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

Directorate-General for Energy
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ESR European Society of Radiology	EFRS European Federation of Radiographer Societies
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FOREWORD

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Since the discovery of radioactivity and x-rays at the end of the 19th century the medical uses of ionising radiation have increased tremendously, both in patient therapy and medical diagnosis. This has involved not only a marked increase in the number of procedures, but also an expansion into different areas of medicine and the creation of new medical specialties. Nowadays, complex radiation-based tools and techniques are used in most areas of modern medicine and by specialists who have differing levels of knowledge about the risks posed to human health by ionising radiation.

The need for education and training in radiation protection of the concerned medical specialists was realised long ago and different international organisations have issued recommendations in this respect. European legal requirements were introduced in this area during the 1980s, when Euratom legislation for radiation protection of patients was first adopted. This legislation was updated in 1997, when important new requirements – e.g., for theoretical and practical training, continuing education, the recognition of qualifications and the introduction of radiation protection in the curricula of medical and dental schools – were introduced. The most recent revision of the European legislation for radiation protection (Council Directive 2013/59/Euratom) maintains the education and training requirements of the previous legislation and provides a further basis for integrating the protection of medical staff and patients.

In 2000 the European Commission published "Radiation Protection 116: Guidelines on education and training in radiation protection for medical exposures". The main objective of the guidance provided on the following pages is to update the publication of 2000. Besides the obvious benefits of taking into account the scientific, technological and regulatory developments of the past decade, the present Guidelines bring several additional advantages: a) the document follows the modern format and terminology of the European Qualifications Framework for Lifelong Learning; b) detailed requirements for initial and continuing training are specified for each of the included professions; and, perhaps most importantly, c) the document was developed and endorsed by the major European professional societies in the area, which should provide strong support for its future implementation in everyday practice.

The publication of this report in the Commission's Radiation Protection series of publications has been recommended by the Group of Experts established under Article 31 of the Euratom Treaty.

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Head of Radiation Protection Unit

EXECUTIVE SUMMARY

Article 7 of the Council Directive 97/43/Euratom (the Medical Exposure Directive, MED), June 30, 1997, on the protection of individuals against the dangers of ionising radiation in relation to medical exposure, lays down requirements for radiation protection education and training.

The European Commission realised that certain aspects of this article required some clarification and orientation for Member States and in 2000 published the 'Radiation Protection Report 116: Guidelines on education and training in radiation protection for medical exposures'. These guidelines contain some specific recommendations for the application of the Directive and it has served the Member States well.

However, the rapid technological development of the past decade and the constant growth of ionising radiation use in medicine have necessitated an update of this document. Furthermore, Radiation Protection Report 116 does not provide learning outcomes compatible with the European qualifications framework and does not include requirements and guidance adequate for new specialists using ionising radiation, in particular those outside imaging departments.

The present guidelines are an update of Radiation Protection Report 116, which take into account the recent technological advances, the education and training requirements of the Euratom Basic Safety Standards Directive, the European qualifications framework and includes new specialists using ionising radiation.

Radiation protection education and training starts at the entry level to medical, dental and other healthcare professional schools. The revised Euratom Basic Safety Standards Directive states that 'Member States shall ensure that practitioners and the individuals involved in the practical aspects of medical radiological procedures have adequate education, information and theoretical and practical training for the purposes of medical radiological practices, as well as relevant competence in radiation protection. For this purpose Member States shall ensure that appropriate curricula are established and shall recognise the corresponding diplomas, certificates or formal qualifications. Individuals undergoing relevant training programmes may participate in practical aspects of medical radiological procedures. 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, training is provided on these techniques and the relevant radiation protection requirements. Member States shall encourage the introduction of a course on radiation protection in the basic curriculum of medical and dental schools'.

Radiation protection courses for medical and dental students should include knowledge needed by a referring physician, i.e. basic knowledge on patient radiation protection such as biological effects of radiation, justification of exposures, risk-benefit analysis, typical doses for each type of examination etc. In addition, knowledge of the advantages and disadvantages of the use of ionising radiation in medicine, including basic information about radioactive waste and its safe management, should be part of radiation protection education and training for medical students. Learning outcomes for referrers are described in chapter three.

Radiation protection courses in dental schools should cover the same basic aspects as medical schools, mentioned above, as well as specific training for the safe operation of diagnostic X-ray equipment. These include the principles of X-ray tube operation, radiographic imaging, image processing, quality assurance programmes, occupational dose control and patient dose control etc.

The core radiation protection learning outcomes described in chapter two at European qualifications framework level three are sufficient for health professionals who are not radiation workers or referrers, e.g. nurses without referring duties. Healthcare professionals who are classified as radiation workers require further knowledge, skills and competence and at higher European qualifications framework levels.

These guidelines have been divided into sections according to the roles of the healthcare professionals in question, and each section includes, in table format, learning outcomes in terms of knowledge, skills and competence. Recommendations at the required European qualifications framework level in radiation protection upon entry to the particular profession and the type of continuous professional development in radiation protection required for the particular profession are also given.

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1 INTRODUCTION

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

It is very important to be aware, as professionals, of the possible dangers from exposure to ionising radiation. This awareness constitutes a key factor for the equitable exploitation of the possibilities ionising radiation has to offer for diagnosis and treatment versus its potential for harm.

Underestimating the health risks from exposure to ionising radiation could lead to unjustifiable patient and/or physician exposure, and to a concomitant increase in the overall population dose.

Overestimating the radiation risks, on the other hand, may lead the professional towards disproportionate concerns, and discourage patients from having necessary diagnostic or therapeutic radiological procedures.

Therefore, an assessment of the health risks from exposure to ionising radiation as opposed to the benefits involved should be carefully conducted in order to ensure appropriate referral (justification).

Exposure to ionising radiation should be minimised as much as possible whilst achieving the required diagnostic or therapeutic outcome (optimisation).

Education and training in general, and specifically training in the field of radiation protection, are widely recognised as key components of justification and optimisation programmes. An appropriate balance between education and training should be ensured, and hands-on training courses with a problem-solving approach should be organised and promoted. The faculty must have profound knowledge in medical radiation protection and, specifically, in the practical aspects of how to train a subject.

International and European organisations such as the International Commission on Radiological Protection (ICRP) [1, 2, 3, 5], International Atomic Energy Agency (IAEA) [6, 7, 8], World Health Organisation (WHO) [9, 10, 11, 12], and the European Commission (EC) [13, 14], recognise the importance of education and training in reducing patient and staff doses while maintaining the necessary level of quality for diagnostic and therapeutic procedures.

1.1 Background

Article 7 of the Council Directive 97/43/Euratom (the Medical Exposure Directive-MED) on the protection of individuals against the dangers of ionising radiation in relation to medical exposure (MED), lays down requirements for radiation protection education and training [15].

The EC realised that certain aspects of this Article required some clarification and orientation for Member States (MS) and in 2000 published the ‘Radiation Protection Report 116: Guidelines on education and training in radiation protection for medical exposures (RP116)’ [14]. These guidelines contain some specific recommendations for the application of the directive and it has served the MS well.

However, the rapid technological development of the past decade and the continuous growth of ionising radiation use in medicine have necessitated an update of these guidelines [16, 17]. Furthermore, RP116 does not provide learning outcomes compatible with the European

Qualifications Framework (EQF) and does not provide adequate coverage of requirements and guidance for new specialists using ionising radiation, in particular those outside imaging departments.

Today, medical procedures constitute by far the most significant artificial source of radiation exposure to the general population [18]. Since training in radiation protection is widely recognised as one of the basic components of optimisation programmes for medical exposure, it is necessary to establish a high standard of education and training, harmonised at European Union (EU) level.

The revised Euratom BSS Directive [19] states that 'Member States shall ensure that practitioners and the individuals involved in the practical aspects of medical radiological procedures have adequate education, information and theoretical and practical training for the purposes of medical radiological practices, as well as relevant competence in radiation protection. For this purpose Member States shall ensure that appropriate curricula are established and shall recognise the corresponding diplomas, certificates or formal qualifications. Individuals undergoing relevant training programmes may participate in practical aspects of medical radiological procedures. 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, training is provided on these techniques and the relevant radiation protection requirements. Member States shall encourage the introduction of a course on radiation protection in the basic curriculum of medical and dental schools'.

Therefore, in 2010, the EC initiated a project to study the implementation of the MED requirements in radiation protection education and training of medical professionals in the member states and to develop European Guidance containing appropriate recommendations for harmonisation at the EU level [20].

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 EU* (MEDRAPET), 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), United Kingdom

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:

1. To carry out an EU-wide study on radiation protection education and training of medical professionals in the MS;
2. To organise a European Workshop on radiation protection education and training of medical professionals in the MS;
3. To develop European guidelines on radiation protection education and training of medical professionals.

This report concentrates on the third objective while taking into account the outcomes of the first two and the requirements of the Euratom BSS [19].

1.2 MEDRAPET survey

The survey was aimed at the main stakeholders within the EU and associated countries, with responsibility for ensuring the application of the MED, particularly in relation to articles 7 and 9 [15].

A response rate of 57% from the Radiation Protection Authorities (RPA) is considered extremely positive. The survey revealed that the regulatory framework of radiation protection education and training is well developed at the national level. Its implementation, however, is considered to be poor.

