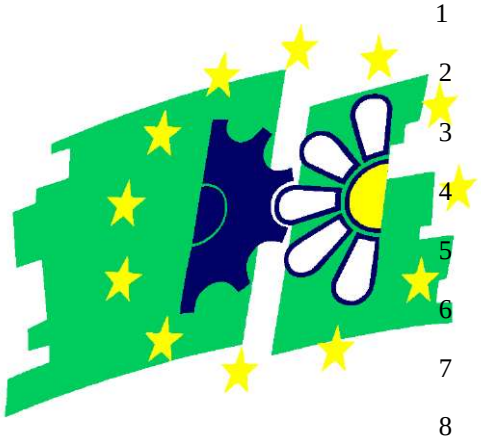

RADIATION PROTECTION XXX

MEDRAPET

Medical Radiation Protection
EDUCATION AND TRAINING

GUIDELINES ON RADIATION PROTECTION EDUCATION AND TRAINING OF MEDICAL PROFESSIONALS IN THE EUROPEAN UNION

European Commission

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Radiation Protection XXX

GUIDELINES ON RADIATION PROTECTION EDUCATION AND TRAINING OF MEDICAL PROFESSIONALS IN THE EUROPEAN UNION

20XX

Directorate General **XXXXX**

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TO BE WRITTEN BY THE EUROPEAN COMMISSION

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TO BE WRITTEN LAST

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1. Introduction

Our knowledge on the effects of ionising radiation on the human body, allows us to comprehend the mechanisms via which it is rendered harmful, as well as the possibilities of using ionising radiation as a tool of diagnosis and treatment.

It is very important to form, as patients or as professionals, the right perception of the dangers from exposure to ionising radiation. This perception constitutes a key factor for the equitable exploitation of the possibilities ionising radiation has to offer for diagnosis and treatment.

Underestimation of the potential biological effects from exposure to ionising radiation may lead us to unjustifiable exposures and increase of the population collective dose with apparent negative consequences.

Overestimation on the other hand, of the likely adverse effects may lead the professional towards unjustifiable stress and concerns, and the patient to self exclusion from exceptionally useful diagnostic procedures.

Therefore,

- The exposure to ionising radiation should be minimised as much as possible to an extent necessary to achieve the required diagnostic or therapeutic outcome.
- The correct risk assessment of the hazardous effects from exposure to ionising radiation as compared to the benefits involved should be carefully conducted in order to eliminate exaggerated perceptions.

Education and training in general, and specifically training in the field of radiation protection are widely recognised as one of the basic components of optimisation programmes for medical exposures.

International organisations such as ICRP [1, 2, 3], IAEA [4, 5, 6], WHO [7, ??], and the EC [8, ??], recognise the importance of education and training in reducing patient doses while maintaining the desired level of quality for diagnostic and therapeutic procedures.

1.1. Background

Article 7 of the 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 lays down requirements for education and training [9]. See Appendix A for relevant extracts from this directive.

The EC realised that certain aspects of this Article may require some clarification and orientation for MS and in 2000 has published the Radiation Protection Report 116 "*Guidelines on education and training in radiation protection for medical exposures*" [8]. This guideline containes some specific recommendations for the application of the Directive and it has served the Member States considerably well.

However due to the rapid technological development of the past decade and due to the constantly growing use of ionising radiation in medicine called for an update of this document [10 find the reference].

Today, medical procedures by far constitute the most significant man-made source of radiation exposure to people [11]. Since training in radiation protection is widely recognised as one of the basic components of optimization programmes for medical exposures, it is necessary to establish a high standard of education and training programmes harmonized at EU level.

Therefore in 2010 the EC has initiated a project to perform a study on the implementation of the MED requirements on radiation protection education and training of medical professionals in the EU MS and to develop European Guidance containing appropriate recommendations for harmonisation at the EU level [12].

This project, with the title "*Study on the Implementation of the Medical Exposures Directive's Requirements on Radiation Protection Training of Medical Professionals in the European Union*", was awarded to a consortium consisting of the following organisations:

European Society of Radiology (ESR, Austria), (Coordinator)

European Federation of Radiographer Societies (EFRS, The Netherlands)

European Federation of Organisations for Medical Physics (EFOMP, UK)

European Society for Therapeutic Radiology and Oncology (ESTRO, Belgium)

European Association of Nuclear Medicine (EANM, Austria)

Cardiovascular and Interventional Radiological Society of Europe (CIRSE, Austria)

The main objectives of this project were:

- The conduction of an EU-wide study on radiation protection training of medical professionals in the EU MS
- The organisation of a European Workshop on radiation protection training of medical professionals in the EU MS
- The development of a European Guidance document on radiation protection training of medical professionals

This document concentrates on the third objective taking into consideration the outcomes of the first two.

1.2. MEDRAPET survey

Parts or the entire executive summary of the survey report will be copied here.

1.3. Role of organizations

The organisations of healthcare professionals have as their prime objective to maintain and improve the status of their profession and therefore provide recommendations to their members on the following main topics not necessarily in the order listed:

a) Education and Training
b) Level of Skills and Competence
c) Continuous Professional Development
d) Ethical and Professional Code of practice

It is obvious that for the health care professions directly or indirectly involved with the use of ionising radiation that radiation protection should form an indispensible part of the above topics at the appropriate level for each profession.

Professional Organisations exist at the national, regional and international level. More often the regional and international organisations are networks of national organisations and provide similar recommendations that aim for their harmonised implementation at the regional or international level.

The European healthcare professional organisations are therefore of paramount importance in the harmonisation of their professions, at least within Europe, and thus ensuring the same level of KSC in their member states.

The role of the relevant European healthcare professional organisations in the MEDRAPET project, directly or indirectly, is very important for their input to the development of the guidance document and also for its dissemination and use.

1.4. The structure of this document

The level of Knowledge, Skills and Competence (KSC) in Radiation Protection required from the different healthcare professionals vary according to their involvement with the use of ionising radiation. For example, the level for a referrer is very much lower than that for a practitioner in interventional radiology.

More emphasis is also given to the curriculum content for the specific fields of application of ionising radiation, especially where specific KSC may be required depending on how ionising radiation is used and the likely radiobiological effects.

For completeness and by taking the above into consideration, this document is divided in sections according to the disciplines of the healthcare professional involved with ionising radiation. All the KSC and Continuous Professional Development (CPD) at the required level are given so that each professional discipline can have these together in their section.

Additionally, a number of annexes are provided that provide information on particular groups of patients and special applications.

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Medical Professionals in the European Union”,
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[13]

2. Basic learning outcomes for radiation protection

International meetings, publications and recommendations with regard to safety culture increasingly stress the need for education and training in the field of radiation protection. In addition, compliance with specific European directives concerning the implementation of coherent approach to education and training becomes crucial in a world of dynamic markets and increasing the workers mobility.

International organisations as ICRP, IAEA, WHO etc, recognise the importance of education and training in reducing patients' doses while maintaining the desired level of quality in medical exposures, as well as precise therapeutic treatments.

The basic guidance includes the general recommendation on radiation protection training of medical professionals. The proposal for basic syllabuses for the radiation protection training of different categories of medical professionals involved in different fields of applications of ionizing radiation in medicine is based on the appropriate level of education.

The basic education for radiation protection must therefore be followed by structured training including further theoretical and practical courses. This training should include the legal aspects of the application of radiation in medicine and the responsibilities of the Competent Authority in radiation protection. Practical experience should involve working in a clinical environment.

The syllabuses for Radiation protection should be prepared according to the European Qualifications Framework for Lifelong Learning, based on Knowledge, Skills and Competences (KSC) [1].

The following groups of professionals have been identified

- Radiologists
- Radiographers
- Medical Physicists
- Radiation Oncologists
- Nuclear Medicine Specialists
- Interventional Radiologists
- Interventional Cardiologists
- Gastroenterologists
- Vascular Surgeons
- Orthopedic Surgeons
- Urologists
- Neurosurgeons
- Pediatrics
- General Practitioners
- Emergency Doctors
- Dentists
- Nurses

A basic training program in radiation protection throughout Europe for the different groups of medical professionals in relation to their roles and responsibilities within their health care system should be established (considered as mandatory).

According to ICRP 113, the basic training program should include the following topics:

- Radiation hazards,
- Radiation quantities and units,
- principles of RP,
- Radiation legislation and RP factors affecting patients and staff doses [2].

The modules, recommended for medical applications of ionising radiation, were agreed in September 1999 at the International Conference on "Radiation protection: What are

the future training needs?" organised by the "Institut National des Sciences et Techniques Nucléaires" in Saclay (France). For Medical Physicists, all the modules are recommended. For medical doctors and paramedical personnel, all the modules are recommended apart from 15, 16 and 20. These recommendations are published in RP 116 (2000).

1 Basic physics, mathematics and biology for radiation protection.
2 Radiation sources of exposure.
3 Interaction of radiation with matter.
4 Dosimetric quantities and units.
5 Theory of radiation detection and measurement.
6 Dosimetric calculations and measurements.
7 Biological effects of ionising radiation.
8 External dose assessment.
9 Internal dose assessment.
10 The role of International Organisations in radiation protection (not essential).
11 Conceptual framework of radiation protection.
12 Occupational radiation protection.
13 Waste safety.
14 Physical protection and security of sources.
15 Transport of radioactive material.
16 Public exposure control.
17 Intervention for protection of the public in chronic and acute exposure situations.
18 Medical exposures.
19 Regulatory control.
20 Communications on nuclear radiation transport and waste safety.
21 Emergency preparedness and response. Accident analysis.
22 Safe use of radiation sources in relation to specific practices [3].

A list of topics to be included in the training programmes in Radiation protection for the different groups of professionals should be established. The following training areas could provide examples of radiation protection programmes in diagnostic radiology (VAÑO 1993):

- The atomic structure and interaction of radiation
- Radiological quantities and units
- Physical characteristics of X-ray machines
- Fundamentals of radiation detection
- Detectors used in diagnostic installations
- Fundamentals of radiobiology: cell, systemic and whole body responses
- Radiation protection. General criteria
- Operational radiological protection
- General RP aspects in diagnostic radiology
- Particular aspects of patient and staff RP
- Quality control and quality assurance
- National and European regulations and standards
- Practical training [4]

There are also British recommendations for areas of training in RP for nuclear medicine (HARDING, 89):

- Nature of ionising radiation and its interaction with tissue
- Genetic and somatic effects and how to assess their risks
- Patient doses
- Quality assurance and quality control
- Dose limitation
- Pregnancy and breast feeding

- Unsealed sources
- Organisation for radiation protection
- Statutory responsibilities [5].

Considering all the references mentioned above, MEDRAPET WP 3 agreed that the topics of Table 2.1 should be considered in the basic curriculum for the training in radiation protection.

Table 2.1: Basic Topics in Curriculum

Training Area	**DR MD**	**RT MD**	**NM MD**	**CD MD**	**DT**	**MD**	**RD**	**NU**	**ME**
1. Atomic Structure, X-ray production and interaction of radiation	m	h	h	l	l	l	m	l	m
2. Nuclear structure and radioactivity	m	h	h	l	--	--	m	l	m
3. Radiological quantities and units	m	h	h	m	l	l	m	l	m
4. Physical characteristics of the X-ray machines	m	h	l	m	l	m	m	l	h
5. Fundamentals of radiation detection	l	m	h	l	l	l	m	l	h
6. Fundamentals of radiobiology, biological effects of radiation	m	h	h	m	l	m	m	l	l
7. Risks of cancer and hereditary disease and effective dose	h	h	h	h	m	m	m	m	l
8. Risks of deterministic effects	h	h	h	h	m	m	m	m	l
9. General principles of RP	h	h	h	h	m	m	h	l	m
10. Operational RP	h	h	h	h	m	m	h	m	m
11. Particular patient RP aspects	h	h	h	h	m	h	h	m	m
12. Particular staff RP aspects	h	h	h	h	m	h	h	m	m
13. Typical doses from diagnostic procedures	h	h	h	h	h	m	h	l	l
14. Risks from foetal exposure	h	h	h	h	m	h	h	m	l
15. Quality control and quality assurance	m	h	h	m	l	l	m	l	h
16. National regulations and international standards	m	m	m	m	m	m	m	l	h
Suggested number of training hours	30-50	40-60	30-50	20-30	10-15	15-20	40-100	10-15	40-60

DR/MD = Diagnostic Radiology Specialists (Medical Doctors)
RT/MD = Radiotherapy Specialists (Medical Doctors)
NM/MD = Nuclear Medicine Specialists (Medical Doctors)

One additional training area on Radiopharmaceuticals: Handling, quality control and detection should also be considered (h level).

CD/MD = Interventional Cardiology Specialists (Medical Doctors)
DT = Dentists
MD = Other Medical Doctors using X-ray systems
RD = Radiographers
The term "radiographer" is understood to include radiographer, medical radiological technologist, radiation therapy technologist or nuclear medicine technologist. Some specific training depending of the kind of job will be needed. The EANM suggest 30-50 h for nuclear medicine technologists and one additional training area on Radiopharmaceuticals: Handling, quality control and detection (h level).
NU = Nurses. Some specific training will be needed in Nuclear Medicine and Radiotherapy
ME = Maintenance Engineers

Other groups of practitioners not included in the table should adapt their training in a similar framework.

Level of knowledge:

L = Low level of knowledge
m = Medium level of knowledge
h = High level of knowledge

Table 2.2: Basic Learning Outcomes for the Medical Professions in Radiation Protection (RP)

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competences (responsibility and autonomy)
	K1. Describe and explain atomic structure; K2. Describe the nuclear structure and explain the laws of radioactive decay; K3. List and explain the fundamental radiological quantities and units; K4. Describe the physical characteristics of the X-ray machines; K5. Explain the fundamentals of radiation detection; K6. Explain the fundamentals of radiobiology and the biological effects of radiation; K7. Explain the relation between the effective dose and the risk of cancer and hereditary diseases; K8. Explain the risks of deterministic effects; K9. Describe the general principles of RP; K10. Administer operational RP; K11. Explain the particular patient RP aspects; K12. Explain the particular staff RP aspects; K13. List and administer the typical doses from diagnostic procedures; K14. Explain the risk from foetal exposure; K15. Arrange quality control and quality assurance; K16. List the National regulations and international standards.	S1. Apply the general concept, principles, theory and practices of physics to the solution of clinical problems concerning the optimised clinical use of medical devices and safety / Risk Management. S2. Manage the reporting of measurements data, assess the individual staff doses. S3. Apply the knowledge when designing radiation protection program in various circumstances. S4. Carry out measurements for different types of radiation ; S5. Apply principles of QC & QA S6. Analyse the relationship between the doses and deterministic effects; S7. Analyse the importance of recoding the dose imparted to every patient; S8. Maintain the records of radiation exposure; S9.Communicate the most important factors that influence stuff doses.	C1.Implement the national regulation and international standards. C2. Implement the operational RP. C3. Coordinate with other medical professionals, support stuff and service users, relatives, carers and comforters within own area of practice. C4. Develop a dose monitoring program according to recommendations and regulations. C5. Advise the pregnant patient to avoid unnecessary radiation. C6. Develop a dose monitoring program according to recommendations and regulations.

