trainee with the process of ordering and acceptance testing of a particular equipment for the Nuclear Medicine laboratory.

- **Acquisition of new equipment in the Nuclear Medicine department**
    - Preparation and compilation of the Technical Specifications needed for the new equipment in the Nuclear Medicine Department.
    - Understanding of the necessity of each equipment in the Nuclear Medicine Department.
    - Ability of the trainee to communicate and explain to the Administration the necessity of each equipment – funding.
    - Market research.
    - Preparation of an economical and technical study according to the available budget.
    - Understanding of the procedures for the acceptance testing and maintenance of the equipment.

- **Acceptance testing of a dose Counter**
    - To understand the working principle of the dose Counter.
    - To be informed and attend (if it occurs) the acceptance tests of a new dose Counter.
    - To perform the following checks on a Dose calibrator:

- – check of its condition
- – check of its accuracy
- – check of the activity linearity
- – calculation of the radioactive background
- – check of geometry
- Factors that affect the accuracy of a Dose calibrator
  (background activity, source geometry, position of source, isotope activity and type)
- Familiarisation with the use of reference sources.
- Understanding of the criteria for the acceptable and satisfactory performance of the equipment.
- Choosing the reference standards for performing periodic quality control QC checks of the equipment.
- Actions in case the equipment does not pass one of the acceptance tests.

- **Acceptance testing of a scintillation detector and a well counter – γ counter**
  - To understand the working principle of the scintillation detector or the well counter – γ counter.
  - Ancillary equipment relevant to scintillation detector or to a well counter – γ counter.
  - To be informed and attend (if it occurs) the acceptance checks of a scintillation detector or of a well counter – γ counter.
  - To perform the following checks:
    - check of its condition
    - check if the counter - timer - rate counter are functional
    - check of calibration of the isotope energy
    - check of energy discrimination capability (% FWHM)
    - sensitivity check
    - check of measurement accuracy (Chi squared test)
    - check of linear response of well counter over a range of energy peaks
    - check of the count rate of the radioactive background
    - check of linear response of well counter over a range of activities
  - Understanding of the criteria for the acceptable and satisfactory performance of the equipment.
  - Choosing the reference standards for performing periodic quality control QC checks of the equipment.
  - Actions in case the equipment does not pass one of the acceptance tests.

- **Acceptance testing of γ-camera SPECT or SPECT/CT**
  - Familiarisation of the trainee with the process of acceptance testing of a γ-camera SPECT or SPECT/CT.
  - Knowledge of the design and the ancillary equipment relevant to a γ-camera SPECT/CT both in terms of hardware and software.
  - Understanding of the procedures and capability to perform the acceptance tests of a γ-camera (planar, SPECT, SPECT/CT).
  - Acceptance testing protocols.
  - Necessary phantoms.

- To be able to perform the following checks for a SPECT system:
  - Check of mechanical movements
  - Pixel size measurement
  - Check of the centre of rotation
  - Tomography's homogeneity
  - Tomography's spatial resolution
  - Measurement of slice thickness
  - Sensitivity check
- Knowledge of the technical specifications and characteristics given by the manufacturer.
- Interpretation of the results from the acceptance testing.
- Acceptance criteria.
- Choosing the reference standards for performing periodic quality control QC checks of the equipment.
- Actions in case the equipment does not pass one of the acceptance tests.

- **Acceptance testing of a PET or PET/CT system**
  - Familiarisation of the trainee with the process of acceptance testing of a PET/CT system.
  - Knowledge of the physical principles of a PET/CT system and how to operate it.
  - To study and comprehend the international protocols related to the acceptance testing of a PET or/and a PET/CT system.
  - The trainee must acquire the skill to perform not only the acceptance testing of a PET system but also the SUV calibration procedure.
  - Interpretation of the results from the acceptance testing.
  - Acceptance criteria.
  - Choosing the reference standards for performing periodic quality control QC checks of the equipment.
  - Actions in case the equipment does not pass one of the acceptance tests.

4: PERIODIC QUALITY CONTROL CHECKS OF NUCLEAR MEDICINE EQUIPMENT

The trainee is familiarised with the performance of periodic quality control checks QC of the equipment used in nuclear medicine.

- **Design and attendance-performance of a daily quality control schedule.**
  - Understanding of the methods for the clinical application and attendance of scheduled quality control checks.
  - Exhibition of the trainee's skills in the management of scheduled quality control checks including handling necessary equipment (phantoms-sources), establishing the relevant procedures and the frequency of their performance.