The responses from the Professional Societies (PS) showed that the fundamental understanding of the complexities of radiation protection and the concomitant knowledge base vary between different specialist groups.

All PS claim to have some kind of radiation protection education and training. The majority of this education and training is carried out at undergraduate level or during residency, with a lower percentage at the continuous professional development (CPD) level.

The results from the Educational Institutes (EI) suggest a need to increase communication between RPA, PS and EI, taking into account that EI should train healthcare professionals according to the professional profile defined by PS and the relevant EC Directives.

An overview of the results from the survey of key stakeholders clearly shows an urgent need to build a bridge between RPA, PS and EI, in order to achieve the goals of the MED and the Euratom BSS.

Creating legislation and providing guidelines at EU or national level is, by itself, not enough to create a radiation protection safety culture among healthcare professionals.

Radiation protection education and training are far from being harmonised, and in some instances have not been implemented.

1.3 Role of organisations

The main objective of organisations representing healthcare professionals is to maintain and improve the status of their profession. Therefore, they provide recommendations to their members on the following topics, not necessarily in the order listed:

- Education and training
- Level of knowledge, skills and competence (KSC)
- Continuous professional development (CPD)
- Ethical and professional code of practice

It is obvious to the healthcare professions, directly or indirectly involved with the use of ionising radiation, that radiation protection should form a part of the above mentioned topics, at the appropriate level for each profession.

PS exist at the regional, national and international level. More often than not, the regional and international organisations are networks of national organisations and provide similar recommendations that aim at harmonised implementation at the regional or international level.

European organisations which represent healthcare professionals are of paramount importance in the harmonisation of their professions, at least within Europe. They are striving to ensure the same level of KSC.

Input from the relevant European organisations involved in the MEDRAPET project was very important for the development of these guidelines and will also be crucial for their dissemination and use.

1.4 Disciplines not covered

The current version of these guidelines focuses on the disciplines mainly found in hospital/clinical environments. For the disciplines outside these environments the core education and training learning outcomes are regarded as sufficient (see chapter two).

The learning outcomes of radiation protection experts (RPE) working in the health-care environment have been developed by the European Network on Education and Training in Radiation Protection (ENETRAP) programme and are, therefore, not included in these guidelines [21].

1.5 Healthcare professional schools

Radiation protection education and training starts at the entry level to the medical, dental and other healthcare professional schools. The Euratom BSS Directive [19] states that 'Member States shall encourage the introduction of a course on radiation protection in the basic curriculum of medical and dental schools'. Radiation protection courses should, however, have a different orientation and content for medical and dental students [13].

Radiation protection courses for medical students should include knowledge needed by a referring physician, i.e. basic knowledge on patient radiation protection such as biological effects of radiation, justification of exposures, procedure optimisation, risk-benefit analysis, typical doses for each type of examination, etc. In addition, knowledge of the advantages and disadvantages of the use of ionising radiation in medicine, including basic information about radioactive waste and its safe management, should be part of radiation protection education and training for medical students. Learning outcomes for referrers are described in chapter three.

Radiation protection courses in dental schools should cover the same basic aspects as medical schools, mentioned above, as well as specific training for the safe operation of diagnostic X-ray equipment. These include the principles of X-ray tube operation, radiographic imaging, image processing, quality assurance (QA) programmes, occupational dose control and patient dose control etc. [13].

The core radiation protection learning outcomes, described in chapter two, at EQF level three are sufficient for health professionals who are not radiation workers or referrers, e.g. nurses without referring duties. Healthcare professionals who are classified as radiation workers require further KSC and higher EQF levels.

1.6 The structure of the guidelines

According to the EU recommendations on the establishment of the EQF for Lifelong Learning (LLL) professional qualifications have been classified into eight levels [22, 23]. Each of the eight levels is defined by a set of descriptors indicating the learning outcomes relevant to the qualifications at that level in terms of KSC. It should be understood that not all subject areas included in the entry qualifications for a particular profession would be at the same level as the entry qualifications for the profession as a whole. Each profession consists of major and minor subject areas, where the major subject areas are considered to be core areas to the profession and their learning outcomes must be at the general level of the profession. Other subject areas that are auxiliary, or supporting, are at lower levels. An example of such a subject area is radiation protection, for which the learning outcomes level depends very much on the level of involvement of a particular health profession with ionising radiation. For example, while entry into the profession as a medical doctor requires at least KSC level 7 for the medical subject areas, radiation protection KSC level 5 may be sufficient if the particular medical doctor acts as referrer for the use of ionising radiation.

Education and training guidelines and KSC tables should be updated regularly to reflect technological and other advances in the field of medical radiation protection.

These guidelines have been divided into sections according to the healthcare profession in question, and each section includes KSC and CPD at the required level.

Each chapter includes two subsections, one on radiation protection level requirements upon entry to the particular profession and the other on the type of CPD in radiation protection for the profession. The first subsection specifies the KSC and the required EQF level in radiation protection upon entry to the particular profession and the second subsection specifies the type of CPD in radiation protection required for the particular profession, i.e. whether the radiation protection CPD is to acquire more KSC or to bring the entry KSC to a higher EQF level.

The structure of these guidelines will facilitate future amendments by various professions and the inclusion of new professions (see section 1.4).

These guidelines do not include details on the number of hours for radiation protection education and training. In accordance with the European recommendations for LLL [22], only learning outcomes are specified. It is up to the educational establishments to decide on the time required to achieve these learning outcomes for the particular profession at the corresponding level of LLL. The levels for radiation protection education and training required are different for the different professions and the KSC of each individual profession is currently at a different level. Guidance on the number of hours for radiation protection education and training with respect to diagnostic and interventional radiology (IR) can be found in ICRP publication 113 (tables 3.1 and 3.2, which are reproduced, with the permission of ICRP, in the annex) [5].

It is also important to note that healthcare professionals involved with multimodality imaging studies acquired using multimodality systems, such as positron emission tomography (PET)/computed tomography (CT) and single photon emission computed tomography (SPECT) /CT [24, 25 and 26] require the competence and certification in radiation protection for both diagnostic radiology and nuclear medicine (NM) as specified in sections 4.1 and 4.4 respectively.

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2 CORE LEARNING OUTCOMES FOR RADIATION PROTECTION

All healthcare professionals who work with ionising radiation, those who refer patients for diagnostic or therapeutic procedures, as well as those working within areas where ionising radiation is used, must acquire essential core KSC in radiation protection during the entry level of education and training in their respective schools (see section 1.5).

A review of the recommendations of international and European organisations [1, 2, 3, 4, 5], the wider literature [6, 7, 8, 9, 10], as well as the conclusions of the survey undertaken as part of the MEDRAPET Project (see section 1.2), suggest that the topics to be covered at this entry level should be those listed in Table 2.1. The corresponding KSC are listed in Table 2.2 and these should be at least EQF level 5.

Upon entering their respective professions, healthcare professionals may be required to have an enhanced KSC level for these topics, as well as additional and specific KSC for their profession (see section 1.6). These are outlined in the following chapters for the healthcare professions currently being considered. For those professions not yet specifically considered in these guidelines, the requirements should at least include the core learning outcomes presented in this section at the EQF level of the particular profession (see section 1.4).

Table 2.1: Core radiation protection topics

No.	Topic
1	Atomic structure, X-ray production and interaction of radiation
2	Nuclear structure and radioactivity
3	Radiological quantities and units
4	Physical characteristics of X-ray systems
5	Fundamentals of radiation detection
6	Fundamentals of radiobiology, biological effects of radiation
7	Risks of cancer and hereditary disease and effective dose
8	Risks of deterministic effects
9	General principles of radiation protection
10	Operational radiation protection
11	Particular patient radiation protection aspects
12	Particular staff radiation protection aspects
13	Typical doses from diagnostic procedures
14	Risks from foetal exposure to ionising radiation
15	Quality control and quality assurance in radiation protection
16	National regulations and international standards
17	Dose management of pregnant patients
18	Dose management of pregnant staff
19	The process of justification of imaging examinations
20	Management of accidents/unintentional exposures

All healthcare professionals who refer patients for diagnostic procedures, as well as those working within areas where ionising radiation is used, must take into consideration that specific population groups need special precautions to protect them from radiation.

Screening programmes involve asymptomatic persons and a prerequisite for a successful screening programme is that the images contain sufficient diagnostic information to be able to detect a given clinical condition, often malignancies, using as low a radiation dose as is reasonably achievable. This quality demand applies to every single screening image. An example of a screening programme is breast cancer screening [11]. Quality Control (QC) therefore must ascertain that the equipment performs at a consistently high quality level and that the exposure protocols used are optimised for the purpose.

Furthermore, diagnostic radiological examinations carry higher risk per unit of radiation dose for the development of cancer in unborn children, infants and children compared to adults [1, 12 and 13]. The higher risk is partly explained by the longer life expectancy in children for any harmful effect of radiation to manifest and the fact that developing organs and tissues are more sensitive to the effects of radiation. Therefore, it is particularly important that all radiological examinations performed on pregnant patients, young children and adolescents are justified and optimised with regard to radiation protection.

Healthcare professionals involved in such procedures, need to have specific KSCs for such procedures in order to assure adequate protection of asymptomatic persons participating in screening programmes, pregnant women, infants and children from routine diagnostic and interventional procedures utilising ionising radiation. The learning outcomes specified in the following chapters include the necessary KSC for these special situations.