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3. Learning outcomes for referrers

Radiological imaging involving use of ionizing radiations (x-rays or radioisotopes) is a major and increasing source of radiation exposure worldwide. In the past till 1970's when CT was introduced; the dominant imaging examination was radiography that involved very small radiation dose to patient typically a fraction of mSv or couple of mSv of effective dose. Currently computed tomography (CT) dominates the scene and is the largest contributor to medical radiation dose patients receive. Typically, CT scans impart doses to organs that are 100 times higher than doses imparted by radiography. In general, a CT examination with typical dose of say 8 mSv implies dose equivalent to several hundreds of chest radiographs, taken as 0.02 mSv/chest X ray giving a figure of 400 in this very case. Many patients undergo multiple CT examinations and some also nuclear medicine examinations [1, 2].

The radiation protection principles as laid down by the International Commission on Radiological Protection (ICRP) are justification and optimization [3]. They are incorporated into the European Basis Safety Standards [4]. Justification requires that the benefit for the patient must always outweigh the adjunct radiation risk. While referrers' are skilled to estimate benefit to an individual patient from a radiological procedure, consideration of radiation risk has not received the attention it deserves. Optimization in radiological examinations falls within the domain of radiologic professionals and justification is a joint responsibility of refers and radiological professionals.

Medical exposure shall show a sufficient net benefit, weighing the total potential diagnostic or therapeutic benefits it produces, including the direct benefits to health or wellbeing of an individual and the benefits to society, against the individual detriment that the exposure might cause, taking into account the efficacy, benefits and risks of available alternative techniques having the same objective but involving no or less exposure to ionizing radiation.

Account shall also be taken of the radiation detriment from the exposure of the medical radiological staff and of other individuals.

In particular:

a) - all new types of practices involving medical exposure shall be justified in advance before being generally adopted,

- existing types of practices involving medical exposure shall be reviewed whenever new, important evidence about their efficacy or consequences is acquired.

(b) all individual medical exposures shall be justified in advance taking into account the specific objectives of the exposure and the characteristics of the individual involved.

If a type of practice involving a medical exposure is not justified in general, a specific individual exposure of this type could be justified in special circumstances, to be evaluated on a case-by-case basis and documented.

The referrer and the practitioner as specified by Member States, shall seek, where practicable, to obtain previous diagnostic information or medical records relevant to the planned exposure and consider these data to avoid unnecessary exposure.

c) medical exposure for biomedical and medical research shall be examined by an ethics committee, set up in accordance with national procedures and/or by the competent authorities.

(d) Specific justification for medical radiological procedures to be performed as part of a health screening programme shall be carried out by the health authority in conjunction with appropriate professional bodies.

2. Exposure of carers and comforters shall show a sufficient net benefit, taking into account also the direct health benefits to a patient, the benefits to the carer / comforter and the detriment that the exposure might cause.

3. Any medical radiological procedure on an asymptomatic individual, intended to be performed for early detection of disease shall be part of a health screening programme, or shall require specific documented justification for that individual by the practitioner, in consultation with the referrer, following guidelines from relevant professional bodies and competent authorities. Special attention shall be given to the provision of information to the patients, as required by Article 82 paragraph 3.

4. If an exposure cannot be justified, it shall be prohibited.

The justification has been approached through establishment of “appropriateness criteria” or “referral guidelines” provided by professional bodies [5,6,7]. The European Commission had issued a booklet with referral guidelines for imaging [8] for use by health professionals referring patients for medical imaging. There have been considerations of updating these guidelines. However, updated guidelines from professional societies are available [5,6,7]. These publications constitute guidelines and aim to guide referring medical practitioners in the selection of the optimum procedure for a certain problem. In case there are alternatives that do not utilize radiation but yield results of similar clinical value, these guidelines encourage the avoidance of radiological procedures. Publications such as those mentioned above give very specific directions to help practitioners perform justification properly.

A number of papers have been published indicating that 20% to 40% of CT scans could be avoided if clinical decision guidelines were followed although some studies provide still higher figures [1,9]. Further, many studies revealed very low awareness of the referral guidelines [10,11,12,13].

The International Atomic Energy Agency (IAEA) has provided information for referrers through its website [14]. It includes the framework for justification, different levels at which justification is applied, responsibilities of referrers, how should justification be practiced, lists reasons for over-investigations and what knowledge is required for proper justification of a radiological procedure. It also amalgamates information from the EC publication and provides following guideline [xxx]:

When is an investigation useful and what are the reasons that cause unnecessary use of radiation?

According to the guidelines that were published by the European Commission (EC) in 2000 [8], and revised in 2008 [15], a useful investigation is one in which the result, either positive or negative, will alter a patient’s management or add confidence to the clinician’s diagnosis. According to the EC guidelines, there are some reasons that lead to wasteful use of radiation. With emphasis on avoiding unjustified irradiation of patients, the EC report has provided a check list for physicians referring patients for diagnostic radiological procedures:

- HAS IT BEEN DONE ALREADY? It is important to avoid repeating investigations which have already been performed relatively recently. Sometimes it is not possible to accurately track the procedures history of patients. Furthermore, patients may not be able to inform the practitioner that they had a similar procedure recently. It is important to attempt retrieving previous patient procedures and reports, or at least procedure history when possible. Digital data stored in electronic databases may help in that direction.

  To help in avoiding repeating investigations, it is necessary to establish a tracking system for radiological examinations and patient dose. The IAEA has taken steps towards that direction by setting up the “IAEA Smart-Card” project [16].

- DO I NEED IT? Performing investigations that are unlikely to produce useful results should be avoided, i.e. request procedures only if they will change patients' management. It is important for the practitioner to be sure that the finding that the investigation yields is relevant to the case under study.
- DO I NEED IT NOW? Investigating too quickly should be avoided. The referring medical practitioner should allow enough time to pass so that the disorder or impact of management of the disorder may be sufficiently evident.
- IS THIS THE BEST EXAMINATION? Doing the examination without taking into consideration the optimal contributions of safety, resource utilization and diagnostic outcome should be prevented. Discussion with an imaging specialist may help referring medical practitioners decide on proper modality and technique.
- HAVE I EXPLAINED THE PROBLEM? Failure to provide appropriate clinical information and address questions that the imaging investigation should answer should be avoided. Deficiencies here may lead to the wrong technique being used (e.g. the omission of an essential view).
- ARE TOO MANY INVESTIGATIONS BEING PERFORMED? Over-investigating. Some clinicians tend to rely on investigations more than others. Some patients take comfort in being investigated.

The referring medical practitioner should be aware about procedures which impart high radiation dose to patients in order to be more cautious in such cases. This does not mean that other procedures should be written without proper justification. A quantitative knowledge of doses of various procedures is useful for the referring medical practitioner. A review of radiation doses, what they mean and their role in risk assessment is available [17,18,19]. Some nuclear medicine procedures are also responsible for high radiation doses to patients and information on doses is available [20]. Information on radiation exposure in pregnancy is available [21].

Minimum Learning Outcomes for the Referrers in Radiation Protection

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competences (responsibility and autonomy)
Patient Safety / Risk Management	K1. Explain …Principles of radiation protection K2. Describe …The role of referrer in justification principle K3. Name …Radiation imaging tests which impart about 100 times higher radiation dose to patient and those which impart about 10 times K4. Discuss…few clinical situations where a test with non-ionizing radiation is better than one using ionizing radiation K5. Be aware about the well-established appropriateness criteria	S1. Assess…the radiation dose a patient has obtained in 2 chest CT scans, 3 chest x-rays and a thallium study for myocardial perfusion S2. Apply …Risk benefit analysis for the patient in S1 above assuming clinical condition as you may deem appropriate and discuss how principles of radiation protection will be applied to arrive at an appropriate test S3. Conduct…an analysis using standard appropriateness criteria and compare your outcome with the outcome you arrived in S2 above. S4. Carry out …survey of literature to find out radiation dose the patient will get if a cardiac CT, coronary angiography and percutaneous coronary intervention was needed in this patient	C1. Take responsibility for …justification in accordance with Basic Safety Standard (BSS) and provide guidance for optimization of the imaging test C2. Implement… Checklist provided in EC 2008 publication for referrers to avoid unjustified irradiation of patient C3. Develop …local guidelines for your colleagues for appropriateness for young patients with non-malignant chronic disease who are typically subjected to frequent CT scans (Pulmonary thromboembolism, Sarcoidosis…) C4. Manage…a patient who underwent an abdomen and pelvic CT scan plus barium follow through and was later found to be pregnant. The exposure occurred in the week when the period was just due C5. Advise…your colleague on what minimum clinical information is needed while sending a referral for CT scan

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[19] Radiation Protection of Patients website of the IAEA. Interventional cardiology: https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/5_InterventionalCardiology/index.htm#IntCardFAQ11

[20] Radiation Protection of Patients website of the IAEA. Nuclear Medicine: https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/3_NuclearMedicine/DiagnosticNuclearMedicine/DiagnosticNuclearMedicine-Generalissues.htm

[21] Radiation Protection of Patients website of the IAEA. Radiation exposure in pregnancy: https://rpop.iaea.org/RPOP/RPoP/Content/SpecialGroups/1_PregnantWomen/index.htm

4. Learning outcomes for physicians involved directly with the use of radiation

The benefits of many procedures that utilise ionising radiation are well established and accepted within the medical profession and by society at large. These benefits should substantially outweigh any of the risks to which patients are exposed during the application of these procedures. This is the basis of including diagnostic and therapeutic applications of ionising radiation in healthcare as common practice. When the procedure requires exposure to ionising radiation, the risks to be considered include the associated short and long-term health risks [1].

Having established the need for use of ionising radiation for the benefit of the patient, the justification process ensures that this benefit substantially outweighs any of the short- or long-term risks that the patient may be exposed to.

The ICRP in its 1990 and 2007 recommendations, state as a principle of justification that "*Any decision that alters the radiation exposure situation should do more good than harm*" [2, 3]. Elaborating on the expression "more good than harm" and taking into account the inherent uncertainty of risk estimation, in order to secure the desired risk-benefit relationship, the benefit should indeed substantially outweigh the incurred risks.

Furthermore, the ICRP suggests the use of three conceptual levels of justification:

- justification of medical uses of radiation in general,
- justification of generic medical procedures (such as the value of mammography as a practice), and
- Explicit justification of a specific procedure with a specific patient.

This document focuses on the latter level of justification, whose responsibility lies exclusively with the practitioner (physicians involved directly with the use of ionising radiation).

The KSC in radiation protection of these physicians should be of a high level to allow them to exercise this principle of justification optimally on a case-by-case base. The aim of this chapter is to provide the necessary KSC on radiation protection for each discipline of physicians involved directly with the use of ionising radiation.

References

[1] Malone, J. et.al, "Justification of a Consultation on Justification of Patient Exposures in Medical Imaging", Radiation Protection Dosimetry, Vol. 135, No.2, pp. 137-144, 2009

[2] ICRP, "The Recommendations of the International Commission on Radiological Protection", ICRP Publication 60, Ann. ICRP 21 (1-3), 1991

[3] ICRP, "The 2007 Recommendations of the International Commission on Radiological Protection", ICRP Publication 103, Ann. ICRP 37 (2-4), 2007

4.1. Diagnostic Radiologists

4.1.1. Entry requirements

4.1.2. CPD

4.2. Interventionalists (Radiologists, Cardiologists etc)

4.2.1. Entry requirements

4.2.2. CPD

4.3. Nuclear Medicine Physicians

Nuclear Medicine (NM) became an independent medical specialty in the European Directives in 1988. The minimum duration of the postgraduate specialized training in the European Union is 4 years, but may be extended beyond this period according to the requirements of training in other clinical disciplines.

Candidates for specialized training should have a good general background in internal medicine as well as the natural sciences. More detailed knowledge has to be acquired of those conditions which may need to be investigated or treated by NM techniques, as well as of some complementary methods as far as they relate to NM procedures. Education and training in basic sciences is required, such as radiation protection, pharmacokinetics, radiochemistry, instrumentation, computer science and quality control.

It is recognized that the practice of nuclear medicine varies from department to department within a country and from country to country. Not all NM physicians will perform all tasks described within this document. However, where a task is performed the relevant competencies represent what is thought to be good practice.

Furthermore, the amount of support to the NM physician in radiation protection issues from NM Technologists, Medical Physicists / Medical Physics Experts, Radiochemists / Radiopharmacists will vary greatly from department to department. In most situations, however, the NM practitioner is legally responsible in all RP affairs, rendering the Radiation Protection learning outcomes presented in this document indispensable.

The Radiation Protection learning outcomes for Nuclear Medicine Specialist physicians (appendix) consist of:

1. Basic Radiation Protection KSC,
2. NM Radiation Protection KSC for the areas of
    a. patient exposures (diagnostic and therapeutic),
    b. occupational and public exposures,
    c. advanced or specialized imaging and therapeutic techniques.

4.3.1. Entry requirements

The basic radiation protection knowledge is expected to be acquired during the general medical education (before specialization) in order for all physicians to possess RP skills and competence to act as referrers.

A Nuclear Medicine Specialist Physician is required to undergo training as detailed in the “Syllabus for postgraduate specialization in Nuclear Medicine” [1] and expected to conform to EQF level 7 in the abovementioned radiation protection KSC.

4.3.2. CPD

CPD for NM Specialist physicians needs to include an updating of RP KSC on a regular basis. One expects at least EQF Level 7 in all RP KSC specific to Nuclear Medicine and EQF Level 8 in RP KSC in the physician’s main areas of expertise or specialization.