4.2: Periodic quality control QC checks of a dose counter

- To assess the trainee's ability to perform all the quality control checks of a dose counter in order to ensure the highest accuracy of the activity measurements.
- Understanding of the effect of the geometrical factors, energy related factors and the different types of measured radioactivity.

- Ability to perform quality control checks of a dose counter including:
  - Check of reproducibility of measurements
  - Check for potential radio-contamination (measurement of physical substrate)
  - Linearity of measurements
  - Accuracy of measurements
- To determine the appropriate acceptance limits for each measured parameter
- To record all measurements in Log-Books
- To determine the actions when measurements are outside the acceptance limits

- **Periodic Quality Control QC Checks of a conventional scintillation detector and well counter- γ counter**
  - To perform the periodic checks of a scintillation detector or/and a well counter – γ – counter competently.
  - To understand the operating principles of the equipment in relation to the procedures for performing quality control checks.
  - To develop the capability to perform quality control checks in non-imaging scintillation detectors.
  - To be familiar with the following periodic quality control checks of a conventional scintillation detector and of a well counter – γ counter:
    - check of its condition
    - check if the counter - timer - rate counter are functional
    - check of calibration of the isotope energy
    - check of energy discrimination (% FWHM)
    - sensitivity check
    - check of measurement accuracy (Chi squared test)
    - check of linear response of well counter over a range of energy peaks
    - check of the count rate of the radioactive background
    - check of linear response of well counter over a range of activities
  - To record all measurements in Log-Books and analyse the results in order to determine if they are within the acceptance limits
  - To suggest the processes in order to appropriately configure the equipment in cases of deviation from the acceptance limits.

- **Periodic Quality Control QC Checks of a γ-camera with SPECT**
  - To acquire full understanding of the procedures for performing quality control checks of a planar and a tomographic SPECT γ-camera
  - The trainee must acquire the ability to perform without any assistance any routine, periodic quality control check both of a planar and a tomographic SPECT γ-camera.
  - To interpret the results-measurements of the periodic quality control checks of the γ-camera.
  - The periodic quality checks of the planar γ-camera must include:
  - – Homogeneity Checks (integrated and differential)
  - – Check of Spatial Resolution
  - Additionally, the periodic control checks of a tomographic γ-camera SPECT must include:
    - homogeneity of the tomographic image
    - tomographic spatial resolution

        - check of the centre of rotation
        - quality control checks of tomographic imaging

- **Periodic Quality Control Checks QC of a PET/CT system**
    - To acquire full understanding of the procedures for performing quality control checks of a PET/CT SPECT system.
    - The trainee must acquire the ability to perform the daily periodic quality control checks of the PET system and of its integrated computer tomograph CT.
    - To take the appropriate measures when a problem-dysfunction in the system is detected.
    - To ensure the optimum performance of the PET/CT system.

5: RADIOACTIVITY MEASUREMENTS AND INTERNAL DOSIMETRY

Clinical training of the trainee and familiarisation with the methods for measuring radioactivity in order to perform calculations of internal dosimetry.

- **Use of reference sources for the measurement of radioactivity**
    - Understanding of the traceability chain with regard to measurements of the various radioisotopes related to nuclear medicine.
    - To develop the ability to apply the principles of quality assurance and assess the potential inaccuracies that occur in the radioactivity measurements of the radioisotopes in clinic.
- **Standardisation and applications of internal dosimetry**
    - Understanding of the standardised and established methodologies for performing internal dosimetry including the restrictions –assumptions that are taken into account.
    - To develop the ability to calculate the absorbed dose in the different organs – tissues of the scanned subject according to the MIRD method as well as the ability to calculate the effective dose.
- **Absorbed dose from the radiopharmaceuticals in diagnostic nuclear medicine**
    - Understanding of the basic methods for generating readily available tables for the estimation of the absorbed and the effective dose of each radiopharmaceutical and for each type of patient including the potential levels of inaccuracies.
- **Quantitative measurements from imaging in nuclear medicine**
    - Understanding of the main factors that affect quantification from imaging in Nuclear Medicine.
    - To develop the ability to perform quantitative measurements in static, dynamic and tomographic images.
    - Knowledge of the relevant software of the imaging system.
- **Personalised patient dosimetry depending on the disease and the clinical image**
    - Understanding of the basic tools needed in order to perform personalised dosimetry of the scanned subject in nuclear medicine.
    - To develop the ability to perform dosimetry individually for each scanned subject from repeated images of the distribution of the radiopharmaceutical in regions – organs of interest and measurements of the radiopharmaceutical uptake.