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Table 2.2: Core learning outcomes in radiation protection for the healthcare professions

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Core radiation protection	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 X-ray systems K5. Explain the fundamentals of radiation detection K6. Explain the fundamentals of radiobiology and the biological effects of radiation K7. Explain the relation between effective dose and the risk of cancer and hereditary diseases K8. Explain the differences between deterministic and stochastic effects and their respective dose ranges K9. Describe the general principles of radiation protection K10. Explain the 'linear no-threshold' (LNT) hypothesis K11. List and explain radiation protection aspects with respect to patients K12. List and explain radiation protection aspects with respect to staff K13. List typical doses from diagnostic procedures K14. Explain the risks to the foetus from exposure to ionising radiation K15. Understand the principles of QC and QA with respect to radiation protection K16. List the regulations and international standards relevant to radiation protection in the healthcare setting K17. Understand the concepts of justification and optimisation K18. Explain accidental/unintended exposures	S1. Apply radiation protection measures in daily practice S2. Communicate the most important factors that influence staff doses S3. Compare reported doses from medical procedures to doses from natural sources S4. Interpret radiation risks in the context of other risks in daily life S5. Identify the legal radiation protection obligations in daily practice	C1. Implement the national radiation protection regulatory requirements in daily practice

3 LEARNING OUTCOMES FOR REFERRERS

Medical imaging involving the use of ionising radiation (X-rays or radionuclides) is a major and increasing source of radiation exposure worldwide. Before CT was introduced in the 1970s, the most common imaging examination was radiography, which usually involved a rather small radiation dose for the patient. Currently, CT is the preferred imaging modality and the largest contributor to radiation dose from medical exposure. CT scans may lead to organ doses that can be several hundred times higher than doses typically delivered during radiography. Many patients undergo multiple CT examinations and some also undergo multiple NM examinations [1,2].

The basic radiation protection principles for medical exposure, as outlined by the ICRP, are the justification of exposure and optimisation of radiation protection [3]. They have been incorporated into the Euratom legislation [4]. Justification requires that the potential benefit for the patient outweighs the associated radiation risk. While referrers are typically skilled at estimating the benefit of a radiological procedure for an individual patient, the radiation risk itself has not received the attention it deserves. Although the radiation protection community uses the word justification, the term ‘imaging appropriateness’ is more common among radiologists who use ‘appropriateness criteria’ developed by professional societies such as the Royal College of Radiologists (RCR) or the American College of Radiology (ACR) [5,6]. The referrer and practitioner should be involved, as specified by the MS, in the justification process at the appropriate level. Optimisation does not fall within the domain of referrers; however, referrers are responsible for providing the imaging facility with clinical information pertaining to the patient, in order to help the practitioner justify or assess the appropriateness of the examination and tailor the examination to the patient.

According to the Euratom BSS, medical exposure should show a sufficient net benefit, weighing the total potential diagnostic or therapeutic benefits it produces, including the direct health benefits to an individual and the benefits to society, against the individual harm 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 ionising radiation.

In particular, the following requirements should be met:

(a) new types of practices involving medical exposure are justified in advance before being generally adopted;

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

(c) if a type of practice involving medical exposure is not justified in general, a specific individual exposure of this type can be justified, where appropriate, in special circumstances, to be evaluated on a case-by-case basis and documented;

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

(e) medical exposure for medical or biomedical research are examined by an ethics committee, set up in accordance with national procedures and/or by the competent authority;

(f) specific justification for medical radiological procedures to be performed as part of a health screening programme are carried out by the competent authority in conjunction with appropriate medical scientific societies or relevant bodies;

(g) *the exposure of carers and comforters show a sufficient net benefit, taking into account the direct health benefits to a patient, the possible benefits to the carer/ comforter and the detriment that the exposure might cause;*

(h) *any medical radiological procedure on an asymptomatic individual, to be performed for the early detection of disease, is part of a health screening programme, or requires specific documented justification for that individual by the practitioner, in consultation with the referrer, following guidelines from relevant medical scientific societies and the competent authority. Special attention shall be given to the provision of information to the individual subject to medical exposure.*

The implementation of the justification principle has been approached through the establishment of 'appropriateness criteria' or 'referral guidelines' as provided by professional bodies [5, 6, 7]. The EC issued in 2000, and updated in 2003, a booklet with referral guidelines for imaging, for use by health professionals referring patients for medical imaging. In 2010 this outdated document was removed from the EUROPA website upon request from the owner of the intellectual property rights. There has been talk of updating these guidelines. Nevertheless, updated guidelines from professional societies are available [5, 6, 7]. These publications constitute decision support tools to guide referring medical practitioners in the selection of the optimal imaging procedure for certain diagnostic questions. Where there is an alternative that does not use ionising radiation, but yields results of similar clinical value, the guidelines advises against radiological procedures with ionising radiation. Publications such as those mentioned above provide specific directions to help practitioners properly justify procedures.

A number of studies have been published indicating that 20% to 40% of CT scans could be avoided if clinical decision guidelines were followed; some studies suggest even higher numbers of avoidable examinations [1]. Furthermore, several studies have revealed a very low awareness of the referral guidelines [9, 10, 11, 12].

The IAEA has provided information for referrers through its website [13]. It includes a framework for justification, different levels at which justification is applied, responsibilities of referrers, practice of justification, reasons for over-investigation and the knowledge required for proper justification of a radiological procedure. It also includes information from the RCR imaging referral guidelines (iRefer) and provides the following guidance [13,14]:

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 EC in 2000, and revised in 2003 and the guidelines published by the RCR [14], a useful investigation is one in which the result, either positive or negative, will alter a patient's management or add confidence to the referrer's diagnosis. According to these guidelines, there are some reasons that lead to wasteful use of radiation. With an emphasis on avoiding unjustified irradiation of patients, these guidelines have 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 procedure history of patients. Furthermore, patients may not be able to inform the practitioner that they had a similar procedure recently. It is important to try to retrieve previous patient procedures and reports, or at least procedure history when possible. Digital data stored in electronic databases may help with this.

To help avoid repeating investigations, it is advisable to establish a tracking system for radiological examinations (especially CT, interventional procedures and NM) and patient dose. The IAEA has taken steps towards this by setting up the "IAEA Smart-Card/SmartRadTrack" project [15]. Countries should consider including necessary provisions in their national requirements for patient radiation exposure tracking.

DO I NEED IT? Performing investigations that are unlikely to produce useful results should be avoided, i.e. procedures should be requested 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 investigation.

DO I NEED IT NOW? Investigating too quickly should be avoided. The referrer should allow enough time to pass so that the patient's symptoms or the impact from managing the symptoms is sufficiently evident.

IS THIS THE BEST EXAMINATION? Doing the examination without first taking into consideration safety, resource utilisation or diagnostic outcome should be avoided. Discussion with a practitioner may help referrers decide on the 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. Failures 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 should be avoided. Some physicians tend to rely on investigations more than others. Some patients take comfort in being investigated.

The referrer should be aware of procedures that expose patients to high radiation doses and exercise extra caution in these instances. This however, does not imply that low-dose procedures can be ordered without proper justification. A quantitative knowledge of doses from various procedures is useful for the referrer. A review of radiation doses, their meaning and their role in risk assessment is available [16, 17, 18]. Some NM procedures are also responsible for high radiation doses to patients and information on doses is available [19]. Information on radiation exposure in pregnancy is also available [20].

Table 3.1 provides learning outcomes for the referrers. The knowledge required covers principles of justification; different levels at which the justification principle is applied; requirements for referrers as specified in the Euratom BSS, including information for patients and specific knowledge required to deal with radiation exposure in pregnancy, women of childbearing age, breastfeeding mothers and children. The corresponding information for skills and competence is provided in the table.

3.1 Radiation protection professional entry requirements

Radiation protection is a minor subject for Referrers and should be at level 5 of the EQF upon their entry to the profession[1].

3.2 Continuous professional development in radiation protection

Referrers should update their radiation protection KSC at regular intervals in order to maintain their radiation protection competence and update their knowledge on new diagnostic procedures and their justification.

It is important to note here that a large number of Referrers may be General Practitioners (GPs)/Family Doctors that practice individually or in small health centres. They may not have daily contact with diagnostic facilities, unlike specialists in major hospitals, or the opportunity

[1] The reader is referred to section 1.6 for more information.

to participate in in-house CPD activities. Therefore they should seek to make arrangements with centres that provide CPD activities in radiation protection as appropriate, in the best interests of patient care.