Reference

[1] Cuocolo A, Milcinski M, Bischof Delaloye A. Syllabus for postgraduate specialisation in Nuclear Medicine: 2006/07 update. Eur J Nucl Med Mol Imaging 2010;37(2):430-3. DOI: 10.1007/s00259-009-1339-y

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Minimum Learning Outcomes for Nuclear Medicine Physicians in Radiation Protection

	Knowledge	Skills	Competence
Basic (General) RP	K1. List sources and properties of ionizing radiation K2. List and explain mechanisms of interaction between ionising radiation and matter / tissues K3. List and explain mechanisms of radioactive decay K4. Describe radiation effects upon cells and DNA K5. Describe cellular mechanisms of radiation response and repair, and cell survival K6. Describe radiation effects upon tissues and organs K7. Explain differences in radiation response between healthy and tumor tissues as basis for radiation treatment K8. Define and explain stochastic, deterministic, and teratogenic radiation effects K9. List and explain definitions, quantities and units of energy dose (Gy), equivalent, organ and effective doses (Sv) K10. Describe concepts of dose determination and dose measurements for patients, occupationally exposed personnel and the public K11. List and explain the basic principles of radiation protection as given by ICRP K12. Define ALARA and describe its applicability to Nuclear Medicine settings K13. Specify types and magnitudes of radiation exposures from natural and man-made sources K14. Describe types and magnitudes of radiation risk from internal and external exposure K15. List national and international bodies involved in RP regulatory processes K16. Specify the relevant regulatory framework (ordinances, directives, etc.) governing the medical use of ionizing radiation in your country	S1. Put into scale a reported dose value for a medical procedure to doses from natural sources. S2. Calculate a nominal risk (for stochastic effects) from a given effective dose. S3. Interpret such nominal risk in the context of other risks in daily life.	C1. Advise patients on the risks and benefits of a planned procedure in the role or referrer or practitioner

Patient RP	K17. Specify the relevant regulatory framework governing Nuclear Medicine practice in your country K18. List expected doses (to a reference person) for frequent Nuclear Medicine diagnostic procedures. K19. Explain the concepts and tools for scaling activity in pediatric Nuclear Medicine (EANM pediatric dosage card) K20. Explain the influence of the gamma camera energy window upon the resulting image K21. Describe the effect of reconstruction algorithms (FBP, iterative) on the properties of a tomographic image. K22. Explain the basic concepts of the MIRD scheme, including time-integrated activity in source region (cumulated activity) and time-integrated activity coefficient (residence time). K23. Explain the concept of determining the activity to be applied for treatment of benign thyroid disease from a radioiodine test K24. List therapeutic procedures performed less frequently or in specialized institutions and their special radiation protection aspects.	S4. Apply the principles of justification (risk / benefit assessment), optimization (including ALARA) and diagnostic reference levels to protect the patient from unnecessary risk from radiation. S5. For each diagnostic or therapeutic procedure, apply European and national laws, regulations, recommendations and standards related to patient safety. S6. Evaluate the radiation risk to embryo / fetus against the benefit of a Nuclear Medicine procedure. S7. Determine the activity to be applied to pediatric patients depending on body mass. S8. Calculate organ doses and effective dose from residence times using tools such as OLINDA. S9. Calculate the activity to be applied for treatment of benign thyroid disease from the data of a radioiodine test. S10. Set up a patient-individual treatment plan (together with a Medical Physics Expert) for a given therapeutic procedure.	C2. Take responsibility for justification of any patient's radiation exposure, taking into special consideration the case of a pregnant patient. C3. Take responsibility for choosing and performing the least dose-intense diagnostic procedure for a given referrer's request. C4. Take responsibility for conforming with diagnostic reference levels, where applicable. C5. Take responsibility for optimizing the activity used for a given diagnostic procedure based on patient-individual information. C6. Supervise quality control procedures on all equipment related to patient exposure (e.g. activimeters, probes, imaging devices like gamma cameras, SPECT, PET) C7. Take responsibility for applying the optimal activity for a given therapeutic procedure as determined in a patient-individual treatment plan (set up together with a Medical Physics Expert).

Occupational & Public RP	K25. Describe the key considerations relevant to radiation protection when designing a new Nuclear Medicine facility. K26. Explain quantitative risk and dose assessment for workers and public from internal and external exposure. K27. Describe the requirements for regulatory compliance with respect to the management and use of sealed and unsealed sources; including requirements for storage, shielding, record-keeping and audit. K28. Describe the requirements for regulatory compliance with regard to the management and disposal of radioactive waste and the transportation of radioactive substances. K29. Explain the nature and sources of internal and external radiation exposure and the relevant dose limits for the worker, including organ doses and dose limits for pregnant workers, and the public, and dose constraints for comforters and carers.	S11. Develop an organisational policy for the safe handling of unsealed radionuclides (e.g. storage, shielding, record keeping, transportation, and waste). S12. Develop an organisational policy to keep doses to personnel from external and internal (inhalation, ingestion) exposure as low as reasonably achievable (ALARA).	C8. Take responsibility for compliance with regulatory requirements concerning occupational and public radiation exposures. C9. Take responsibility for compliance with ALARA principles concerning occupational and public radiation exposures. C10. Take responsibility for the establishment of formal systems of work (Standard Operating Procedures)
advance and specialized procedures	K30. SPECT-CT K31. PET-CT K32. PET-MRT K33. therapy RSO / beta emitters K34. therapy targeted e.g. Y-90 K35. therapy DOTA-xx eg. Lu-177, Y-90 K36. Biologically equivalent dose (BED) from protracted irradiation as in NM	S13.	C11.

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4.4. Radiation Oncologists

In 2010 ESTRO issued updated guidelines for the education and training of radiation oncology based. The new guidelines are an update of the guidelines that for the first time was published in 1991 and last updated in 2002.

Contemporary medical education and training is based on competencies. ESTRO decided consequently to revise the core curriculum based on the principles of competency based training. These competencies are defined by the Canadian CANMEDS system and includes the following:

1. Medical expertise
2. Communication
3. Collaboration
4. Knowledge and science
5. Health advocacy/Social actions
6. Management/Organisation
7. Professionalism.

Knowledge and science (item 4) required for the profession includes comprehension of basic radiation physics, radiation physics applied to radiation therapy, radiation biology as well as radiation protection as follows:

Radiobiology

- interaction of radiation on molecular level (knowledge)
- DNA damage (comprehension)
- cellular effects, mechanisms of cell death (knowledge)
- repair of radiation damage (knowledge)
- cell survival curves (comprehension)
- normal tissue systems (knowledge)
- solid tumour and leukaemia systems (knowledge)
- effects of oxygen, sensitizers and protectors (comprehension)
- effect of time-dose-fractionation, LET, and different radiation modalities and
- interaction between cytotoxic therapy and radiation (comprehension)
- predictive assays (knowledge).

Basic radiation physics

- atomic and nuclear structure (knowledge)
- radioactive decay (knowledge)
- properties of particle and electromagnetic radiation (analysis)
- radioisotopes (knowledge).

Radiation physics applied to radiation therapy

- mechanism of action of an X-ray tube (comprehension)
- mechanism of action of a linear accelerators (comprehension)
- collimating systems (knowledge)
- brachytherapy systems (knowledge)
- mechanism of action of a cyclotron (comprehension)
- absorbed dose (comprehension)
- treatment planning including 3D planning, virtual and CT simulation and applies these
- procedures to plan patients' treatments (application)

- evaluate the benefits of conformal and special radiotherapy techniques (IORT, stereotactic
- radiotherapy) (evaluation)
- define target absorbed dose specification in external RT knowledge)
- define target absorbed dose specification in brachytherapy (knowledge)
- algorithms for 2D dose calculations (application)
- algorithms for 3D dose calculations (knowledge)
- applications of conformal RT, IMRT, IGRT, stereotactic RT and particle therapy (comprehension).

Concepts and principles of radioprotection

- general philosophy of radioprotection including ALARA (comprehension)
- stochastic and deterministic effects (analysis)
- risk of induction of secondary tumours (comprehension)
- radiation weighting factor (knowledge)
- equivalent dose – tissue weighting factor (comprehension)
- occupational/public health consequences of radiation exposure, radioprotection and dose
- limits for occupational and public exposure (comprehension)
- European and national legislation (knowledge)
- evidence based in radioprotection (knowledge)

Based on these and clinical as well as other scientific insight and knowledge under item 4 a set of learning outcomes has been set competence item 1, medical expertise. Those learning outcomes that are most closely linked to radiation protection are:

Ability to:

- relate knowledge of clinical and radiological anatomy, physics and biology to diagnosis and therapy
- discuss treatment options in the light of the prognosis
- develop an evidence based treatment strategy and to assess patients for curative and palliative external beam radiotherapy and brachytherapy
- evaluate and synthesise research evidence to change practice
- consent patients for radiotherapy
- prescribe appropriate dose and fractionation schedule for curative and palliative external beam radiotherapy and brachytherapy
- develop a radiotherapy treatment strategy and technique
- evaluate an external beam radiotherapy/brachytherapy treatment plan in collaboration with physicists and radiographers and knowing the responsibilities of own and others actions
- evaluate the risk of a external beam radiation therapy and brachytherapy treatment plan
- modify treatment plans according to patient’s individual needs, pre-morbid conditions, toxicity of radiotherapy and systemic treatments
- participate in quality assurance (QA) and follow safety policies
- contribute to planning using IMRT and other techniques such as stereotactic, particle and IGRT
- verify a radiotherapy treatment
- be aware of the clinical implications of IGRT
- be aware of the clinical implications and procedures of brachytherapy using sealed and unsealed sources
- assess and manage patients undergoing external beam radiotherapy and brachytherapy

- modify course of radiotherapy treatment for individual patients according to severity of reactions including adjustment for gaps in treatment
- assess patients for combined modality therapy
- administer and take clinical responsibility for the delivery of radiation therapy together with systemic agents (and where necessary to work in collaboration with other medical specialists involved in systemic therapies) on an in- or outpatient basis.

The guidelines haven been endorsed by European national radiation oncology societies as well as by the European Union of Medical Specialists (UEMS), and can be found at:

http://www.estro-education.org/europeantraining/Documents/CC_FINALapprovedESTRO_CCApril2010.pdf

4.4.1. Entry requirements

The ESTRO guidelines for education and training in radiation oncology is based on the entry criteria for medical specialisation (residential programme) as defined by UEMS, .i.e. the degree of MD or equivalent corresponding to minimum 5 year education and training at medical school.

4.4.2. CPD

There are currently no recommendations issued at the European level with respect to continuous professional development (CPD) for radiation oncologists. ESTRO do, however, provide an extensive educational programme covering novel treatment strategies that is highly relevant also from a radiation protection perspective. National regulations with respect to CPD requirements may though vary.

5. Learning outcomes for Dental Surgeons ~~and Dental Assistants~~

In 1995, the Commission of the European Communities adopted a directive from the European Parliament and it's Council on the recognition of professional qualities (REF). In that document the following has been stated on the profession of Dentistry: 'All Member States must recognise the profession of dental practitioner as a specific profession distinct from that of medical practitioner, whether or not specialised in odonto-stomatology. The Member States must ensure that the training given to dental practitioners equips them with the skills needed for prevention, diagnosis and treatment relating to anomalies and illnesses of the teeth, mouth, jaws and associated tissues'.

In the context of radiation protection, dentistry is unique in that it is largely primary care based and the roles of referrer and practitioner are usually combined. In addition, dentists often work in relative isolation from colleagues and without readily available support from a dental peer group and radiation protection support professionals. Notwithstanding this, practice in this area is governed by the European BSS and MED [REF].

In addition, the radiation protection situation in dentistry involves specialist dental and maxillofacial radiologists and a number of ancillary groups/ dental care professionals who play roles in radiography. With regard to the dental and maxillofacial radiologists, this group is most logically treated in the same way as Diagnostic Radiologists (section 4.1), Other groups of medical and dental care professionals (e.g. radiographers, dental nurses, hygienists, therapists, etc.) play varied and important roles and need to be treated separately, particularly in the context of variability of practice and role classification within Europe.

5.1. Entry requirements

The professional activity of the dental practitioner must be carried out by holders of a qualification as dental practitioner, as set out by the Commission [REF]. It is further stated that 'dental education shall comprise at least a total of 5 years full-time theoretical and practical study, comprising a study given in a university (or in an institute providing training and recognised as being of an equivalent level or under the supervision of a university)'. Work is ongoing to achieve alignment with the levels defined in the Bologna process. It is normally required that dentists must also hold professional registration (normally statutory).

5.2. CPD

In the case of dentists, CPD is regarded as essential to maintain good practice. In some European countries it is a requirement for continued professional registration [GDC; Cowpe et al]. Radiation Protection is recognized as a key component of CPD in dentistry [MED, RP136] and efforts are being made to harmonize practice in Europe [dentCPD.org].

References

Advisory Committee on the Training of Dental Practitioners. Report and recommendation concerning clinical proficiencies required for the practice of dentistry in the European Union. European Commission, Directorate General XV, (XV/E/8316/7/93-EN). Brussels:

ACDTP, 1995.

RP136

The Dent*CPD* Team (Cowpe J, Bullock A, et al) (2011) Harmonisation and Standardisation of European Dental Schools' Programmes of Continuing Professional Development for Graduate Dentists – DentCPD. *Journal of the European Higher Education Area*A3.3-7 pg1-26

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	Knowledge *Unless otherwise stated, the following outcomes apply to all of intraoral, panoramic, cephalometric and CBCT imaging*	Skills	Competence
Nature of X-radiation	K1. Be aware of the electromagnetic spectrum. K2. Understand the place of x-rays as ionizing radiation within the electromagnetic spectrum. K3. Explain background radiation.	S1. Create a context for risk/benefit discussions	C1. Implement radiation protection based on a sound understanding of the nature of ionizing radiation
Production of X-rays	K4. Describe how x-rays for diagnostic applications are produced		
Interaction of X-rays with matter	K5. Explain how x-rays interact with matter. K6. Understand absorption and scatter of X-rays in different materials, including tissues.	S2. Select radiation protection measures which use appropriate attenuation of x-rays. S3. Implement measures to avoid scatter and unnecessary absorption to patients, staff and the public	
Biological effects of radiation	K7. Explain the biological effects of radiation. K8. Understand somatic and genetic effects of x-rays on tissues. K9. Understand stochastic effects and radiation-induced tissue reactions.	S4. Communicate effectively to patients the nature of radiation risks.	

Radiation dose and risk	K10. Define the units of radiation dose. K11. Understand the concepts of clinical radiation dose measurement. K12. Describe the factors which influence radiation exposure and dose. K13. Understand the influence of patient age on radiation risk. K14. Understand Diagnostic Reference Levels and European or national dose surveys. K15. Understand the level of radiation-related risk associated with dental imaging to patients, operators and the public.	S5. Take account of dose when establishing imaging protocols. S6. Use exposure factors to optimize dose. S7. Take account of patient age when establishing imaging protocols.	C2. Implement protection measures appropriate to the level of exposure and risk C3. Establish a framework for dose monitoring. C4. Compare patient doses with DRLs and take appropriate actions when necessary.
Radiation Protection	K16. Understand the principles of radiation protection. K17. Understand the need for justification, including consent. K18. Describe referral guidelines for dental imaging. K19. Understand the role of other forms of clinical examination and diagnosis not involving ionizing radiation. K20. Understand when to refer to specialists in dental and maxillofacial, or medical, radiologists. K21. Explain the ALARA principle. K22. Understand the inter-relationship of radiation dose and image quality. K23. Describe the practical steps available in dental imaging to optimize patient dose. K24. Describe practical dose reduction strategies for dental staff and the public, including the use of shielding and dose monitoring. K25. Describe a quality assurance programme for dental imaging. K26. To understand the clinical audit cycle as applied to dental imaging.	S8. Perform the justification process, taking into account the risks and benefits. S9. Source referral guidelines for dental imaging. S10. Apply referral guidelines to specific clinical situations. S11. Source advice on optimization. S12. Apply measures to optimize exposure consistent to diagnostic image production. S13. Apply measures to limit staff and public exposures. S14. Source advice on quality assurance programmes. S15. Detect and act on significant changes in imaging performance. S16. Source advice and perform clinical audit.	C5. Lead the implementation of the evidence-based radiation protection programme. C6. Take responsibility for and implement justification. C7. Take responsibility for and establish practices to ensure optimization of dental radiographic exposures. C8. Take responsibility for and establish practices to ensure dose limitation for dental staff and the public. C9. Take responsibility for and establish practices to ensure implementation of a quality assurance programme. C10. Review justification, optimization and limitation though clinical audit.