6: RADIOISOTOPE THERAPY WITH THE USE OF OPEN SOURCES

The purpose is for the trainee to develop the necessary practical skills in handling the radiopharmaceuticals destined for therapeutic administration and to understand the relevant regulations for radiation protection.

- **Basic Principles of radioisotope therapy**
    - Understanding of the basic principles according to which radioisotope therapy is performed. In specific:
    - – Uptake and excretion of therapeutic radioisotopes
    - – Amount of therapeutic radioisotopes
    - – Physical – Biological – effective half life
    - – Metabolic and organic factors which affect the uptake – excretion
    - – Factors related with choosing the desired type of radiation and activity.

- **Design – functionality of a clinical department for performing applications with therapeutic radioisotopes**
    - Understanding of the principles of room design and shielding calculation for each therapeutic application (type of isotope, amount of isotope, energy of isotope)
    - To develop the ability to design and perform a shielding calculation study of a clinical room where patients will be administered therapeutic radiopharmaceuticals.

- **Procedures for administrations for therapeutic purposes**
    - Understanding the objective of the procedures for preparing and administering the therapeutic radiopharmaceuticals.
    - To develop the ability to manage the patients from the perspective of radiation protection prior and after the administration of the relevant therapeutic radiopharmaceutical.

- **Choice of the Radiopharmaceutical for therapeutic purposes in nuclear medicine**
    - To study and understand the indications from a clinical perspective for the administration of each radiopharmaceutical in nuclear medicine.
    - To get familiar with the wide range of diseases requiring therapy with radioisotopes and the selection of the appropriate radiopharmaceutical.

- **Patient dosimetry in the applications of radioisotope therapy**
    - Understanding of the basic principles of internal dosimetry.
    - To know how the selected radiopharmaceutical is distributed and metabolised.
    - To develop the ability to calculate the required amount of radioisotope to be administered to the patient.

- **Radiation protection regulations in the applications of radioisotope therapy**
    - To get familiar with the regulations (legislation) for radiation protection and know the international practices in order to ensure the optimum level of radiation protection BEFORE and AFTER the administration of therapeutic radioisotopes.
    - To understand how the radiopharmaceutical is distributed in the environment after being excreted by the patient or after an accident (dispersion, radio-contamination).

- To develop the ability to impose the rules of radiation protection both to staff and to the patient's family and carer.
- To develop the ability to inform not only the patients but also the general public regarding the potential dangers when handling great amounts of open sources.

7: CLINICAL APPLICATIONS OF NUCLEAR MEDICINE

To get familiar with the basic knowledge of Nuclear Medicine

- **Clinical routine protocols**
  - To understand and appreciate the technological factors for processing each clinical protocol applied in Nuclear Medicine.
  - To get familiar with technical factors related with the acquisition and the generation of the final image from a scintigraphy.

- **Common artefacts in clinical imaging – scintigraphy.**
  - To get familiar with the common artefacts and the reasons which are causing them.
  - To acquire the ability to detect artefacts in all scintigraphy types, to know what is causing them and take measures in order to prevent them or eliminate them.
  - To get familiar with the factors which could potentially cause an image artefact during the application of a clinical protocol.

- **Basic principles and Pathophysiology of the daily applied clinical protocols in Nuclear Medicine**.
  - Understanding of the physiology and the metabolism of the imaged organ and the method with which Nuclear Medicine could assist with the differential diagnosis of the function or dysfunction of the studied organ.
  - Assessment of the applied clinical protocols in terms of radiation protection of the patient and his administered dose.
  - Assessment of the risk / benefit ratio both in the diagnostic and the therapeutic protocols.
  - To develop the ability to distinguish normal uptake of the radiopharmaceutical from abnormal distribution in each organ in the body (brain, heart, lungs, kidneys, bones, liver etc.)

8: PREPARATION AND QUALITY CONTROL OF THE RADIOPHARMACEUTICALS

To get familiar with the checks related with the preparation of the radiopharmaceuticals

- **Production and preparation of the radiopharmaceuticals**
  - To understand the basic principles of producing radiopharmaceuticals in order to be used in the relevant application of Nuclear Medicine.
  - To get familiar with the equipment in a hot lab in order to handle radioisotopes and cold kits and be able to safely produce radiopharmaceuticals.
  - To be particularly able to handle Tc-99m radiopharmaceuticals.
  - To be able to skilfully handle the Mo99 - Tc99m generator.

- **Quality checks of radiopharmaceuticals**

- To understand the procedures for performing quality assurance checks on the produced radiopharmaceuticals.
- To test the elution for Mo99 breakthrough.
- Radiochemical purity.
- To know the method for assessing the radiolabelling efficiency of the radiopharmaceutical.