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Table 3.1: Learning outcomes in radiation protection for referrers

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Patient safety/risk management	K1. Explain the principle of justification and its application at different levels including for asymptomatic individuals and on a case by case basis K2. List the diagnostic and therapeutic practices that are formally approved through legislative or administrative acts at the national or state level. K3. Explain why certain groups are more susceptible to harmful effects of ionising radiation (e.g. children, pregnant patients) K4. Explain the joint responsibility of referrers and imaging specialists in the justification process of a radiological examination as specified by European and national legislation. K5. List approximate values of radiation doses for common diagnostic examinations K6. Explain the importance of the utilisation of clinical and radiological information from previous examinations in the process of justification K7. Discuss some clinical situations where a test with non-ionising radiation is better than one using ionising radiation K8. List and describe available appropriateness criteria and guidelines applicable in your area of practice K9. Discuss the information to be provided to patients with respect to benefits and radiation risk and risk of procedures in own area of practice K10. Explain principles governing the use of ionising radiation in woman of child-bearing age K11. Discuss the pros and cons of an examination involving the use of a radiopharmaceutical for breastfeeding women and action warranted to protect the child K12. Explain circumstances in your practice where use of ionising radiation on a child is justified	S1. Apply the principle of justification to specific groups of patients and individuals including the exposure of asymptomatic individuals, comforters and carers S2. Identify situations in which the use of ionising radiation is justified in the case of pregnant women, women of reproductive age, children or breast feeding mothers S3. Assess the cumulative effective dose for a series of exams for a given individual patient S4. Carry out a review of the literature to aid justification in cases for which appropriateness criteria are not yet available S5. Explain benefits and risks of particular procedures to specific patients S6. Inform patients of their health problems and the planned procedure S7. Communicate the radiation risk to the patient at an understandable level, whenever there is a significant deterministic or stochastic risk, or when the patient has a question	C1. Take responsibility for justification in accordance with requirements in European and national legislation and guidelines of professional bodies C2. Implement published appropriateness criteria in own practice C3. Provide necessary information in referral for imaging facility to aid in optimisation of an examination C4. Advise actions in case of inadvertent radiation exposure of a pregnant patient C5. Be competent to diagnose radiation induced skin injury and other potential radiation effects in a patient or a worker in a radiation facility and avoid unnecessary referral C6. Act as a role model for junior colleagues to support the processes of justification and optimisation of radiation protection

4 LEARNING OUTCOMES FOR PHYSICIANS DIRECTLY INVOLVED WITH THE USE OF RADIATION

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

Having established the benefits of ionising radiation for 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 states, 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, the benefit should, indeed, substantially outweigh the incurred risks.

Furthermore, the ICRP recommends using three conceptual levels of justification:

- justification of medical use 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 chapter focuses on the latter level of justification, the responsibility for which lies jointly with the referrer and the practitioner.

The radiation protection education and training of physicians directly involved in the use of ionising radiation should be of high standards as to allow them to follow this principle of justification on a case-by-case base. The aim of this chapter is to provide the necessary KSC on radiation protection for each discipline involved directly with the use of ionising radiation.

References

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4.1 Diagnostic radiologists

The ESR has issued the European Training Charter [1] with the aim of harmonising and enhancing the quality of radiological care in Europe by providing a template for trainees and educators. The charter defines a five-year training period in radiology. The core knowledge of the first three years of training should not only include relevant radiographic anatomy, principles of imaging technology, basis of molecular medicine regarding imaging, fundamentals of clinical research and evidence-based medicine, but also physics and radiation protection.

During the fourth and fifth years, trainees may opt for training in a subspecialty alongside general radiology, or opt for general radiology itself as a subspecialty interest area. After the initial radiology training of five years, fellowship training can be undertaken in a single subspecialty, which requires a specific curriculum.

The ESR recognises the need for organ system-based subspecialisation rather than technology-based subspecialisation. It is likely that disease-oriented education will be required in certain areas. The publication of regular editions of the Training Charter will keep it up-to-date with developments in various fields of radiology so it can continue to meet the requirements of radiologists in training.

As healthcare systems vary among countries within the EU, hopefully this document will help national societies structure their programmes, in coordination with their government and other competent authorities, into training programmes with a minimum of five years. The completed training scheme should be sufficient for performing independent practice safely. However, bearing in mind differences among countries, it is generally accepted that application of the proposed structure will vary in some aspects among countries [2].

The EC has identified a lack of knowledge on the inherent risks of diagnostic imaging, among both referring doctors and radiological staff [3]. The White Paper on radiation protection from the ESR summarises all the different aspects of X-ray-based medical imaging [4]. It is of the utmost importance for radiologists to understand the scientific basis of diagnostic imaging, including the associated risks, in order to make the best use of diagnostic modalities for the benefit of the patient. Therefore, education and training in radiation protection should start from the very beginning of radiology training and continue throughout the entire career [5]. Professional education has to keep pace with the development of new, more sophisticated diagnostic tools, as static curricula are producing medical professionals without sufficient competence [6]. Specific training in related radiation protection aspects should be organised, together with the development of imaging tools and the implementation of new techniques in an institution.

The complete list of topics from the EC document RP116 [7] should be included in radiation protection programmes in diagnostic radiology. These are included in Table 4.1.1.

4.1.1 Radiation protection professional entry requirements

The professional entry requirements for Diagnostic Radiologists should be equivalent to EQF[2] level 7. Radiation protection is a major subject for Diagnostic Radiologists and should be at the same level as their professional entry level requirements for the EQF [8].

4.1.2 Continuous professional development in radiation protection

Through their careers Diagnostic Radiologists advance to EQF level 8 and this should be through CPD activities that enhance their KSC to level 8 [9]. Special emphasis should be given to new diagnostic systems, the acquisition of skills in the practical use of such systems and in general to advance their justification competence in diagnostic procedures.

References

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Table 4.1.1: Learning outcomes in radiation protection for diagnostic radiologists

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Radiation physics	K1. List sources and properties of ionising radiation K2. List and explain mechanisms of interaction between ionising radiation and matter/tissues K3. List and explain mechanisms of radioactive decay K4. Explain the phenomena of X-ray interaction with matter and the consequences for image generation, image quality and radiation exposure K5. List and explain definitions, quantities and units of kerma, absorbed energy dose (Gy), organ and effective doses (Sv), as well as exposure rate and dose rate	S1. Apply radiation physics to optimally select the best imaging modality S2. Apply radiation physics to optimise the protocols, using minimal exposure to reach the image quality level needed for the task S3. Use the laws of physics to minimise scatter and optimise contrast S4. Use the correct terms to characterise exposure in daily radiograph fluoroscope and CT examinations and define organ risk, and estimate the genetic and cancer risk	
Equipment	K6. Explain the mechanism of X-ray production K7. List the components of an X-ray unit and explain the process of X-ray generation K8. Explain the function of filters and diaphragms K9. List the common analogue and digital detectors, explain their function and their relative pros and cons K10. Explain the role of screens (in analogue radiography) and grids and their effect on image quality and exposure	S5. Continuously check image quality to recognise and correct technical defects S6. Demand the best in image quality, technical innovation and exposure reduction for the lowest cost S7. Coordinate the commissioning of new equipment with the other members of the core team (radiographer, medical physicist) S8. Use the technical features of the specific equipment and take advantage of all quality-improving and dose-reducing capabilities while recognising the limits of the machine	C1. Choose the best equipment for your patient spectrum based on the resources available

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Radiobiology	K11. Describe radiation effects on cells and DNA K12. Describe cellular mechanisms of radiation response, repair, and cell survival K13. Describe radiation effects on tissues and organs K14. Explain differences in radiation response between healthy tissue and tumours as basis for radiation treatment K15. Define and explain stochastic and teratogenic radiation effects and tissue reactions K16. Describe types and magnitudes of radiation risk from radiation exposure in medicine	S9. Inform patients of their health problems and the planned procedure S10. Communicate the radiation risk to the patient at an understandable level, whenever there is a significant deterministic or stochastic risk, or when the patient has a question	
General radiation protection	K17. Describe the basic principles of radiation protection, as outlined by the ICRP K18. Specify types and magnitudes of radiation exposure from natural and artificial sources K19. Describe concepts of dose determination and dose measurement for patients, occupationally exposed personnel and the public K20. Explain the nature of radiation exposure and the relevant dose limits for the worker, including organ doses and dose limits for pregnant workers, comforters, careers, and the general public	S11. Communicate with referrer regarding justification; if necessary, suggest a different test S12. Apply the three levels of justification in daily practice, with respect to existing guidelines, but also to individual cases (e.g. polymorbidity)	C2. Take responsibility for choosing the best imaging modalities for the individual patient (radiography, CT, alternatives such as ultrasound or MRI) by taking into consideration the risk of the disease, patient, age and size, the dose level of the procedure, and exposure of different critical organs C3. Consult both the patient and staff on pregnancy related concerns in radiation protection C4. Take responsibility for patient dose management in different imaging modalities being aware of specific patient dose levels

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Radiation protection in radiology (X-rays)	K21. Define ALARA and its applicability to diagnostic radiology settings K22. Explain the concepts and tools for dose management in diagnostic radiology with regard to adult and paediatric patients K23. Explain the factors influencing image quality and dose in diagnostic radiology K24. Describe the methods and tools for dose management in diagnostic radiology: radiography, fluoroscopy, CT, mammography, and those for paediatric patients K25. Explain the basic concepts of patient dose measurement and calculation for the different modalities in diagnostic radiology K26. Describe the key considerations relevant to radiation protection when designing a diagnostic radiology department K27. List diagnostic procedures performed outside radiology department with relevant radiation protection considerations K28. List expected doses (reference person) for frequent diagnostic radiology procedures K29. Explain quantitative risk and dose assessment for workers and the general public in diagnostic radiology K30. Explain the concepts and tools for radiation protection optimisation	S13. Optimise imaging protocols by using standard operating procedures (SOPs) and by adapting these to the specific patient's size S14. Use specific paediatric protocols, by taking into consideration the physics of small size, but also the elevated risk, vulnerability and specific pathology of each age group S15. Choose the best compromise between risk-benefit ratios, image quality and radiation exposure on a case-by-case basis. S16. Supervise the use of personal protective equipment. Support monitoring of the workplace and individuals. Support exposure assessment, investigation and follow up, health surveillance, and records S17. Apply radiation protection measures in diagnostic radiology (radiography, fluoroscopy-intervention, CT, mammography and paediatric patients) and advise on their use. S18. Stay within guidance/ reference levels in daily practice S19. Set up size-specific protocols for high-dose procedures S20. Estimate organ doses and effective doses for diagnostic radiology examinations, based on measurable exposure parameters (KAP,DLP)	C5. Advise patients on the radiation-related risks and benefits of a planned procedure C6. Take responsibility for justification of radiation exposure for every individual patient, with special consideration for pregnant patients C7. Take responsibility for choosing and performing the diagnostic procedure with the lowest dose for a given referrer's request C8. Take responsibility for optimising the radiographic technique/protocol used for a given diagnostic procedure based on patient-specific information C9. Take responsibility for applying the optimal size-adapted and problem-adapted individual protocol for high-dose procedures (CT, fluoroscopy-intervention) C10. Implement the concepts and tools for radiation protection optimisation.