Regulations & Medico-legal issues	K27. Name and explain the relevant, international, European, national and local regulations relating to dental imaging. K28. Understand the responsibilities and roles of different professionals relating to use of X-rays in dental imaging.	S17. Comply with relevant regulations. S18. Seek advice from appropriate sources with regard to regulations and compliance.	C11. Consult with appropriate professionals to achieve optimal radiation protection within the regulations.
Equipment and Techniques	K29. Describe the concept of the imaging "chain", from initiating the x-ray exposure to display of the image. K30. Explain the difference between 2D / 3D imaging, analogue/ digital, and extraoral/ intraoral imaging. K31. Describe how x-rays interact with image detectors to give an image. K32. Describe the different examination techniques in dental and maxillofacial imaging. K33. Describe the construction and function of equipment for dental imaging (intraoral and extraoral). K34. Understand the influences of chemical film processing and digital post-acquisition processing on the final image.	S19. Select appropriate techniques and equipment factors for acquisition and post-acquisition processing.	C12. Establish a procurement policy for equipment which takes account of radiation protection principles. C13. Establish and implement a preventative maintenance programme for dental imaging equipment. C14. Establish and implement an equipment applications training programme for staff, based on radiation protection considerations.
INTERPRETATION	K35. Understand the need to perform and record a clinical evaluation of dental x-ray imaging examinations. K36. Understand the principles of diagnostic imaging. K37. Describe the appearance of normal anatomical structures in radiographs. K38. Describe the radiological appearances of pathoses affecting the teeth and jaws. K39. Explain principles of projection and its influence on image interpretation.	S20. Recognize the appearances of normal anatomy on dental imaging examinations, including normal variants. S21. Recognize the signs of pathoses on dental radiological examinations. S22. Interpret dental radiological images and construct and record a report	C15. Implement practices which put optimal patient care at the centre of dental imaging.

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6. Learning outcomes for Radiographers

6.1. Radiology

6.1.1. Entry requirements

6.1.2. CPD

6.2. Nuclear Medicine

6.2.1. Entry requirements

6.2.2. CPD

6.3. Radiation Oncology

6.3.1. Entry requirements

6.3.2. CPD

7. Learning outcomes for Medical Physicists/Medical Physics Experts

The mission statement for Medical Physics Services is: “Medical Physics Services will contribute to maintaining and improving the quality, safety and cost-effectiveness of healthcare services through patient-oriented activities requiring expert action, involvement or advice regarding the specification, selection, acceptance testing, commissioning, quality assurance including quality control, and optimised clinical use of the medical devices used in Diagnostic and Interventional Radiology, Nuclear Medicine and Radiation Oncology and regarding risks from associated physical agents (particularly though not exclusively ionising radiation); all activities will be based on current best evidence or own scientific research when the available evidence is not sufficient. The scope includes risks to volunteers in biomedical research, workers and public (when associated with patient safety and including carers and comforters)” (EC, 2012, Guidelines on the Medical Physics Expert).

The term ‘physical agent’ includes both ionising and non-ionising radiations. The use of non-ionising radiation imaging modalities as alternatives to ionising radiation is mandated by Article 3 of 97/43/Euratom and Article 80 of its proposed successor (‘Proposal for a Council Directive laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation’ of 29.09.2011).

This mission includes the following key activities: Comprehensive Physics Problem Solving Service, Radiation Dosimetry Measurements, Patient Safety / Risk Management (including volunteers in biomedical research), Occupational and Public Safety / Risk Management (when associated with patient safety and including carers and comforters), Clinical Medical Device Management (particularly specification, selection, acceptance testing, commissioning and quality assurance including quality control), Clinical Involvement, Development of Service Quality and Cost-Effectiveness, Expert Consultancy, Education of Healthcare Professionals (including Medical Physics trainees), Health Technology Assessment (HTA) and Innovation.

Definitions of these key activities and a complete inventory of the underpinning KSC can be found in the document ‘Guidelines on Medical Physics Expert’ (EC,). Owing to the special and extensive role of Medical Physicists and Medical Physics Experts in radiation protection the KSC inventory is quite extensive. An illustrative subset is presented in this document. Readers are directed to the aforementioned reference for a complete set of KSC.

The Radiation Protection learning outcomes presented in this document are divided into:

a) Core Radiation Protection learning outcomes common to all three areas of Medical Physics,
b) Radiation Protection learning outcomes specific to each area of the three areas of Medical Physics.

These are presented as an appendix to this chapter.

7.1. Diagnostic & Interventional Radiology

7.1.1. Entry requirements

At entry level in Diagnostic and Interventional Radiology one expects EQF level 7 in:

(a) all the knowledge learning outcomes in the Core KSC and the KSC specific to Diagnostic and Interventional Radiology
(b) the skills and competences in the document “Clinical Training of Medical Physicists Specializing in Diagnostic Radiology” (IAEA, 2010).

7.1.2. CPD

In the case of Medical Physicists the term CPD has a special meaning which is: advanced education, training and experience leading to recognition as Medical Physics Expert (in this case in Diagnostic and Interventional Radiology). One expects EQF Level 8 in all the Core KSC and the KSC specific to Diagnostic and Interventional Radiology.

7.2. Nuclear Medicine

7.2.1. Entry requirements

At entry level in Nuclear Medicine one expects EQF level 7 in:

(a) all knowledge learning outcomes in the Core KSC and the KSC specific to Nuclear Medicine
(b) the skills and competences in the document “Clinical Training of Medical Physicists Specializing in Nuclear Medicine” (IAEA, 2011).

7.2.2. CPD

In the case of Medical Physicists the term CPD has a special meaning which is: advanced education, training and experience leading to recognition as Medical Physics Expert (in this case in Nuclear Medicine). One expects EQF Level 8 in all the Core KSC and the KSC specific to Nuclear Medicine.

7.3. Radiation Oncology

7.3.1. Entry requirements

At entry level in Radiation Oncology one expects EQF level 7 in:

(a) all the knowledge learning outcomes in the Core KSC and the KSC specific to Radiation Oncology
(b) the skills and competences in the document “Clinical Training of Medical Physicists Specializing in Radiation Oncology” (IAEA, 2009).

7.3.2. CPD

In the case of Medical Physicists the term CPD has a special meaning which is: advanced education, training and experience leading to recognition as Medical Physics Expert (in this case in Radiation Oncology). One expects EQF Level 8 in all the Core KSC and the KSC specific to Radiation Oncology.

Appendix: Illustrative Subset of Radiation Protection Learning Outcomes for Medical Physicists and Medical Physics Experts

Core Radiation Protection KSC for Medical Physics

	Knowledge	Skills	Competence
Comprehensive Physics Problem Solving Service	K6. Explain quantitatively using biological models the beneficial and/or adverse biological effects of radiation, the factors influencing the magnitude of the biological effect and the way these can be manipulated to improve clinical outcomes e.g., in the case of ionizing radiation this would include radiobiological models, radiation epidemiology, mutagenesis, carcinogenesis (including leukaemogenesis), genetic effects on offspring from irradiation of gametes, teratogenic effects on the conceptus, skin effects, eye cataracts, cell survival curves, linear-quadratic model, absorbed dose, type of radiation (RBE, radiation weighting factor), tissue radiosensitivity (LET, RBE, tissue weighting factor), dose rate, presence of radiosensitisers, oxygen and radioprotectors, age, dose-effect relationships.	S5. Apply the general concepts, principles, theories and practices of physics to the solution of clinical problems concerning safety / risk management with respect to radiation. S6. Use the general concepts, principles, theories and practices of physics to analyze the research literature concerning safety / risk management with respect to radiation. S7. Use physics research skills to develop the experimental evidence base for safety / risk management with respect to radiation when present evidence is insufficient. S8. Use the general concepts, principles, theories and practices of physics to ensure effective and safe practice in own area of medical physics.	C6. Take responsibility for the setting-up and organization of a Medical Physics Service in own area of medical physics practice. C7. Take responsibility for applying the general concepts, principles, theories and practices of physics to the solution of clinical problems concerning the optimal use of medical devices and management of risk from radiation in own area of medical physics practice. C8. Take responsibility for using the general concepts, principles, theories and practices of physics to analyze the research literature concerning the optimal use of medical devices and management of risk from radiation and to transfer relevant published research results to the clinical environment in own area of medical physics practice. C9. Take responsibility to use the general concepts, principles, theories and practices of physics for the selection and insertion of new medical devices within own area of medical physics practice and to facilitate safe use of said devices. C10. Take responsibility to use physics research skills to develop the evidence base for the safe use of medical devices in own area of medical physics practice when present evidence is insufficient.

Radiation Dosimetry Measurements	K7. Define and explain the dosimetric quantities used to assess beneficial or adverse biological effects of radiation in own area of medical physics practice (*use ICRU 85, 2011 definitions*). K8. Define patient dosimetric quantities for each clinical procedure in own area of medical physics and explain methods for measurement / calculation. K9. Explain the relationship between the various dosimetric quantities used. K10. Define operational quantities used in personal dosimetry e.g., H*(10), H'(0.07, angle), $H_p(10)$, $H_p(0.07)$ and methods for measurement / calculation. K11. Describe and explain in detail and quantitatively the structure, operation and advantages / disadvantages of the various types of patient and personal dosimeters and area monitors available for the various types of radiation including criteria for selection, management, calibration, traceability and user protocols.	S9. Select and use instruments for dosimetric quantities for patients, workers and public in own area of medical physics practice. S10. Develop rigorous dosimetry protocols in own area of medical physics practice. S11. Interpret the results of dosimetry measurements. S12. Maintain calibration of dosimetry instruments. S13. Implement cross-calibration procedures for dosimetry instruments. S14. Convert dosimetry quantities measured in air or other medium to relevant dosimetric quantities in tissue.	C11. Take responsibility for statutory and institutional requirements for Medical Physics Services in own area of medical physics practice with respect to Radiation Dosimetry Measurements (*including ionising and non-ionising radiations*). C12. Equip an appropriate laboratory for the measurement of dosimetric quantities for the radiation protection of patients, workers and public in own area of medical physics practice. C13. Take responsibility for the selection, acceptance testing, commissioning and quality control of instruments for the measurement of dosimetric quantities in own area of medical physics practice. C14. Take responsibility for the handling, management, calibration and maintenance of dosimetry instruments in own area of medical physics practice. C15. Take responsibility for dosimetric investigations and the supervision of dosimetry measurements.

Patient Safety / Risk Management	K12. Explain the principles of patient risk management as applied to radiation in own area of medical physics. K13. Explain relevant international, EU, national and local legislation, recommendations and documentation regarding risk from radiation with the purpose of hazard prevention and emergency preparedness in the healthcare environment with regard to patient safety / risk management. K14. Describe the process and practical implementation of patient risk assessments in own area of medical physics practice. K15. Describe and explain the procedures for the prevention, investigation and handling of adverse incidents (including use of Root Cause Analysis / Failure Modes and Effects Analysis or alternative methodology; recommendations of appropriate remedial actions) with respect to patients in own area of medical physics practice. K16. Name and explain the function of the main National, European and International organizations concerned with protection of patients from radiation. K17. Explain how research exposures are managed in own area of medical physics practice including the processes of ethical review and including the use of dose constraints where appropriate. K18. Describe the requirements for, and the practical implementation of, appropriate systems for the monitoring of doses to patients from radiation in own area of medical physics practice. K19. Describe the principles and practice of contingency planning and emergency procedures with respect to patient safety in own area of medical physics. K20. Describe the key considerations for the design of a new facility with regards to patient safety. K21. Explain how the application of good safety practices and the use of appropriate devices and techniques are used to optimize clinical protocols. K22. Explain the characteristics and limitations of the various models / algorithms used in the quantification of patient doses from external sources and compartmental / bio-kinetic models of the MIRD model for internal radionuclide patient dosimetry.	S15. Calculate patient risk from measurement data of the dosimetry quantities used to assess adverse biological effects. S16. Assess patient risks from given procedures in own area of medical physics practice from measured patient dose data and dose-effect relationships. S17. Apply the principles of justification (risk / benefit assessment), optimization (including ALARA) and the setting up of reference levels to protect the patient from unnecessary risk from radiation. S18. Apply the various means of dose reduction (appropriate source strengths, exposure time, distance, shielding) in protocol optimization. S19. Calculate risks to the unborn child in the case of exposure to radiation. S20. Develop an organisational policy to achieve regulatory compliance for patient safety from radiation in own area of medical physics practice. S21. Investigate incidents to determine the cause(s) and recommending appropriate remedial action with respect to patient safety in own area of medical physics practice. S22. Conduct critical examinations (interlocks, warning systems, safety design features and barriers) related to patient safety in own area of medical physics practice. S23. Give advice on the choice and use of protective equipment related to patient safety in own area of medical physics practice. S24. Assess patient risks for a given experimental procedure.	C16. Inventorize sources of radiation present in the hospital environment with respect to patient safety. C17. Take responsibility for the ongoing optimization of existing and newly introduced protocols in own area of medical physics practice with respect to patient protection and in accordance with the latest published evidence or own research when the available evidence is not sufficient. C18. Carry out a radiation dose audit with respect to patient safety in own area of medical physics practice. C19. Take responsibility for the development of patient safety teams in own area of medical physics practice. C20. Implement corrective procedures with regard to patient safety in own area of medical physics practice. C21. Take responsibility for the planning for emergency situations with regard to patient safety in own area of medical physics practice. C22. Implement a detailed organisational policy to support the safety of patients in own area of medical physics practice. C23. Take responsibility for the establishment and use of appropriate reference levels with respect to risks from radiation. C24. Develop contingency plans for emergency procedures with respect to patient safety in own area of medical physics practice. C25. Take responsibility for the design of a new facility (including waiting and resting rooms) in own area of medical physics practice taking into consideration patient safety. C26. Take responsibility for the surveillance of installations with respect to protection of patients from radiation. C27. Take responsibility for the management of good and safe practice in the use of ionising radiation beams and sealed / unsealed sources in own area of medical physics practice in relation to patient safety.