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Quality	K31. Define QA in radiology, QA management and responsibilities, outline a QA and radiation protection programme for diagnostic radiology K32. List the key components of image quality and their relation to patient exposure K33. Explain the principle of diagnostic reference levels (DRLs)	S21. Apply standards of acceptable image quality. Perform retake analyses. Understand the effects of poor-quality images S22. Avoid unnecessary radiation exposure during pregnancy by screening the patient before examination (warning signs, questionnaire, pregnancy test, etc.) S23. Double check the appropriate protection measures when exposing a pregnant woman (size and positioning of the x-ray field, gonad shielding, tube-to-skin distance, correct beam filtration, minimising and recording the fluoroscopy time, excluding non-essential projections, avoiding repeat radiographs) S24. Develop an organisational policy to keep doses to the personnel ALARA	C11. Supervise QC procedures on all equipment related to patient exposure C12. Take responsibility for the establishment of formal systems of work (SOPs) C13. Take responsibility for organisational issues and implementation of responsibilities and local rules C14. Take responsibility for organising the radiological workflow in order to avoid accidental / unintended exposures and for adequate handling of such an event
Laws and regulations	K34. List national and international bodies involved in radiation protection regulatory processes K35. Specify the relevant regulatory framework (ordinances, directives, regulations, etc.) governing the medical use of ionising radiation in your country and the EU K36. Specify the relevant regulatory framework governing the practice of diagnostic radiology in your country	S25. Find and apply the relevant regulations and guidance for any clinical situation in radiology	C15. Take responsibility for compliance with regulatory requirements concerning occupational and public radiation exposures C16. Take responsibility for compliance with ALARA principles concerning occupational and public radiation exposure C17. Take responsibility for conforming with patient protection regulations (DRLs, where applicable)

4.2 Interventional radiologists

Interventional radiology (IR) is a branch of radiology which utilises minimally invasive image-guided procedures to diagnose and treat diseases in nearly every organ system [1]. The concept behind IR is to diagnose and treat patients using the least invasive techniques currently available in order to minimise risk to the patient and improve health outcomes.

There are a number of other medical specialties using image-guided interventional techniques with ionising radiation. These include surgeons, e.g. orthopaedic surgeons, vascular surgeons, and medical specialists such as cardiologists, gastroenterologists, etc. [2]. These are considered in section 4.3.

The main advantages of using an image-guided minimally invasive interventional approach are the reduction of scars and pain and faster post-operative recovery. Moreover, interventional procedures are now considered the gold standard of care in many diseases of both vascular and non-vascular origin, and have replaced traditional surgical procedures in several fields. It has to be noted that in almost every case, IR procedures are justified from the point of view of radiation protection [3, 4, 5].

Knowledge of radiation protection by itself is not enough and further skills and competences are needed. Training in radiation protection should become an essential part of the IR training process. Clearly, the best IR performer will use less fluoroscopy. The dose management and radiation protection training should therefore be an integral, essential component of any training and not stand alone [6].

Recently, medical simulators have been introduced in almost every field of modern medical practice, including fluoroscopy-guided procedures [7]. The scenarios are almost identical to the real procedure, but have no limitations regarding the complications or use of ionising radiation, which mean the skills required are also the same. Moreover, many new techniques used by any trained specialist can be, and are initially, rehearsed on the simulator. Simulators include procedure logs that allow individual recording and documentation of any learning (self-assessment) process, as well as a means to examine the trainee.

4.2.1 Radiation protection professional entry requirements

IR is a specialty of diagnostic radiology and the entry level to this profession is level 7 and above[3], therefore the radiation protection entry requirements should be equivalent to those of Diagnostic Radiology at level 7.

4.2.2 Continuous professional development in radiation protection

Through their careers Interventional Radiologists advance to EQF level 8 and this should be through CPD activities that enhance their KSC to level 8. Apart from enhancing their general KSC, particularly on new IR systems, special emphasis should be given to the acquisition of skills in the practical use of IR systems.

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Table 4.2.1: Additional learning outcomes for interventional radiologists

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Radiation physics	K1. Understand special requirements of image formation and image quality aspects with respect to fluoroscopy	S1. Apply radiation physics to optimise interventional protocols, using minimal exposure to reach the desired procedure outcome	
Equipment	K2. Understand and 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, cine runs, last image hold, road mapping)	S2. Use the technical features of the specific equipment, on a daily basis, applying all quality-improving and dose-reducing capabilities, while recognising the limits of the imaging machine or interventional device	C1. Choose the best interventional equipment for your patient range based on the resources available
Radiobiology	K3. Explain radiobiological dose-effect relationships relevant to IR 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, hereditary risks; and radiation effects on adults, children and conception.		

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Radiation protection in interventional radiology (X-rays)	K4. Define ALARA and its applicability to IR settings K5. Explain the meaning of justification and optimisation as applied to IR practices K6. Explain the concepts and tools for dose management in IR of adult and paediatric patients K7. Explain the factors influencing image quality and dose in IR K8. Describe the methods and tools for dose management in IR K9. Explain the basic concepts of patient dose measurement and calculation in IR K10. Describe the key considerations relevant to radiation protection when designing an IR unit K11. List expected doses (reference person) for the main IR procedures K12. Explain quantitatively the risk and dose assessment for workers and public in IR K13. Explain and discuss the latest evidence of low-dose effects on Interventional Radiologists	S3. Optimise procedure protocols by using SOPs for IR and by adapting these to the specific patient size S4. Choose the best compromise between risk-benefit ratio, image quality, procedure outcome and radiation exposure on a case-by-case basis S5. Supervise the use of personal protective equipment by interventional staff, support the monitoring of the workplace and individuals and exposure assessment, investigation and follow up, health surveillance and records S6. Apply and advise on the use of radiation protection measures in IR, particularly for the eyes S7. Estimate effective doses from IR procedures based on measurable exposure parameters (KAP, skin dose) S8. Estimate cases of high doses to the skin S9. Calculate patient risk from measurement data from the dosimetry quantities used to assess adverse biological effects	C2. Advise patients on the radiation-related risks and benefits of a planned interventional procedure C3. Take responsibility for justification of radiation exposure in every individual patient undergoing an IR procedure, with special consideration for pregnant (or possibly pregnant) patients C4. Take responsibility for optimising the technique/protocol used for a given interventional procedure based on patient-specific needs C5. Take responsibility for applying the principles of justification (risk/benefit assessment), optimisation (including ALARA) and the setting up of reference levels to protect the patient from unnecessary risk from radiation C6. Take responsibility for applying the optimal size-adapted and problem-adapted individual protocol for high-dose procedures (TIPS etc.) C7. Take responsibility for avoiding very high doses to the skin, which can cause deterministic effects C8. Follow-up patients to check for the appearance of deterministic effects C9. Take responsibility for and establish practices to ensure dose limitation to staff

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Quality	K14. Define QA in IR. Explain its management and responsibilities. K15. List the key components of image quality and their relation to procedural patient exposure K16. Explain the principle of DRLs in IR procedures	S10. Understand the effects of poor-quality images in IR procedures S11. Avoid unnecessary patient radiation exposure during IR procedures by optimising the techniques performed (size and positioning of the x-ray field, gonad shielding, tube-to-skin distance, correct beam filtration, minimising and recording the fluoroscopy time, excluding non-essential projections) S12. Develop an organisational policy to keep doses to IR personnel ALARA	
Laws and regulations	K17. Specify the relevant regulatory framework governing the practice of IR in your country	S13. Find and apply the relevant regulations for any clinical situation in IR	C10. Take responsibility for conforming with patient protection regulations (including procedural reference levels, where applicable)

4.3 Non-radiological specialists employing ionising radiation in interventional techniques

The extensive use of ionising radiation outside of radiology departments, by non-radiologists, means that these medical specialists require similar radiation protection education and training. These medical specialists include interventional cardiologists, electrophysiologists, vascular surgeons, angiologists, urologists, orthopaedic surgeons, neurosurgeons, gastroenterologists, gynaecologists and anaesthetists involved in pain management.