Occupational & Public Safety / Risk Management	K23. Describe the possible adverse biological effects (including mechanism) to workers / public from radiation including the factors impacting the magnitude of the biological effect. K24. Explain the principles of occupational risk audit and management, hazard prevention and emergency preparedness as applied to radiation in own area of medical physics practice. K25. Explain relevant international, European, national and local legislation, recommendations and documentation regarding risk from radiation with regard to occupational and public safety in own area of medical physics practice. K26. Explain how the principles of justification, optimization (including ALARA), and risk limitation are used for occupational and public protection from the deleterious effects of radiation. K27. Name and explain the function of the main National, European and International organizations concerned with protection of workers and the general public from radiation (e.g., ICRP, ICNIRP, IAEA). K28. Explain how sites and facilities are designed to ensure protection of workers and the general public. K29. Describe and explain the procedures for the prevention, investigation and handling of adverse incidents (including root causes and recommendations of appropriate remedial actions) with respect to workers/public in own area of medical physics practice. K30. Define and measure or calculate the operational quantities (including units and inter-relationships) used in personal dosimetry in own area of medical physics practice (e.g., ambient, directional and personal dose equivalents at recommended depth, annual limit on intake, derived air concentration). K31. Calculate doserate from a point source.	S25. Perform occupational / public risk assessment based on facility survey and estimated / measured dosimetry data in own area of medical physics. S26. Assess occupational risk from given procedures in own area of medical physics practice from measured occupational dose data and dose-effect relationships. S27. Carry out a risk audit with respect to occupational / public safety from radiation in own area of medical physics. S28. Evaluate facilities/systems/procedures in terms of occupational / public safety from radiation in own area of medical physics. S29. Develop a detailed organisational policy to support the safety of staff / public in own area of medical physics. S30. Carry out specialized safety related calculations (e.g., shielding calculations including use of specialized shielding calculation software). S31. Investigate incidents to determine causes and recommending appropriate remedial action with respect to occupational / public safety in own area of medical physics practice. S32. Give advice on personal protective equipment and fixed and mobile shielding devices in own area of medical physics.	C28. Inventorize physical agent sources present in the hospital environment with respect to occupational / public safety / risk management. C29. Manage the optimization of protocols with respect to radiation and occupational / public risk in own area of medical physics. C30. Take responsibility for the conduct of radiation surveys and implementation of resultant recommendations. C31. Take responsibility for the management and organization of measures for the safety of staff and public from radiation, practical measures to support protection, good safety practice, methods of compliance, record keeping and the use of personal protective equipment in own area of medical physics. C32. Develop occupational and public safety / risk management teams in own area of medical physics. C33. Take responsibility for the prevention, investigation and handling of adverse incidents (including root causes and recommendations of appropriate remedial actions) with respect to workers/public in own area of medical physics. C34. Take responsibility for the management of emergency situations with regard to occupational and public safety in own area of medical physics. C35. Take responsibility for the establishment of formal systems of work (‘local rules’). C36. Develop an organisational policy to achieve regulatory compliance for occupational / public safety from radiation in own area of medical physics (e.g., security considerations, storage, shielding, record keeping, audit, waste, transportation of hazardous materials).

Occupational & Public Safety / Risk Management (cont.)	K32. Explain the roles of occupational / public safety personnel associated with radiation such as Radiation Protection Expert and Radiation Protection Officer as defined in European, national and local legislation / documentation. K33. Explain in quantitative terms the various means of dose reduction for external radiation (source strengths, exposure times, distance, shielding) and internal radionuclides with respect to occupational / public safety. K34. Describe the process and practical implementation of occup. / public risk assessments in own area of medical physics practice, using techniques for the qualitative and quantitative assessment of risk. K35. Describe the key considerations for the design of a new facility (including waiting and resting rooms) with regards to occupational / public safety in own area of medical physics. K36. Describe the principles and practice of contingency planning and the implementation of emergency procedures with respect to occupational / public safety in own area of medical physics. K37. Describe suitable processes for the reporting of radiation incidents involving workers / members of the general public in the context of own area of medical physics practice, using root cause analysis and/or other tools to determine the underlying cause(s). K38. Describe the requirements for, and the practical implementation of, appropriate systems for the monitoring of radiation dose to the worker, including extremity doses and dose limits for pregnant and lactating workers, and young workers; and for the public; including selection, management and calibration of devices used to measure such doses, dose records and techniques for dose measurement. K39. Explain how the application of good radiation safety practice and the use of appropriate personal protective equipment minimises worker and public doses in medicine.	S33. Conduct critical examinations (interlocks, warning systems, safety design features and barriers) related to occupational / public safety in own area of medical physics practice. S34. Develop contingency plans for emergency situations with respect to occupational / public safety in own area of medical physics practice. S35. Design new facilities in own area of medical physics practice with due consideration to occupational / public safety. S36. Set up area surface/air monitoring devices where appropriate and according to hazard type and level. S37. Manage a contamination incident. S38. Implement appropriate systems for monitoring radiation doses from external / internal sources for workers (including pregnant / lactating workers), comforters, carers and the public; including selection and management of devices used to record doses in own area of medical physics practice. S39. Assess occupational risks for a given experimental procedure.	C37. Take responsibility for the management of good and safe practice in the use of radiation beams and sealed / unsealed sources in own area of medical physics practice in relation to occupational and public safety. C38. Take responsibility for the design of a new facility (including waiting and resting rooms) in own area of medical physics practice taking into consideration occupational / public dose limits, dose constraints, designation of areas and ALARA. C39. Take responsibility for the planning for emergency situations with regard to occupational and public safety in own area of medical physics practice. C40. Implement contingency plans for emergency procedures in own area of medical physics practice. C41. Classify work areas and workers according to hazard levels. C42. Investigate incidents. C43. Assess occupational risks for a given experimental procedure particularly when this is linked to patient risk (e.g., interventional procedures). C44. Take responsibility for the surveillance of radiological installations with respect to radiation protection of the workers and public. C45. Take responsibility for regulatory compliance with respect to the management of radiation sources, radiation waste and the transportation of radioactive substances.
	K40. List and explain the functioning of safety systems found in own area of medical physics practice vis-a-vis occupational / public safety.		

Clinical Medical Device Management	K41. Explain the meaning of 'acceptability criteria' as applied to medical devices. K42. Define and explain the principles of quality, quality assurance, quality control, performance indicators, constancy testing, quality control tests, test frequency, tolerances, and action criteria with respect to medical devices. K43. Describe and explain in detail international, national and local protocols for assessing the performance of medical devices in own area of medical physics practice. K44. Explain the principles of medical device (including associated software) management including planning, evaluation of clinical needs, specification for tender purposes, evaluation of tendered devices, procurement, acceptance testing, commissioning, constancy testing, maintenance and decommissioning; service contract management. K45. List and explain the functions of the major International and European standard (e.g., IEC, CENELEC) setting bodies (and others such as NEMA) for medical devices and describe the various types of documentation issued by these bodies and their use in medical device management.	S40. Use appropriate physical / software test objects / phantoms, data acquisition protocols, data recording forms, national / European / international protocols to measure the performance indicators of medical devices in own area of medical physics, assess deviations from acceptable values (as indicated by manufacturer and international / European / national standard setting bodies), evaluate the relevance of deviations for clinical practice and suggest actions for restoring default performance. S41. Evaluate technical specifications of commercial devices in own area of medical physics. S42. Carry out acceptance testing, commissioning and constancy testing procedures in own area of medical physics practice. S43. Evaluate whether medical device service agreements (including software updates) are adequate to ensure patient and occupational safety in own area of medical physics practice. S44. Interpret and apply local occupational protection rules as applicable to medical device QC procedures. S45. Evaluate and participate in the selection of medical devices in a tender in own area of medical physics practice.	C46. Take responsibility for medical device (including software, information systems, PACS) management including planning, evaluation of clinical needs, specification for tender purposes, evaluation of tendered devices, acceptance testing, commissioning, constancy testing (including setting of warning and suspension levels), maintenance, decommissioning and service contract management in own area of medical physics practice. C47. Participate in the procurement of new devices in own area of medical physics practice. C48. Take responsibility for the maintenance of quality control records. C49. Establish and plan QA/QC procedures in appropriate support of the specific activity in own area of medical physics practice. C50. Take responsibility for the development of an institutional quality assurance / quality control medical device service as required by European and national medical device standard setting bodies in own area of medical physics practice. C51. Take responsibility for the development and ongoing update of departmental quality control protocols for medical devices in own area of medical physics practice. C52. Participate in the installation of new devices in own area of medical physics practice. C53. Negotiate device acceptance with provider and own department management following acceptance tests. C54. Organize, manage and train quality control teams in own area of medical physics practice. C55. Decide if actions are required on a medical device to restore default performance. C56. Define warning and suspension levels for devices.

Clinical Involvement	K46. Explain the risk/benefit justification of procedures in own area of medical physics K47. Explain protocol optimization principles in own area of medical physics practice. K48. Explain the design principles, relevant legislation issues and approval procedures for clinical trials. K49. Describe general indications and contra-indications for the use of devices in own area of medical physics practice. K50. Describe the purpose and implementation of local systems for formal incident reporting and internal review with regard to risk management.	S46. Analyze critically protocol proposals in terms of feasibility, effectiveness and safety. S47. Operate medical devices in own area of medical physics practice effectively and safely.	C57. Oversee daily patient safety / risk management in procedures involving radiation in own area of medical physics. C58. Participate in the evaluation and optimization of clinical protocols and risk elimination / reduction in own area of medical physics in both routine and non-routine procedures. C59. Participate in definition of clin. procedure acceptability limits. C60. Advise on the most appropriate procedure with respect to risk/benefit ratio. C61. Supervise paediatric investigations with respect to dose optimiz. C62. Advise other healthcare professionals on optimization and safety of individual patient examination / treatment and examination / treatment protocols.
Development of Service Quality vis-à-vis Safety	K51. Define quality objectives in own area of medical physics practice. K52. Describe the institutional framework of QA activity and regulation in own area of medical physics practice. K53. Describe the purpose and implementation of local systems for formal incident reporting and internal review with regard to improvement of service quality.	S48. Set up a service quality development strategy for own area of medical physics practice. S49. Measure quality management performance and improvements in own area of medical physics practice. S50. Participate in the reporting, review and analysis of incidents.	C63. Advise on the technical aspects impacting the clinical effectiveness and safety of new medical devices or techniques prior to their introduction into clinical practice. C64. Participate in the design and implementation of QA systems in own area of medical physics practice. C65. Assume responsibility for quality management audits involving medical devices and associated radiation. C66. Take responsibility for the formal review and analysis of incidents within own area of medical physics practice.
Expert Cons.	K54. Describe the general role of the medical physicist as consultant in own area of medical physics practice. K55. Discuss the specific ethical issues involved in delivering a consultancy service in own area of medical physics practice (including conflict of interest issues).	S51. Identify and manage ethical issues involved in delivering a consultancy service in own area of medical physics practice (including conflict of interest issues).	C67. Produce and/or audit reports as an independent provider for organizations other than one's own. C68. Design and evaluate continuous professional courses in own area of medical physics practice for organizations other than one's own.

Educ. of Healthcare Professionals (including Medical Physics trainees)	K56. Discuss the principles of modern adult pedagogy and apply them to the radiation protection educational needs of healthcare professionals (including continuous professional development activities) and including training associated with the introduction of new devices and techniques. K57. Discuss the factors which impact the choice of learning outcomes and methods of knowledge transfer to the case of medical device and radiation knowledge for specific healthcare professionals in specific clinical environments (such as previous education and training and the usability and safety features of devices).	S52. Set up an inventory of learning outcomes tailored to the specific learning needs of specific healthcare professionals in specific clinical environments in conjunction with the leaders of the respective healthcare professions. S53. Prepare effective and efficient modes of knowledge transfer activities specific to the specific learning needs of specific healthcare professionals in specific clinical environments in conjunction with the leaders of the respective healthcare professions.	C69. Take responsibility for the education of healthcare professionals (including Medical Physics trainees) regarding the optimised clinical use of medical devices and safety from radiation in specific clinical environments in own area of medical physics practice. C70. Take responsibility for the education of healthcare professionals in performing QC procedures in own area of medical physics. C71. Take responsibility for the education of healthcare professionals regarding protection from radiation including the use of personal dose monitors and personal protection equipment. C72. In conjunction with other healthcare professionals take responsibility for ensuring that referrers are knowledgeable of current referral criteria in own area of medical physics practice.
Health Technology Assessment	K58. Explain the principles of HTA as applied to medical devices and procedures in own area of medical physics practice. K59. Discuss the ethical issues associated with clinical trials involving radiation. K60. Describe how to apply for approval from a hospital and /or university based ethics committee for a clinical trial involving radiation. K61. Describe the fundamentals and design models of clinical trials in own area of medical physics practice.	S54. Perform a systematic review of the existing evidence base to evaluate the clinical effectiveness and safety of a new medical device or new procedure involving radiation. S55. Conduct the technical components of an HTA project in own area of medical physics practice.	C73. Use the methodologies of HTA to carry out a HTA in conjunction with other healthcare professionals. C74. Take responsibility for the technical component of a HTA involving radiation. C75. Take responsibility and communicate with relevant authorities with regards to safety from radiation in the case of clinical trials. C76. Apply for approval from a hospital and /or university based ethics committee for a clinical trial involving radiation. C77. Advise on and take responsibility for the preclinical device aspects of the ethical review of a clinical trial involving radiation.
Innovation		S56. Apply the methodology of horizon scanning (including listing of specific information sources) for new and emerging technologies to own area of medical physics practice.	C78. Take responsibility for the development of new radiation devices (including software) and modification of existing radiation devices (including software), including their implementation and evaluation in response to clinical needs and legal issues in own area of medical physics practice.

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Radiation Protection KSC for Medical Physics in Diagnostic and Interventional Radiology

	Knowledge	Skills	Competence
Comprehensive Physics Problem Solving Service	K1. For each imaging modality, list and explain user controlled variables/settings and their impact on image quality/diagnostic efficacy and patient risk. K2. For each imaging modality, describe and explain differences in device design and their effects on image quality and patient safety for dedicated devices (e.g., mammography, dental systems for projection x-ray imaging). - Describe in detail x-ray projection and CT imaging devices for general projection x-ray imaging, chest systems, mammography (including tomosynthesis), dental systems (intra-oral, OPG, cephalometric systems), mobile, dual energy projection x-ray imaging, flat panel/image intensifier/mobile/over/under table fluoroscopes and C-arms, interventional systems, paediatric systems, radiostereometric (RSA) systems, stereotactic / biopsy systems (e.g., mammography), dual energy X-ray absorptiometry (DXA), sequential/axial and helical mode CT, multidetector CT, dual source/energy CT, volumetric CT scanners, CT scanners for radiotherapy planning, CT fluoroscopy and cone-beam CT, including: - image quality related performance indicators - device design for image quality and patient/occupational dose optimization, including special features for dedicated systems - user determined parameters and their manipulation for optimising image quality and patient dose K3. Explain in detail the following features of fluoroscopes: flat-panel / image intensifier detectors (including problems with image intensifiers such as geometric distortion, environmental magnetic field effects), continuous and pulsed acquisition including frame rate, automatic brightness control, high dose rate fluoroscopy, digital spot imaging, cine runs, last image hold, roadmapping, 3D - cone beam CT acquisition.	S1. For each modality, operate imaging devices at the level necessary for give advice on optimization of imaging protocols, quality control, image quality manipulation, and carry out research when the available evidence for advice is not sufficient. S2. Manipulate acquisition parameters for all forms of projection x-ray imaging devices (e.g., kV, filtration, mAs, sensitivity (‘speed’), collimation, magnification, SID, SSD, frame rate, screening time, manual/AED modes, compression), explain the effect on image quality and relevant patient dose quantities (and occupational dose particularly when this is correlated with patient dose) and relevance to specific clinical studies. S3. Manipulate acquisition parameters for all forms of CT imaging, explain the effect on image quality and relevant patient dose quantities (and occupational dose particularly when this is correlated with patient dose) and relevance to specific clinical studies. S4. Use specialised test tools e.g., contrast-detail test objects, to evaluate imaging systems.	C1. Carry out or supervise as appropriate the measurement of physical quantities relevant to the safe use of radiation in Diagnostic and Interventional Radiology.