These specialists should receive basic radiation protection education and training during their general medical education as outlined in chapter two. To rely on this basic training to provide sufficient levels of patient and practitioner safety without further training or education is, however, not realistic. Further education of non-radiological specialists is therefore essential [1].

It is important to make a distinction between those specialists who perform procedures that have the potential to deliver high radiation doses, e.g. cardiologists, angiologists, vascular surgeons who use mobile or fixed digital subtraction angiography (DSA) units to acquire multiple DSA runs and neurosurgeons who work with C arms, and those specialists who perform low-dose procedures, e.g. gastroenterologists [2], orthopaedic surgeons, urologists who use fluoroscopy- often pulsed- with occasional static images to document a procedure.

For specialists who perform potentially high-dose procedures, learning objectives that are similar to those for interventional radiologists are required. For specialists who perform low-dose procedures, practical aspects of radiation protection should have a priority and training programmes should focus on the achievement of skills.

Radiation protection education and training for all specialties involved in the use of ionising radiation should be conducted under the auspices of the Institutional Radiation Safety Committee or Officer in accordance with regulatory requirements, local rules and procedures.

The involvement of the radiological department in radiation protection education and trainings advisable as radiologists have the necessary radiation protection knowledge and expertise, understand the legal framework, are familiar with the equipment in the local setting and receive dedicated CPD.

Practical training should be performed by a dedicated team of experts (radiologists, interventional radiologists, other relevant specialists and MPs) in conjunction with the department of radiology.

4.3.1 Radiation protection professional entry requirements

Radiation protection education and training does not form a formal requirement for the entry into these medical specialties and the radiation protection entry requirements[4] for their professions should at least correspond to the core learning outcomes at EQF level 5 (see chapter 2).

However, before any such professional starts to perform IR techniques, they must acquire additional KSC specific to their profession. This must be at least EQF level 6.

4.3.2 Continuous professional development in radiation protection

It is comparatively rare that non-radiological specialists employing interventional techniques have the necessary radiation protection KSC upon entry to their profession and therefore must acquire these through appropriate CPD activities before starting to employ interventional techniques. The required radiation protection KSC EQF level should be level 6.

[4] The reader is referred to section 1.6 for more information.

Throughout their careers they should aim to enhance their radiation protection KSC, with particular emphasis on the acquisition of practical skills in the use of IR procedures appropriate for their profession.

References

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Table 4.3.1: Learning outcomes in radiation protection for non-radiological specialists employing high-dose interventional techniques

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Radiation physics	K1. Understand the nature of X-rays as ionising radiation within the electromagnetic spectrum K2. Explain background radiation K3. Describe how X-rays for diagnostic applications are produced		
Equipment	K4. Understand the basic function of X-ray systems K5. Describe the concept of the imaging 'chain', from initiating the X-ray exposure to displaying the image K6. Describe the construction, function and variety of equipment for applying specific interventional procedures (C-arm system, Portable C-arm, Hybrid or installed angiography suite equipment)	S1. Continuously check image quality to recognise technical defects in specific interventional procedures	
Radiobiology	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	S2. Inform patients of their problems and the planned procedure S3. Communicate the nature of radiation risks effectively to patients.	

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Radiation protection in specific interventional procedures (according to specialty)	K10. Describe the basic principles of radiation protection, as outlined by the ICRP K11. Understand the need for justification, including consent in specific interventional procedures. K12. Understand the need for optimisation and explain the ALARA principle in specific interventional procedures K13. Explain the nature of radiation exposure and the relevant dose limits for the worker, including organ doses; dose limits for pregnant workers, and the public, and for comforters and careers K14. Explain the concepts and tools for dose management in specific Interventional procedures of adult and paediatric patients K15. List expected doses (to a reference person) for the main specific Interventional procedures (according to specialty) K16. Explain the concepts and tools for radiation protection optimisation	S4. Apply the three levels of justification in daily practice, respecting existing guidelines but also individual specificities (e.g. polymorbidity) S5. Stay within guidance/ reference levels in daily practice S6. Estimate high skin-dose cases S7. Apply the concepts and tools for radiation protection optimisation S8. Develop an organisational policy to keep doses to the personnel ALARA	C1. Implement protection measures appropriate to the level of exposure and risk C2. Take responsibility for avoiding very high doses to the skin which can have deterministic effects C3. Take responsibility for and establish practices to ensure dose limitation for staff cooperating in specific interventional procedures C4. Consult with appropriate professionals to achieve optimal radiation protection within the regulations C5. Follow up patients to check for the appearance of deterministic effects C6. Implement the concepts and tools for radiation protection optimisation
Quality	K17. Understand the concept of QA K18. List the key components of image quality and their relation to patient exposure in specific Interventional procedures K19. Explain the principle of DRLs in specific Interventional procedures	S9. Avoid unnecessary radiation exposure during pregnancy by screening the patient before examination (warning signs, questionnaire, pregnancy test, etc.) S10. Double check the appropriate protection measures when exposing a pregnant woman (size and positioning of the x-ray field, gonad shielding, tube-to-skin distance, correct beam filtration, minimising and recording the fluoroscopy time, excluding non-essential projections, avoiding repeat radiographs)	C7. Take responsibility for the establishment of formal systems of work (SOPs) in specific Interventional procedures
Laws and regulations	K20. Specify the relevant regulatory framework governing specific Interventional procedures practice in your country	S11. Find and apply the relevant regulations for any clinical situation in specific Interventional procedures	C8. Take responsibility for conforming with patient protection regulations (including DRLs, where applicable)

Table 4.3.2: Learning outcomes in radiation protection for non-radiological specialists employing low level interventional techniques

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Nature of X-radiation	K1. Be aware of the electromagnetic spectrum K2. Understand the place of X-rays as ionising 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 ionising 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 the 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 by patients and vascular operating room (OR) staff	
Biological effects of radiation	K7. Explain the biological effects of radiation. K8. Understand somatic and genetic effects of X-rays on tissue K9. Understand stochastic effects and radiation-induced tissue reactions K10. List and explain radiation protection aspects with respect to staff	S4. Communicate the nature of radiation risks to patients effectively	

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Radiation dose and risk	K11. Define the units of radiation dose K12. Understand the concepts of clinical radiation dose measurement K13. Describe the factors which influence radiation exposure and dose K14. Understand the influence of patient age on radiation risk K15. Understand DRLs and European or national dose surveys	S5. Take account of dose when establishing imaging protocols S6. Use exposure factors to optimise dose S7. Take account of patient age and Body Mass Index (BMI) 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 action when necessary

4.4 Nuclear medicine specialists

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

NM differs from other medical specialties that use ionising radiation in a number of ways, which also leads to different issues in radiation protection. As a consequence of the use of unsealed radionuclides:

a. there are risks from external and internal exposure and contamination for all NM personnel, in particular during preparation and administration of the radioactive substances;

b. there is very limited control of the behaviour of the radioactive substance once it has been administered to the patient;

c. the dose absorbed by a specific organ and the effective dose are strongly dependent upon the patients' individual bio-kinetics;

d. there are potential radiation risks to the patients' relatives (e.g. dose to an unborn in utero or to a breastfed infant) and even to the general public (e.g. external dose from residual activity in a patient or internal dose from incorporation of radioactivity excreted by a patient).

Thus candidates for specialised training should have a good general background in internal medicine as well as the natural sciences. More detailed knowledge has to be acquired on those medical conditions that may need to be investigated or treated by NM techniques, as well as on some complementary methods as far as they relate to NM procedures, education and training in subject areas beyond medicine, such as radiation protection, pharmacokinetics, radiochemistry, instrumentation, computer science and QC.

The practice of NM is known to vary from department to department within a country, and from country to country. Not all physicians specialised in NM perform all tasks or procedures. However, where a task is performed the relevant competence represents what is thought to be good practice.

Furthermore, the allocation of roles amongst healthcare professions involved in NM (NM specialist physicians, NM technologists (NMT), and MPs) varies greatly between departments and countries, with consequences for radiation protection.

While in the majority of cases the NM specialist is legally responsible for all radiation protection issues, the other professions mentioned can share those responsibilities according to the nature of their education, as well as legal constraints and specifics of the health system in the country of their practice. Thus, the radiation protection learning outcomes in this section are deemed indispensable for NM specialists, but may also be applied to the education of NM technologists and MPs (whenever not explicitly mentioned in their respective sections).

The radiation protection learning outcomes for NM Specialists consist of:

1. Basic radiation protection KSC, most of which are not specific to NM and should be part of the undergraduate education and training in radiation protection, but may need to be repeated or completed during postgraduate specialisation. Those learning outcomes consist predominantly of knowledge, with a set of skills and competences as laid out in tables 2.2 and 3.1.

2. Radiation protection KSC (not limited to, but with an emphasis on the specialities of NM) for the areas of:

a. patient exposure (diagnostic and therapeutic),
b. occupational and public exposure,
c. advanced or specialised imaging and therapeutic techniques as presented in Table 4.4.1,
d. exposure to comforters and carers.