Ionizing & Non-Ionizing Radiation Dosimetry Measurements	K4. For each imaging modality define patient safety /dosimetry related indicators/quantities (use *both ICRU 74 and commonly used terminology for x-radiation*): - projection radiography: photon / energy fluence and fluence rate, absorbed dose, terma, kerma, KAP (P_{KA}, DAP), IAK (K_i), ESAK (K_e),ESD, effective dose, glandular dose in mammography - fluoroscopy: cumulative fluoroscopy time, cumulative fluoroscopy KAP, cumulative fluorography KAP, total cumulative KAP, cumulative air kerma at the international reference point, peak skin dose, organ absorbed dose, effective dose … - CT: $CTDI_{air}$ ($C_{a,100}$), $CTDI_W$ (C_W), $CTDI_{vol}$ (C_{VOL}), KLP ($P_{KL,CT}$), organ absorbed dose, effective dose … - MRI: SAR - Ultrasound: mechanical and thermal indices, acoustic output K5. Define and explain methods of measurement of occupational / public dose indicators suitable for ensuring adherence to exposure limit values and dose constraints.	S5. For each imaging modality, identify and carry out appropriate patient / occupational / public safety related dosimetric measurements and calculations. S6. For each imaging modality measure / calculate patient safety /dose related indicators/quantities and wherever possible verify independently values supplied by manufacturers. S7. For each imaging modality, select appropriate phantoms/phantom materials for dosimetry. S8. Use specialized dosimetry software / conversion coefficients to calculate effective doses and organ absorbed doses from dosimetry measurements.	C2. For each imaging modality, take responsibility for the measurement of appropriate patient / occupational / public safety related dosimetric monitoring quantities. C3. Carry out a dose assessment for the conceptus in the case of pregnant patients.
Patient Safety / Dose Optimization	K6. Explain radiobiological dose-effect relationships relevant to Diagnostic and Interventional Radiology with respect to patient safety including discussion of the physical and biological background, response of tissues to radiation on molecular, cellular and macroscopic level, models of radiation induced cancer and hereditary risks and radiation effects on humans in general, children and the conceptus. K7. Explain the meaning of justification and optimization as applied to medical imaging practices. K8. For each imaging modality, list and explain the target patient safety outcomes with respect to hazards from radiation. K9. For each imaging modality, list and explain in detail and whenever possible quantitatively protocol design variables which impact patient safety and optimization of practices, procedures and acquisition protocols. K10. Explain the methodology for the setting up of DRLs. K11. For each imaging modality explain the physical principles underpinning use of protective barriers, accessories and apparel with regard to patient safety. K12. For each imaging modality, describe the key considerations for the design of a new facility with respect to patient safety. K13. Describe the practical implementation of patient safety / dose audits. K14. For each imaging modality, explain the physical basis of any contraindications for device use and procedures for avoiding adverse events.	S9. Use radiobiological dose-effect relationships relevant to Diagnostic and Interventional Radiology to estimate patient risk (including adverse incidents involving high exposures). S10. Apply the concepts of justification, optimization and diagnostic reference levels to patient protection. S11. For each imaging modality, apply local European laws, regulations, recommendations and standards related to patient safety. S12. Optimize patient radiation protection in high dose or high risk practices: interventional radiology, CT, health screening programmes, irradiation of children, neonates or the foetus, genetic predisposition for detrimental radiation effects.	C4. Take responsibility for the protection of patients by optimization of practices, procedures and acquisition protocols. C5. Take responsibility for establishment of DRLs. C6. Take responsibility for ensuring that doses in a facility are measured, are consonant with European, national and local diagnostic reference levels and advise management and imaging professionals on means of reducing doses when necessary. C7. Participate in the establishment of referral criteria and justification of practices.

Occupational & Public Safety / Dose Optimization	K15. For each imaging modality list and explain target occupational/public safety outcomes with respect to hazards from radiation. K16. Explain the practical application of ALARA to promote the radiation safety of the worker and public in Diagnostic and Interventional Radiology. K17. Explain radiobiological dose-effect relationships relevant to Diagnostic and Interventional Radiology with respect to occupational/public safety including models of radiation induced cancer and hereditary risks and radiation effects on humans in general, children and the conceptus. K18. For each imaging modality, explain the physical principles underpinning the use of protective barriers, accessories and personal protective equipment. K19. For each imaging modality explain the protocol design variables which occupational/public safety. K20. Explain the principles of time, distance and shielding with respect to external radiation exposure, and the practical application of these principles to the radiation safety of the worker and public in Diagnostic and Interventional Radiology. K21. Define and describe the role of the RPE and RPO in the establishment and management of systems for radiation safety. K22. For each imaging modality define and explain appropriate occupational/public physical agent dose monitoring quantities. K23. Explain the special requirements with respect to occupational radiation protection in fluoroscopy (e.g., particularly in paediatrics and interventional procedures).	S13. Use radiobiological dose-effect relationships relevant to Diagnostic and Interventional Radiology to estimate occupational/public risk (including adverse incidents involving high exposures). S14. For each modality apply local European laws, regulations, recommendations and standards related to occupational/public safety. S15. Perform shielding calculations for x-ray rooms (general radiography, mammography, CT, fluoroscopy, interventional radiology, mammography, dental). S16. Verify that radiation protection and risk management is in compliance with guidelines, directives, and legislation (including dose limits).	C8. Take responsibility for occupational / public risk assessment in Diagnostic and Interventional Radiology facilities. C9. Take responsibility to evaluate and optimise the risks of a given Diagnostic and Interventional Radiology procedure or protocol for healthcare professionals or public. C10. Give advice on personal protective equipment, including protective garments, and fixed and mobile shielding.

Clinical D&IR Device Management	K24. Demonstrate an understanding of the required technological infrastructure for a Diagnostic and Interventional Radiology department and knowledge of how to establish the necessary interactions with the infrastructures of other medical specialities within the hospital that utilize medical imaging (e.g., nuclear medicine, radiation oncology; cardiology, surgery). K25. For each imaging modality list and explain acceptability criteria and tender specifications. K26. For each imaging modality, explain EU and national legislation, recommendations and regulations impacting the use of the modality.	S17. Evaluate imaging device performance for each imaging modality, from the measurement of suitable performance indicators using suitable test objects / phantoms. S18. For each imaging modality, carry out acceptance testing, commissioning and QC procedures. S19. Calibrate the various types of devices used in Diagnostic and Interventional Radiology. S20. Conduct critical examinations for each imaging modality (interlocks, warning systems, safety design features and barriers).	C11. Advise on the purchase of the most appropriate image device model for a specific clinical application. C12. Select hardware / software systems for image display and image processing. C13. Take responsibility for the acceptance, commissioning and constancy testing of image display and processing systems. C14. Take responsibility to ensure conformity with European and national laws, regulations, recommendations and standards (including acceptability criteria).
Clinical Involvement	7. For each imaging modality, list and explain the protocol design variables (including appropriate device settings, accessories, and safety measures) which impact image quality and discuss possible effects on diagnostic accuracy. 8. For each imaging modality, explain the physical principles underpinning the effective and safe use of any ancillary medical devices and the safe disposal of non-reusable ancillary medical devices. 9. For each imaging modality explain the different acquisition protocols used to perform common types of examinations (e.g., obstetrics and gynaecology, cardiac, abdominal, small parts- breast, testes, thyroid, musculo-skeletal, paediatric and vascular in ultrasound imaging).	S21. For each imaging modality, recognize normal anatomy as well as pathology in images to a level necessary for the clinical involvement role of the MPE. S22. For each imaging modality, manipulate acquisition parameters (e.g., tube voltage, filtration, contour filters, tube current, exposure time, field size, magnification in projection x-ray imaging) to optimize image quality and patient dose. S23. For each imaging modality identify and correct causes of below target image quality and safety criteria.	C15. For each imaging modality, give advice regarding the adjustment of protocols to the needs of particular clients in studies which are complex, unusual, beyond-protocol and non-predictable. C16. For each imaging modality, advise on protocol modifications for paediatric imaging. C17. For each imaging modality, provide practical safety-related guidelines.
Expert Cons.	K30. Discuss the particular ethical issues involved in expert consultancy in areas involving a high level of collective dose.		

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Radiation Protection KSC for Medical Physics in Nuclear Medicine

	Knowledge	Skills	Competence
Comprehensive Physics Problem Solving Service	K1. List and describe the radiation detectors specific to Nuclear Medicine. K2. Illustrate the characteristics of a Nuclear Medicine counting system including the effect of background counts and minimum detectable counts. K3. Discuss the characteristics of electronics related to Nuclear Medicine devices K4. Describe the concepts of fundamental detector properties and how they affect the performance of Nuclear Medicine devices. K5. Explain how statistical techniques are used for radiation measurement in Nuclear Medicine K6. Describe the basic concepts of image reconstruction in Nuclear Medicine including analytical and iterative reconstruction techniques. K7. Explain the concepts of compartmental analysis and its use in Nuclear Medicine. K8. List and explain the main types of computer codes used for dose calculation.	S1. Operate radiation measurement devices/detectors and interpret the results in the context of Nuclear Medicine. S2. Operate radiation measurement devices/detectors and interpret the results in the context of Nuclear Medicine. S3. Realize experiments for the measurement of properties relevant for instrument specific performance assessment, especially with reference to established national and international standards (NEMA, IEC). S4. Develop, assess and implement new methods and technologies in Nuclear Medicine. S5. Analyze and handle images from a Nuclear Medicine imaging device. S6. Extract parametrical information/image from Nuclear Medicine data. S7. Calculate biological parameters from Nuclear Medicine images using compartmental modelling.	C1. Take responsibility for statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Comprehensive Physics Problem Solving Service. C2. Take responsibility for good practice in the use of sealed/unsealed sources of ionizing radiation. C3. Take responsibility for inventory of sealed radiation sources present in the laboratory and in the hospital environment. C4. Take responsibility for the handling, management and maintenance of radiation measurement devices.

Diag.& Therap. NM Dosimetry Measurements	K9. List the various equipments and devices required within the context of patient dosimetry including probes, well counters, dose calibrators, gamma cameras & PET scanners (incl. hybrid systems) K10. Describe calibration factors including phantoms, phantom setup and measurements for dosimetry image quantification. K11. Explain how cumulated activity is calculated from time-activity curve data by appropriate methods, including curve fitting algorithms and compartmental analysis. K12. Describe the influence of equipment settings (e.g. choice of energy windows, collimators) on activity results and how temporal sampling affects the results obtained. K13. Describe the influence of the reconstruction method and processing parameters used in PET/SPECT (e.g. cut-off frequency, number of iterations) on activity measurements. K14. List methods for determining patient-specific organ masses including the respective errors and explain the difference between morphological and functional volume of organs or lesions. K15. Explain the fundamental limitations of dosimetry at the organ level, for instance in deriving tumour dosimetry, taking into account activity and density heterogeneities. K16. Describe the application and use of techniques for the estimation of dose at the sub-organ, voxel and cellular level, in the context of radionuclide therapy (including radioimmunotherapy). K17. Describe how DVH or isodose curves are calculated and what results should be provided.	S8. Distinguish between requirements for radiation protection dosimetry and the need for patient-specific dosimetry in a therapeutic setting. S9. Design optimal dosimetry protocols and calculation procedures for molecular radiotherapies. S10. Assess the requirements for quantitative imaging and/or other measurements for dosimetric purposes. S11. Calculate cumulative activities (incl. curve-fitting techniques and use of compartmental modelling). S12. Develop methods for ensuring reproducibility of dosimetry assessments. S13. Perform dosimetric calculations using the MIRD formalism. S14. Delineate the differences between methods used for calculating dose factors (point-kernel vs. Monte-Carlo). S15. Determine organ masses using different imaging modalities. S16. Determine whole body, organ and effective doses using tools such as OLINDA. S17. Apply correct radiobiological concepts. S18. Determine when voxel-based dosimetry and use of dose-volume histograms are appropriate. S19. Understand the concept of reference sources, both internal and external for absolute radioactivity determination (e.g., traceability, reference laboratories, accuracy).	C5. Take responsibility for dosimetric measurements necessary for dosimetric investigations. C6. Take responsibility and supervise the development of appropriate dosimetry protocols including quantitative imaging aspects, time-sampling, time-activity curves derivation and dose calculations.

Patient Safety / Dose Optimization	K18. Explain the concepts of absorbed dose and effective dose as applied to Patient Safety / Dose Optimization in Nuclear Medicine. K19. Explain the MIRD scheme and fundamental characteristics and limitations of the formalism, and how this governs its usage. K20. Explain how standard geometric models may be made patient-specific by scaling to individual characteristics. K21. Explain how the main types of computer codes used for dose calculation can be used for dose optimization. K22. Describe how diagnostic and therapeutic exposures are managed, including optimization of dose through prescription of activity and protocol. K23. Explain how research medical exposures are managed, including the processes of ethical review, clinical trial administration and the use of appropriate dose constraints. K24. Describe the process and practical implementation of radiation risk assessments using the assessment of dose to the patient arising from both internal and external sources of exposure.	S20. Participate in the development of optimized imaging and therapeutic protocols. S21. Systematize the inclusion of dosimetry reports based on injected activity and ICRP data for diagnostic procedures in patient medical records. S22. Apply relevant guidance document in dosimetry reporting for molecular radiotherapy. S23. Interpret radiation dose quantities related to CT devices as part of hybrid systems and apply these appropriately to dose optimization.	C7. Take responsibility for patient dose optimization within the Nuclear Medicine facility. C8. Advise on the optimization of clinical protocols for Nuclear Medicine (including software aspects).