4.4.1 Radiation protection professional entry requirements

NM is a medical specialty and the basic radiation protection KSC should be acquired during the period of general medical education at level 5 of the EQF[5] (see chapter 2) [1]. During specialisation their level of radiation protection KSC is expected to be enhanced to the same level as the overall profession at EQF level 7, with radiation protection forming an integral part of their specialisation [2, 3].

If required by national regulations, certification in radiation protection should be part of the certification as NM Specialist through a national board after education and training as detailed in the ‘Syllabus for postgraduate specialisation in NM’ [2].

4.4.2 Continuous professional development in radiation protection

During their careers NM Specialists advance to EQF level 8 through CPD activities that enhance their radiation protection KSC to level 8. Apart from enhancing their general KSC, e.g. on new diagnostic techniques or radiopharmaceuticals, emphasis should be given to the acquisition of KSC in the safe use of radiopharmaceuticals for therapeutic procedures.

If required by national regulations, re-certification in radiation protection should be conducted at, at least, EQF level 7.

References

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5 The reader is referred to section 1.6 for more information.

Table 4.4.1: Additional learning outcomes **for nuclear medicine specialists**

	Knowledge (facts, principles, theories, practices)	**Skills (cognitive and practical)**	**Competence (responsibility and autonomy)**
Nuclear medicine patient radiation protection	K1. Specify the relevant regulatory framework governing the practice of NM in your country K2. List DRLs and expected doses for common NM diagnostic procedures K3. Explain the magnitude of risk as a function of patients' dose, age and prognosis K4. Explain the concepts and tools for scaling activity in paediatric NM (EANM paediatric dosage card) K5. Explain the relevant regulations concerning treatment on an in-patient/out-patient basis, as well as patient release criteria K6. Explain the principle and process of QA for non-imaging devices such as activity meters (dose calibrators) and probes K7. Explain the principle and process of QA of NM imaging devices, such as gamma camera, SPECT, PET (and their combination with CT) K8. Describe the principles and process involved in intravenous, oral, and inhaled radiopharmaceutical administrations K9. Describe action to be taken after misadministration K10. Explain clinical consequences of administration to a pregnant patient or a patient becoming pregnant in the weeks following a radionuclide therapy K11. Describe procedures for dealing with incontinent patients K12. Explain the main factors in optimisation of image quality versus administered activity, like choice of collimator, energy window, or tomographic reconstruction algorithm	S1. Apply the principles of justification (risk / benefit assessment) and optimisation (including ALARA), taking into account existing guidance on indications for NM procedures S2. Decide on radiopharmaceuticals and procedures to be used, taking into account DRLs S3. For each diagnostic or therapeutic procedure, apply European and national laws, regulations, recommendations and standards related to patient safety S4. Evaluate the radiation risk to embryo/foetus against the benefits of a NM procedure S5. Determine the activity to be applied to paediatric patients, depending on body mass S6. Calculate organ dose and effective dose from residence times, using tools such as OLINDA/EXM S7. Choose the procedure to be applied for treatment of benign thyroid disease, from the data of a radioiodine test S8. Set up a patient-specific treatment plan (together with an MPE) for a given therapeutic procedure S9. Design appropriate safety measures for management of in-patients administered with therapeutic doses of radiopharmaceuticals S10. Identify clinical indications permitting the use of low-dose CT in combined imaging procedure	C1. Advise patients on the risks and benefits of a planned NM procedure C2. Take responsibility for the justification of every patient's radiation exposure, with special consideration for cases of pregnant patients C3. Take responsibility for choosing and performing the least dose-intense diagnostic procedure for a given referrer's request, taking into account availability of radiopharmaceutical compounds as well as the possibility of using other imaging modalities, which do not expose the patient to ionising radiation C4. Take responsibility for conforming with DRLs, where applicable C5. Take responsibility for optimising the radiopharmaceutical and the activity used for a given diagnostic procedure based on patient-specific information C6. Take responsibility for optimising patients' exposure from CT in combined imaging modalities, depending on the clinical situation and the feature set of the imaging device C7. Supervise QC procedures on all equipment related to patient exposure (e.g. activity meters, probes, imaging devices like gamma cameras, SPECT, PET) C8. Take responsibility for therapeutic procedures concerning indication and adherence to authorised procedures C9. Take responsibility for applying the optimal activity for a given therapeutic procedure as determined in a patient-specific treatment plan (set up together with an MPE) C10. Implement SOPs for all diagnostic investigations performed regularly

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Nuclear medicine patient radiation protection	K13. Explain the options for optimising patient dose from CT when using combined imaging modalities like PET/CT, SPECT/CT etc. K14. Explain the basic concepts of the MIRD scheme, including time-integrated activity in source region (cumulated activity) and time-integrated activity coefficient (residence time) K15. Explain how to determine which procedure should be applied for the treatment of benign thyroid disease from a radioiodine test K16. List therapeutic procedures performed less frequently or in specialised institutions and their special radiation protection aspects	S11. Design appropriate measures for the management of accidental/unintended exposure, e.g. intravenous extravasation	C11. Implement SOPs for all therapeutic procedures performed regularly at one's institution C12. Implement SOPs for the management of accidental/unintended exposure C13. Advise breastfeeding patients on temporal or complete abandonment of breastfeeding depending on the radiopharmaceutical and administered activity C14. Advise both female and male patients on periods during which they should avoid conception following radionuclide therapy
Nuclear Medicine occupational and public radiation protection	K17. Describe general rules for working with unsealed radionuclides K18. Describe the key considerations relevant to radiation protection when designing a new NM facility K19. Explain the nature and sources of internal and external radiation exposure for workers in NM and the public K20. Explain quantitative risk and dose assessment for workers in NM K21. List procedures with potentially high doses for extremities and eye lenses, such as the use of high-energy beta emitters. K22. Explain quantitative risk and dose assessment (where applicable) for the public, with regard to NM procedures K23. 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.	S12. Develop an organisational policy for the safe handling of unsealed radionuclides (e.g. storage, shielding, record keeping, transportation, and waste) S13. Develop an organisational policy to keep doses to personnel from external and internal (inhalation, ingestion) exposure ALARA S14. Identify procedures that require special operational protection, e.g. extra shielding or remote handling S15. Identify procedures that require special dose monitoring, e.g. finger dosimeters or incorporation monitoring S16. Identify procedures that require instructions for patients (and comforters, carers) on minimising exposure (external and internal) S17. Apply for ethical and legal approval of exposure in medical research	C15. Take responsibility for compliance with regulatory requirements and ALARA principles concerning occupational and public radiation exposures in own department C16. Take responsibility for the establishment of formal systems of work (SOPs) C17. Implement a monitoring programme for external and internal exposure of workers according to the procedures performed and the corresponding risks C18. Implement an organisational policy for protecting pregnant workers from incorporation risks in controlled areas. C19. Implement instructions to patients leaving NM diagnostic units, particularly with ^{111}In C20. Give instructions to patients leaving NM therapy units, particularly with ^{131}I administered for treatment of thyroid cancer and hyperthyroidism

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Nuclear Medicine occupational and public radiation protection	K23. Describe the requirements for regulatory compliance with regard to the management and disposal of radioactive waste and the transportation of radioactive substances K24. List relevant dose limits for workers (including organ doses), for pregnant workers and general public, as well for comforters and carers. K25. Explain the ethical and legal issues regarding the exposure of volunteers in medical research, involving administration of radiopharmaceuticals K26. List and explain the relevant occupational radiation protection issues associated with all specialised procedures performed at one's own institution, e.g. radio-synovectomy, targeted therapies with alpha or beta emitters	S18. Develop organisational policies for the optimisation of patients' and workers' exposures in all specialised procedures	C21. Take responsibility for compliance with legal and ethical requirements when exposing volunteers in medical research or patients in clinical studies C22. Implement SOPs for all specialised procedures performed regularly at one's own institution

4.5 Radiation oncologists

In 2010, ESTRO issued revised guidelines for education and training in radiation oncology. The new guidelines are an updated version of the guidelines that were first published in 1991 and then updated in 2002 and 2010 [1, 2].

Contemporary medical education and training is based on competence. With that in mind, ESTRO decided to revise the core curriculum based on the principles of competence-based training. These competences are defined by the Canadian CanMEDS system [3] and include 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 above, includes comprehension of basic radiation physics, radiation physics applied to radiation therapy, radiation biology and radiation protection as follows:

- Radiobiology
- Basic radiation physics
- Radiation physics applied to radiation therapy
- Concepts and principles of radiation protection

Based on these competences, as well as clinical insight and other scientific insight and knowledge, a set of learning outcomes have been summarised in Table 4.5.1.

These guidelines have been endorsed by European National Radiation Oncology societies and the European Union of Medical Specialists (UEMS) [4].

4.5.1 Radiation protection professional entry requirements

The professional entry requirements for Radiation Oncologists should be equivalent to EQF level 7[6]. Radiation protection is a major subject for Radiation Oncologists and should be at the same level as their professional EQF entry level requirements.

4.5.2 Continuous professional development in radiation protection

Through their careers Radiation Oncologists advance to level 8 of the EQF and this should be through CPD activities that enhance their KSC to level 8. Special emphasis should be placed on new therapeutic systems, techniques and procedures, and the acquisition of skills in the practical use of particularly new procedures. This should help advance their justification competence in therapeutic procedures.

[6] The reader is referred to section 1.6 for more information.