Occupational & Public Safety / Dose Optimization	K25. Describe the key considerations when designing a new Nuclear Medicine facility that optimise radiation safety of workers and the public; to include diagnostic Nuclear Medicine imaging with PET and multi-modality imaging, non-imaging or in-vitro laboratory procedures, radionuclide therapy, and radiopharmaceutical production including cyclotron PET tracer production. K26. Explain quantitative risk and dose assessment to workers and public from internal and external exposure. K27. Describe the requirements for regulatory compliance with respect to the management and use of sealed and unsealed sources ; including security considerations, requirements for storage, shielding, record-keeping and audit. K28. Describe the requirements for regulatory compliance with regard to the management and disposal of radioactive waste and the transportation of radioactive substances. K29. Explain the nature and sources of internal and external radiation exposure and the relevant dose limits in Nuclear Medicine for the worker, including extremity doses and dose limits for pregnant and lactating workers, and young workers, and the public, and dose constraints for comforters and carers. K30. Explain how therapeutic exposures are managed in both inpatient and outpatient contexts. K31. Describe factors for optimizing acquisition/processing procedures to decrease CT dose in combined modalities. K32. Describe appropriate systems for monitoring dose to pregnant and lactating workers, young workers, and the public, including selection, management and calibration of devices used to record doses and practical techniques for dose measurement. K33. Explain how good radiation safety practice and appropriate personal protective equipment minimises internal radiation exposure of the worker and public in Nuclear Medicine. K34. Explain the nature of contamination and practical measures required to affect environmental and personal decontamination in Nuclear Medicine; its relevance to radiation safety of the worker and public, and the principles, systems and precautions required to minimise the hazard. K35. Describe the principles of contingency planning and emergency procedures in Nuclear Medicine.	S24. Design a new Nuclear Medicine facility, including PET and multi-modality imaging, non-imaging or in-vitro laboratory procedures, radionuclide therapy, and radiopharmaceutical production including cyclotron PET tracer production with respect to occupational and public radiation protection. S25. Classify appropriately radiation areas within a Nuclear Medicine facility. S26. Develop a detailed organisational (hospital) policy to support the radiation safety of staff and public in Nuclear Medicine. S27. Develop an organisational (hospital) policy for regulatory compliance with regard to the management of radiation sources and radiation waste. S28. Develop a policy for regulatory compliance with regard to the transportation of radioactive substances. S29. Implement appropriate systems for monitoring the dose of the worker (also pregnant and lactating workers), comforters and carers and the public; including selection, management and calibration of devices used to record doses and practical techniques for dose measurement. S30. Apply the concept of ALARA and the principles of time, distance and shielding to the radiation safety of the worker and public in Nuclear Medicine. S31. Apply good radiation safety practice and the appropriate use of personal protective equipment to minimise internal and external radiation exposure of workers and the public arising from Nuclear Medicine. S32. Develop formal systems of work (‘local rules’) with regard to radiation safety in Nuclear Medicine. S33. Investigate radiation incidents in Nuclear Medicine to determine the cause(s) and recommending appropriate remedial action(s). S34. Develop a detailed organisational (hospital) policy to support the radiation safety of staff and public in Nuclear Medicine. S35. Develop contingency plans for emergency procedures relevant to Nuclear Medicine.	C9. Take responsibility for the design of a Nuclear Medicine facility, including PET and multi-modality imaging, non-imaging or in-vitro laboratory procedures, radionuclide therapy, and radiopharmaceutical production including cyclotron PET tracer production. C10. Take responsibility for the classification of radiation areas within a Nuclear Medicine facility. C11. Take responsibility for the implementation of a detailed organisational policy to support the radiation safety of staff and public. C12. Take responsibility for regulatory compliance with respect to the management of radiation sources and radiation waste. C13. Take responsibility for regulatory compliance with regard to the transportation of radioactive substances. C14. Take responsibility for the implementation of formal systems of work (‘local rules’). C15. Take responsibility for the radiation safety of staff and public, systems for monitoring doses of workers and public, and practical measures to support this. C16. Take responsibility for the management of radiation risk including the implementation of the risk assessment findings. C17. Take responsibility for the implementation of
	K36. Describe suitable processes for the reporting of radiation incidents in Nuclear Medicine, using root cause analysis and other tools to determine the underlying cause(s)		

Clinical Nuclear Medicine Device Management	K37. Define the specifications of a Nuclear Medicine imaging device for tender purposes, generally and as tailored to particular clinical requirements. K38. Specify acceptability criteria for medical devices. K39. Describe the principles of QC for Nuclear Medicine devices, such as gamma probes, well counters, dose calibrators, gamma cameras, SPECT, PET, hybrid systems etc. K40. List the physical and chemical properties of radionuclide compounds selected to implement Quality Control (QC) and their radioprotection implications. K41. Describe duties and responsibility of other health professionals involved in QA activities K42. Explain the principles of Quality Control for production of isotopes and synthesis of radiopharmaceuticals. K43. Describe QC measures in sequential imaging (several patient visits).	S36. Design a Nuclear Medicine facility. S37. Evaluate Nuclear Medicine devices in a tender both generally and with respect to particular clinical requirements. S38. Adapt QC protocols to the specific types/models. S39. Analyze results of QC procedures; assess device performance by comparison to reference values as indicated by the manufacturer and/or local, national, European and other authorities/bodies. S40. Design and test physical and technical methods for the assessment of devices used in Nuclear Medicine procedures. S41. Interpret and apply local radioprotection rules as applicable to QC procedures. S42. Assess deviations of performance parameters from reference levels and interpret their relevance. S43. Implement cross-calibration procedures between devices. S44. Perform a documented risk assessment for equipment not within suspension levels.	C19. Take responsibility for the statutory and institutional requirements for Medical Physics Services in Nuclear Medicine with respect to Clinical Medical Device Management. C20. Organize infrastructures for distribution, archiving and retrieval of Nuclear Medicine images. C21. Organize infrastructures for display and reading of examinations and for the reporting and archiving of findings. C22. Organize and supervise the preparation of radioactive sources for QC procedures.

Clinical Involvement	K44. Describe the general role of Nuclear Medicine procedures in diagnosis, therapy (including radioimmunotherapy) and treatment response evaluation. K45. Describe radiopharmaceutical preparation and quality control. K46. Describe radiopharmaceutical biodistribution in normal organ and target tissues. K47. Describe the fundamentals of molecular radiotherapy (including radioimmunotherapy). K48. Explain the fundamentals of the use of PET in EBRT planning. K49. Describe general indications and contra-indications for Nuclear Medicine procedures. K50. Describe diagnostic procedure and clinical procedure guidelines. K51. Describe protocol optimization principles. K52. Describe the risk/benefit justification of Nuclear Medicine diagnostic and therapeutic procedures. K53. Explain the interactions/synergism between chemotherapy, EBRT and molecular radiotherapy. K54. Illustrate methodologies for the measurement of lesion response to therapy. K55. List laboratory and imaging procedures to evaluate organ toxicity. K56. Illustrate dose limiting toxicity classification and quantification. K57. Describe how dosimetric calculations may be made in diagnostic and therapeutic practice, and how this conditions the level of accuracy required. K58. Explain how standard geometric models (e.g., MIRD) may be made patient-specific by scaling to individual body mass, organ volume/mass and tissue density. K59. Explain how standard exposures and procedures can be modified in special cases e.g., the pregnant patient, the lactating patient, paediatric patients. K60. Explain the radiation protection principles underpinning current referral criteria for Nuclear Medicine procedures.	S45. Participate in the design of a patient specific treatment plan. S46. Estimate relevant activity to inject to paediatric patients according to international recommendations. S47. Analyze how molecular radiotherapy could impact on other treatment modalities. S48. Analyze critically new protocol proposals (i.e. feasibility, safety…). S49. Analyze the limits of acceptability of clinical Nuclear Medicine procedures. S50. Calculate patient and operator doses and consequent risks for a given clinical or experimental procedure. S51. Perform dosimetric calculations using the MIRD formalism, including the appropriate adaptation of standard models and data to achieve patient-specific estimates.	C23. Advise Nuclear Medicine physicians in imaging interpretation and quantification. C24. Take responsibility for deriving semi-quantitative and quantitative data for clinical application. C25. Advise on different treatment schedule options. C26. Advise on the most appropriate procedure with respect to risk/benefit ratio. C27. Advise on and take responsibility for daily optimization of clinical acquisition protocols for individual patients in both standard and non-standard situations and their adaptation for particular patients. C28. Supervise procedures for paediatric investigations. C29. Advise on the use of Nuclear Medicine data for radiotherapy planning. C30. Assume responsibility for data handling / recording. C31. Support Nuclear Medicine staff with physical-technical guidelines. C32. Supervise image reconstruction and image handling procedures.

Education of Healthcare Professionals	K61. Describe appropriate programmes for staff training in radiation safety in Nuclear Medicine.	S52. Develop appropriate programmes for staff training in radiation safety with regard to Nuclear Medicine.	C33. Take responsibility for the delivery of appropriate programmes for staff training in radiation safety and optimized use of devices.

Radiation Protection KSC for Medical Physics in Radiation Oncology

	Knowledge	Skills	Competence
Comprehensive Physics Problem Solving Service	K1. Explain the function of TPS software as a virtual treatment system with dose distribution calculator (including associated features e.g., BEV, DRR, DVH). K2. Discuss the limitations of dose calculation algorithms for heterogeneity corrections in low density tissue and tissue interfaces where electronic equilibrium is not fully established. K3. Explain the AAPM TG-43 dose calculation algorithm and modern model based algorithms for brachytherapy.	S1. Operate devices used in radiation oncology. S2. Operate radiation measurement devices/detectors and interpret the results in the context of Radiation Oncology.	C1. Carry out or supervise the measurement of physical quantities relevant to the effective and safe use of devices in Radiation Oncology. C2. Evaluate and implement new methods and technologies in Radiation Oncology.

External Beam & Brachy. Dosimetry Measurements	K4. Explain the terminology used in photon, electron and proton Radiation Oncology dosimetry (e.g., PDD, TMR, TPR, OAR). K5. Describe and explain recommended national and international (e.g., IAEA) absorbed dose measurement protocols based on absorbed dose in water/solid phantoms for photon, electron, proton and heavier ion beams using different sensors types of sensors (ionisation chambers, diodes, film, TLD). K6. Explain the various approaches to in-vivo dosimetry for Radiation Oncology beams and discuss choice of appropriate sensors. K7. Describe the calibration chain for dosimetry sensors used in Radiation Oncology. K8. Explain the theoretical and practical aspects of reference dosimetry for high-energy photons, electrons and brachytherapy sources. K9. Explain the concepts of in-vivo dosimetry for ion beam Radiation Oncology including range verification methods using PET. K10. Describe and explain recommended methods for reference air kerma (RAK) determination for LDR/HDR/PDR brachytherapy sources. K11. Describe and explain the functioning, characteristics, strengths and limitations of sensors used for RAK measurement. K12. Define reference conditions for fixed-SSD and isocentric approaches. K13. Explain basic dosimetry in non-reference conditions (e.g. extended SSD, off-axis). K14. Explain the following concepts and methods of relative dosimetry: central axis dose distribution in water, output factors, 3D dose distribution, beam profiles (e.g., penumbra region, flatness, and symmetry), effects of beam modifiers such as hard and virtual wedges, compensators and bolus.	S3. Select the most appropriate detector for measuring absolute and relative dose distributions in different irradiation conditions for photon and for electron beams. S4. Calculate uncertainties in Radiation Oncology dosimetry measurements. S5. Use the national recommended Code of Practice for the determination of absorbed dose to water from external radiotherapy photon beams. S6. Measure absorbed dose in external radiotherapy beams under both reference and non-reference conditions. S7. Cross-calibrate ionization chambers and diode dosimeters at the local facility. S8. Perform brachytherapy source calibration (including measurement uncertainties). S9. Interpret source calibration certificates. S10. Perform constancy checks (e.g., strontium-90 based) on ionization chambers and calibrate diode dosimeters. S11. Perform in-vivo dosimetry with appropriately chosen protocols and sensors including verification of the delivered dose at single points or planes.	C3. Take responsibility for in-vivo dosimetry in external beam and brachytherapy Radiation Oncology. C4. Set up a program for acceptance testing, calibration and quality control of dose measurement systems used in Radiation Oncology. C5. Carry out a Radiation Oncology dose audit. C6. Take responsibility for the calibration of ionizing chambers in a traceable dosimetry laboratory. C7. Determine brachytherapy source strengths according to national and international (e.g., IAEA) protocols and recommendations. C8. Perform pre-treatment dosimetric verification of treatment plans for standard and sophisticated Radiation Oncology techniques (such as standard 3D-CRT plans, special technique plans, IMRT) in a phantom.

Patient Safety / Dose Optimization	K15. Explain dose-effect relationships relevant to Radiation Oncology with respect to patient safety including discussion of the physical and biological background, response of tissues to radiation on molecular, cellular and macroscopic level, models (including limitations of existing models) of radiation induced cancer and hereditary risks and radiation effects on humans in general, children and the conceptus. K16. Describe and explain the principles and structure of treatment planning and dose optimization (including limitations) in the case of patients undergoing treatment with photon, electron, proton and heavier ion beams (including special techniques such as stereotactic treatments, IMRT, IMAT). K17. Describe and explain the principles and structure of brachytherapy treatment planning systems, dose calculation algorithms (TG 43, model based algorithms) and optimization algorithms for HDR, LDR and PDR. K18. Explain limitations in existing models for treatment planning systems. K19. Explain how conventional techniques are used to optimize dose distributions. K20. Explain P+, utility function and other appropriate models used in optimization of treatment outcomes.	S12. Use radiobiological dose-effect relationships relevant to Radiation Oncology to estimate patient risks (including potential adverse incidents involving high exposures). S13. Assess sources and levels of uncertainty in geometry and dose delivery and apply methods for their monitoring and control. S14. Evaluate the clinical implications of the strengths and limitations of the locally available afterloading systems and sources.	C9. Take responsibility for patient dose optimization within the Radiation Oncology facility. C10. Investigate radiation incidents involving patients to determine the cause(s) and recommend appropriate remedial action. C11. Take responsibility for good practice in the use of sealed/unsealed sources of ionizing radiation with respect to patient safety. C12. Evaluate critical radiobiological calculations performed by commercial treatment planning systems. C13. Set the requirements of PET studies specifically for Radiation Oncology planning.

Occupational & Public Safety / Dose Optimization	K21. Explain dose-effect relationships relevant to Radiation Oncology with respect to occupational/public safety including discussion of the physical and biological background, response of tissues to radiation on molecular, cellular and macroscopic level, models of radiation induced cancer and hereditary risks and radiation effects on humans in general and the conceptus. K22. Explain the principles of risk management as applied to Radiation Oncology devices and ionising radiation in the case of workers / public with respect to external beam therapy and brachytherapy. K23. Explain international, European and local radiation protection regulations regarding the use of radiation producing devices and sealed radioactive sources. K24. Explain how comforters and carers are managed in the context of radiation oncology and the use of appropriate dose constraints. K25. Explain the principles underpinning the design of radiation safety plans for radiation producing devices in Radiation Oncology. K26. Describe suitable processes for the reporting of radiation incidents involving workers / members of the general public in the context of radiation oncology, using root cause analysis and/or other tools to determine the underlying cause(s).	S15. Use radiobiological dose-effect relationships relevant to Radiation Oncology to estimate occupational/public risks (including adverse incidents involving high exposures). S16. Carry out a comprehensive risk analysis of a Radiation Oncology facility. S17. Apply International, European and National regulations for the transport, handling, storage and use of radioactive sources in Radiation Oncology. S18. Perform radiation protection calculations for the design of new treatment, simulator and, sealed / unsealed source storage rooms with respect to occupational/public protection.	C14. Take responsibility for the assessment and optimization of the risks of a given procedure or protocol for healthcare professionals and public. C15. Take responsibility for regulatory compliance in management of radiation sources and waste, and the transportation of radioactive substances. C16. Take responsibility for environmental radiation surveys. C17. Set-up, implement, evaluate and improve radiation safety plans. C18. Develop plans for the avoidance of incidents involving staff/public. C19. Investigate radiation incidents to determine the cause(s) and recommending appropriate remedial action with respect to occupational / public safety. C20. Develop contingency plans for emergency procedures with respect to occupational / public safety. C21. Take responsibility for good practice in the use of sealed/unsealed sources of ionizing radiation with respect to occupational/public safety.

Clinical Radiation Oncology Device Management	K27. Explain the principles of quality control of external beam, brachytherapy, TPS and associated imaging systems.	S19. Specify criteria for selecting treatment and in-room imaging devices. S20. Import measured beam data into a TPS. S21. Specify the criteria for selecting a TPS. S22. Evaluate the specifications for external beam therapy devices. S23. Perform acceptance testing, commissioning and QC of treatments units, TPS, imaging systems and networks. S24. Perform acceptance testing, commissioning and constancy testing of treatment units and in-room imaging devices. S25. Perform acceptance testing, commissioning and QC of after-loading equipment (LDR, HDR, PDR), treatment planning systems, sources and applicators, imaging systems in brachytherapy, networks, etc. using national, international recommendations and local protocols.	C22. Take responsibility for acceptance testing, commissioning and quality control of treatments units, TPS, imaging systems and networks in Radiation Oncology. C23. Take responsibility for acceptance testing, commissioning and constancy testing of treatment and in-room imaging devices. C24. Take responsibility for acceptance testing, commissioning and QC of after-loading equipment (LDR, HDR, PDR), TPS, sources and applicators, imaging systems in brachytherapy, etc. using national and internat. recommend. and local protocols. C25. Manage brachytherapy sources including source specification, security, loss & disposal. C26. Setup and manage a QC program for brachytherapy sources (including leakage tests), source calibration equipment, applicators and treatment planning systems. C27. Take responsibility for inventory of sealed brachtherapy sources.

Clinical Involvement	K28. Explain models for DNA damage, cell survival, repair and fractionation models. K29. Explain the mechanisms involved in novel drugs commonly used in combination with radiation. K30. Describe the radiosensitivity of relevant tissues and tolerance doses for normal tissues (e.g., QUANTEC). K31. Explain how the radiosensitivity of tumour and normal tissues is influenced by combinations of chemotherapy and radiation therapy. K32. Explain the radiobiological rationale underpinning the various treatment strategies (fractionation, dose rate, radiosensitization and reoxygenation) in radiation therapy. K33. Explain therapeutic ratio, tumour control probability, normal tissue complication probability, tolerance doses, dose-volume effects. K34. Explain the response to therapeutic levels of X-ray, electrons, protons and heavier ions at the molecular, cellular, tissue and macroscopic levels for tumour and normal tissue. K35. Explain and use ICRU terminology and recommendations regarding target volumes (e.g., GTV, CTV, PTV, PRV), organ at risks and specification of dose and volumes, margin decisions, including international recommendations (ICRU 50, 62, 83). K36. Describe quantitatively the radiation fields produced by external beam devices and their clinical specification.	S26. Use a TPS for patient specific treatment plan generation and optimization. S27. Use conventional techniques for creating optimized patient specific dose distributions using beam combinations, beam shaping, weighting and normalization, wedges, bolus, compensators, MLCs, field matching. S28. Operate treatment devices and in-room imaging devices effectively and safely. S29. Use immobilization (incl stereotactic) devices for the immobilization of patients. S30. Design and test physical and technical aids for simulation/treatment of patients. S31. Perform detailed dose-response analysis from clinical data & patient series. S32. Analyze dose specifications and volume definitions according to national and international protocols and recommendations (including ICRU 38 and 58, GEC ESTRO, ABS). S33. Use conventional and CT/CBCT simulators for planning and verification. S34. Evaluate how normal tissue tolerances are set up in own department.	C28. Take responsibility for patient specific patient treatment plan optimization and minimizing absorbed doses to organs at risk. C29. Take responsibility for the accuracy of MU calculations and treatment MU verification using suitable measurements or independent calculation. C30. Evaluate image quality acquired during the Radiation Oncology process. C31. Give advice on optimization and safety of individual patient simulation/treatment and simulation/treatment protocols. C32. Optimise treatment parameters and perform specific dose measurements for pregnancy cases. C33. Advise on fractionation and dosimetry for completion of a Radiation Oncology treatment following omission of a wedge in early fractions. C34. Give advice regarding the most appropriate technique according to tumour site and intent of the treatment.

Clinical Involvement (cont.)	K37. Describe the characteristics of clinical beams in air and water / solid phantoms. K38. Explain the use of the various imaging modalities (including PET/CT, PET/MRI, and ultrasound) in the different stages of the Radiation Oncology process. K39. Explain the methods for management of patient organ motion in Radiation Oncology. K40. Explain how CT patient simulators provide a virtual (immobilized) patient for treatment plan generation and optimization purposes. K41. Compare national and international treatment protocols for different irradiation techniques with those used at own institution. K42. Describe the effect of various beam arrangements, beam modification devices (hard and virtual wedges, compensators, blocks, MLCs, bolus) and beam weights on dose distribution. K43. Explain how IMRT techniques are used for creating optimized dose distributions: fixed-gantry IMRT (static or dynamic MLC), rotating-gantry IMRT (serial and helical tomotherapy, intensity-modulated arc therapy). K44. Discuss the use of 4D treatment planning systems. K45. Compare different levels of treatment planning complexity in relation to clinical requirements and the uncertainties involved. K46. List and describe the various radionuclides and types of sealed sources used in brachytherapy and their clinical use. K47. Describe in mathematical terms dose calculation algorithms (correction-based, model-based and Monte Carlo) for photon and electron beams. K48. Explain pre-planning models for intracavitary and interstitial brachytherapy (GEC ESTRO, Manchester, Paris, image based dosimetry). K49. Explain how research medical exposures are managed in the context of Radiation Oncology, including the processes of ethical review and clinical trials administration and governance (GCP) and the use of appropriate dose constraints.	S35. Perform fractionation calculations, response calculations (using NTCP/TCP models), effective dose calculations and volume effect corrections using established models. S36. Perform plan optimization and evaluation using uniformity criteria, constraints, DVHs and biological parameters (TCP, NTCP). S37. Operate imaging systems used in brachytherapy. S38. Use classical dose distribution calculation systems for LDR (e.g., Paris and Manchester systems) and extension to HDR, PDR. S39. Participate in special brachytherapy techniques. S40. Participate in the verification of the different steps of treatment: patient positioning, target localisation, and plan verification. S41. Perform conformal 3D and IMRT treatment plans of a suitable set of the most representative tumour sites. S42. Perform optimised plans for LDR/HDR/PDR. S43. Perform optimised plans for permanent seeds prostate brachytherapy implantation. S44. Use the 'record and verify' system available at the institution to verify data transfer from the TPS to the treatment unit. S45. Apply the principles of optimization in daily routine in a Radiation Oncology facility with respect to patient dose optimization. S46. Perform independent monitor unit calculation for dosimetric verification of treatment plans.	C35. Record and report dosimetric parameters according to international recommendations. C36. Take responsibility for the evaluation of magnitudes and sources of day-to-day treatment variability / uncertainties in radiation oncology and their clinical implications, set tolerances and action levels. C37. Involve oneself closely in the overall clinical process of brachytherapy from operating theatre through simulator localization, treatment planning, source preparation and delivery. C38. Take responsibility for independent verifications of calculated treatment times of intra-cavitary insertions and interstitial implants using manual methods. C39. Take responsibility to verify, optimize and QA treatment plans for individual patients. C40. Implement techniques for minimizing errors due to target motion resulting from respiration (respiratory gating, breath hold and tumor tracking). C41. Take responsibility for the verification of correct data transfer from the TPS to the treatment unit.
		S47. Implement different IGRT on-line or off-line correction protocols to improve accuracy of patient positioning, target localization, and minimize intra and inter-fraction set-up errors. S48. Create optimized dose distributions for	

Service Quality	K50. Explain why development of service quality and cost-effectiveness in radiation oncology involves the development of all steps of treatment i.e., simulation, planning, verification, delivery and reporting.		
Expert Cons.	K51. Discuss the particular nature of consultancy and ethical issues involved in the clinical use of high levels of ionising radiation.		C42. Take responsibility for the particular nature of consultancy and ethical issues involved in use of high levels of radiation.
Educ. of HCP	K52. Discuss the particular education and training issues associated with the clinical use of high levels of ionising radiation.		C43. Take responsibility for the particular education and training issues associated with the use of high levels of radiation.
HTA	K53. Discuss the particular issues associated with HTA activities involving the clinical use of high levels of ionising radiation.		
Innovation	K54. Discuss the particular issues associated with innovation involving Radiation Oncology and in particular the clinical use of high levels of ionising radiation.		C44. Take responsibility for the particular issues associated with innovation involving use of high levels of ionising radiation.

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8. Learning outcomes for Nurses

8.1. Entry requirements

8.2. CPD

9. Learning outcomes for maintenance engineers and maintenance technicians

9.1. Entry requirements

9.2. CPD

10. Accreditation, Certification and Recognition of the Medical Education and Training in Radiation Protection

There is high demand for developing education and training courses in medical radiation protection due to the rapid development of medical techniques based on ionizing radiation, growth of hospitals and the continuous need to produce competent health professionals in radiation protection. However, external assessment of the quality of education or training provision is needed [1].

Accreditation is a process by which a recognized body assesses and recognizes that education and/or training on medical radiation protection provided by an institution meets acceptable levels of quality. Therefore, there are two parties involved in this process: the institution that provides education and training and an external organization which performs the external assessment and awards accreditation as a result of positive evaluation.

Recognition is a process by which a national authority recognizes the professional equivalence of foreign higher education diplomas or other evidence of formal qualification awarded upon the completion of a course at a higher education institution.

Certification is a process that recognizes an individual medical professional who has demonstrated special knowledge and expertise on medical radiation protection and has completed successfully the education or training provided by an accredited organization. Medical personnel certified in radiation protection bring important benefits to their patients and themselves. Because of their special education and training, certified medical personnel demonstrate knowledge and confidence in the field of medical radiation protection, enabling them to justify and optimize medical procedures and provide better patient care.

Accreditation should be based upon established standards and guidelines [2]. The minimum requirements for accreditation of a training programme should take into account aspects related to admission policy, facilities, staff, certification program, educational material, teaching methods, administration and archive, course update and course evaluation. Training in medical radiation protection should be provided in clinical radiation facilities. Hands-on training can be very effective because it provides real world experience by allowing the trainee to carry out measurements and understand radiation protection techniques rather than just hear about them. All staff should possess appropriate qualifications and experience in medical radiation protection. Scientific program contents and educational material should be reviewed periodically to ensure they remain up-to-date. Course evaluation is usually performed at the end of a course or semester using a questionnaire. Course participants answer questions related to several aspects of educational process such as educational material, course duration and teaching effectiveness. An accreditation decision should be made following a periodic on-site evaluation by a team of experts in the field of medical radiation protection.

Certification is usually based on examinations. Several evaluation methods can be considered to examine knowledge in medical radiation protection including written examinations, oral examinations and research projects. Re-certification programs ensure that certified professionals maintain, develop or improve knowledge in the area of medical radiation protection they are certified.

There are several initiatives and tools developed by the European Commission to facilitate the accreditation, certification, validation and recognition of knowledge as well as to promote the mobility of students, educators and researchers. The European Qualification Framework (EQF) for lifelong learning is a tool based on learning outcomes and aims to relate national qualifications frameworks to a common European reference framework [3]. The European Credit Transfer and accumulation System (ECTS) is a grading system developed to facilitate the transfer of students. ECTS is compatible with the EQF and can help medical radiation protection schools to implement quality

assurance procedures [4]. The European Credit system for Vocational Education and Training (ECVET) is a system for credit accumulation and transfer for vocational education and training [5].

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11. Education and training resources

Education and Training Resources for Referrers

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12. Glossary

References

If decided the references for each section will be combined and listed here.

Personally I think that each section should have its own reference list as it is in the current version of the document.

Abbreviations

CIRSE	Cardiovascular and Interventional Radiological Society of Europe (, Austria)
CPD	Continuous Professional Development
EANM	European Association of Nuclear Medicine (, Austria)
EC	European Commission
EFRS	European Federation of Radiographer Societies (, The Netherlands)
EFOMP	European Federation of Organisations for Medical Physics (, UK)
ESR	European Society of Radiology (, Austria), (Coordinator)
ESTRO	European Society for Therapeutic Radiology and Oncology (, Belgium)
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
MED	Medical Exposures Directive
MS	Member States
WHO	World Health Organisation

Appendices

Appendix A: Relevant Extracts from the Medical Exposures Directive (97/43/EURATOM

Article 5: Responsibilities

3. the practical aspects for the procedure or part of it may be delegated by the holder of the radiological installation or the practitioner, as appropriate, to one or more individuals entitled to act in this respect in a recognized field of specialization.

Article 6: Procedures

3. In radiotherapeutic practices, a medical physics expert shall be closely involved. In standardized therapeutical nuclear medicine practices and in diagnostic nuclear medicine practices, a medical physics expert shall be available. For other radiological practices, a medical physics expert shall be involved, as appropriate, for consultation on optimization including patient dosimetry and quality assurance including quality control, and also to give advice on matters relating to radiation protection concerning medical exposure, as required.

Article 7: Training

1. Member States shall ensure that practitioners and those individuals mentioned in Articles 5 (3) and 6 (3) have adequate theoretical and practical training for the purpose of radiological practices, as well as relevant competence in radiation protection.

For this purpose Member States shall ensure that appropriate curricula are established and shall recognize the corresponding diplomas, certificates or formal qualifications.

2. Individuals undergoing relevant training programmes may participate in practical aspects for the procedures mentioned in Article 5 (3).

3. Member States shall ensure that continuing education and training after qualification is provided and, in the special case of the clinical use of new techniques, the organization of training related to these techniques and the relevant radiation protection requirements.

4. Member States shall encourage the introduction of a course on radiation protection in the basic curriculum of medical and dental schools.

ANNEXES

1. Outline of specific educational objectives for mammography

The Annexes will be written once the rest of the sections are finalised.

2. Outline of specific educational objectives for paediatric radiology

The Annexes will be written once the rest of the sections are finalised.

3. Addendum for paediatric nuclear medicine

The Annexes will be written once the rest of the sections are finalised.