References

[1] Eriksen JG, et al., The updated ESTRO core curricula 2011 for clinicians, medical physicists and RTTs in radiotherapy/radiation oncology, Radiotherapy and Oncology 2012 Apr;103(1):103-8, http://www.estro-education.org/courses/Documents/The%20updated%20ESTRO%20core%20curricula%202011%20for%20clinicians,%20medical%20physicists%20and%20RTTs.pdf (Last time accessed was on the 14th of December 2012).

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Table 4.5.1: Additional learning outcomes in radiation protection for radiation oncologists

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Radiobiology	K1. Describe the interaction of radiation on the molecular level K2. Explain DNA damage K3. Describe the cellular effects, mechanisms of cell death K4. Describe the repair of radiation damage K5. Explain the cell survival curves K6. Describe the normal tissue systems K7. Describe solid tumour and leukaemia systems K8. Explain the effects of oxygen, sensitizers and protectors K9. Explain the effect of time-dose fractionation, Linear energy transfer (LET), different radiation modalities and the interaction between cytotoxic therapy and radiation K10. Describe predictive assays	S1. Communicate knowledge of clinical and radiological anatomy, physics and biology to diagnosis and therapy	
Basic radiation physics	K11. Describe atomic and nuclear structure K12. Describe radioactive decay K13. Describe radioisotopes	S2. Analyse the properties of particle and electromagnetic radiation	

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Radiation physics applied to radiation therapy	K14. Explain the mechanism of operation of an X-ray tube K15. Explain the mechanism of operation of a linear accelerator K16. Describe collimating systems K17. Describe brachytherapy systems K18. Explain the mechanism of action of a cyclotron K19. Explain absorbed dose K20. Define target absorbed dose specification in external RT K21. Define target absorbed dose specification in brachytherapy K22. Illustrate algorithms for 3D dose calculations K23. Explain applications of conformal RT, IMRT, IGRT, stereotactic RT and particle therapy	S3. Apply treatment planning including, 3D planning and virtual and CT simulation. Apply these procedures to plan patients' treatments S4. Evaluate the benefits of conformal and special radiotherapy techniques (IORT, stereotactic radiotherapy) S5. Address algorithms for 2D dose calculations S6. Examine treatment options in the light of the prognosis S7. Develop an evidence-based treatment strategy and assess patients for curative and palliative external beam radiotherapy and brachytherapy S8. Analyse and synthesise research evidence to change practice S9. Develop a radiotherapy treatment strategy and technique S10. Adapt treatment plans according to patient's individual needs, pre-morbid conditions, toxicity of radiotherapy and systemic treatments S11. Assess and manage patients undergoing external beam radiotherapy and brachytherapy S12. Adapt course of radiotherapy treatment for individual patients according to severity of reactions, including adjustment for gaps in treatment	C1. Consult patients on radiotherapy and ensure follow up of treatment response C2. Recommend appropriate dose and fractionation schedule for curative and palliative external beam radiotherapy and brachytherapy C3. Audit an external beam radiotherapy/brachytherapy treatment plan in collaboration with physicists and radiographers and be aware of the consequences of one's actions and those of others C4. Assess the risk of an external beam radiation therapy and brachytherapy treatment plan C5. Engage in planning using IMRT and other techniques such as stereotactic, particle and IGRT C6. Authorise a radiotherapy treatment C7. Assess patients for combined modality therapy C8. 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-patient or out-patient basis C9. Take responsibility for the clinical implications of IGRT C10. Take responsibility for the clinical implications and procedures of brachytherapy using sealed and unsealed sources

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Concepts and principles of radiation protection	K24. Explain the general philosophy of radiation protection including ALARA K25. Explain the risk of induction of secondary tumours K26. Describe radiation weighting factor K27. Explain equivalent dose – tissue weighting factor K28. Explain occupational/public health consequences of radiation exposure, radiation protection and dose limits for occupational and public exposure K29. Explain the management of accidental/unintended exposures K30. Describe the European and national legislation K31. Describe evidence based in radiation protection	S13. Analyse stochastic effects and tissue reactions S14. Investigate accidental/unintended exposures	C11. Engage in QA and follow safety policies C12. Manage accidental/unintended exposures

5 LEARNING OUTCOMES FOR DENTISTS/DENTAL SURGEONS

In 2005, the European Parliament and the Council adopted the Directive 2005/36/EC on the recognition of professional qualifications [1]. In that document the following has been stated on the profession of dentistry: "All MS 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 MS 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 or radiation protection support professionals. Notwithstanding this, practice in this area is governed by the Euratom BSS [2]. Guidance for dental professionals on radiation protection at a European level is available from the EC radiation protection publications 136 and 172 [3, 4, 5].

The Association for Dental Education in its document 'Profile and Competences for the European Dentist' published in 2004 stated that a graduating dentist should have knowledge of the hazards of ionising radiation and its effects on biological tissues, together with the regulations relating to its use, including radiation, protection and dose reduction and should be competent in managing ionising radiation [6].

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, the most logical way to treat this group is the same 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. The KSC learning outcomes in Table 5.1 are those applicable to dental surgeons. Learning outcomes for ancillary groups/dental care professionals should be selected from these, taking into account their specific roles in imaging.

5.1 Radiation protection professional entry requirements

In general the entry level to the profession of dentist/dental surgeon is EQF level 6[7] and since the use of ionising radiation is an indispensable diagnostic tool and the dentist/dental surgeon is almost always both acting as a referrer and a practitioner, the required radiation protection KSC level upon entry to the overall profession should be the same as for entry to the profession at EQF level 6.

Specialist dental and maxillofacial radiologists are radiologists and therefore their radiation protection KSC should be at the same level as their entry into their profession at level EQF 7.

Other supporting medical and dental care professionals play varied roles and the radiation protection KSC entry into their profession should be at the appropriate level specific to their professional roles as specified elsewhere in these guidelines and they should have at least the core radiation protection learning outcomes (see chapter two).

[7] The reader is referred to section 1.6 for more information.

5.2 Continuous professional development in radiation protection

Dentists/Dental surgeons must maintain and advance their radiation protection KSC through appropriate radiation protection CPD activities essential to maintain good practice [3, 4, 5].

Other professionals working in dentistry should maintain and advance their radiation protection KSC at the appropriate level of their professional roles within dentistry.

References

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Table 5.1: Learning outcomes in radiation protection for dentist/dental surgeons

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Nature of X-radiation	K1. Be aware of the electromagnetic spectrum K2. Understand the place of X-rays as ionising 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 ionising 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 by 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. Explain and communicate effectively the nature and magnitude of radiation risk and benefits, in order to obtain informed consent	

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
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 DRLs and European or national dose surveys K15. Understand the level of radiation-related risk associated with dental imaging of patients, operators and the public	S5. Take account of dose when establishing imaging protocols S6. Use exposure factors to optimise 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 action 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, which do not involve ionising radiation K20. Understand when to refer to specialists in dental and maxillofacial, or medical, radiologists K21. Explain the ALARA principle K22. Understand the relationship between radiation dose and image quality K23. Describe the practical steps available in dental imaging to optimise 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 QA programme for dental imaging K26. Understand the clinical audit cycle as applied to dental imaging K27. Explain the concepts and tools for radiation protection optimisation	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 optimisation S12. Apply measures to optimise exposure consistent to diagnostic image production S13. Develop an organisational policy to keep doses to the personnel ALARA S14. Apply measures to limit staff and public exposure S15. Investigate accidental/unintended exposure S16. Source advice on QA programmes S17. Detect and act on significant changes in imaging performance S18. Source advice and perform clinical audit S19. Apply the concepts and tools for radiation protection optimisation	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 optimisation of dental radiographic exposures C8. Take responsibility for and establish practices to ensure dose limitation for dental staff and the public C9. Manage accidental/unintended exposures C10. Take responsibility for and establish practices to ensure implementation of a QA programme C11. Review justification, optimisation and limitation though clinical audit C12. Implement the concepts and tools for radiation protection optimisation

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Regulations and medico-legal issues	K28. Name and explain the relevant, international, European, national and local regulations relating to dental imaging K29. Understand the responsibilities and roles of different professionals relating to use of X-rays in dental imaging	S20. Comply with relevant regulations S21. Seek advice from appropriate sources with regard to regulations and compliance	C13. Consult with appropriate professionals to achieve optimal radiation protection within the regulations
Equipment and techniques	K30. Describe the concept of the imaging 'chain', from initiating X-ray exposure to displaying the image K31. Explain the difference between 2D/3D imaging, analogue/digital, and extraoral/intraoral imaging K32. Describe how X-rays interact with image detectors to produce an image K33. Describe the different examination techniques in dental and maxillofacial imaging K34. Describe the construction and function of equipment for dental imaging (intraoral and extraoral) K35. Understand the influences of chemical film processing and digital post-acquisition processing on the final image	S22. Select appropriate techniques and equipment factors for acquisition and post-acquisition processing	C14. Establish a procurement policy for equipment which takes account of radiation protection principles C15. Establish and implement a preventative maintenance programme for dental imaging equipment C16. Establish and implement an equipment applications training programme for staff, based on radiation protection considerations
Interpretation	K36. Understand the need to perform and record a clinical evaluation of dental X-ray imaging examinations K37. Understand the principles of diagnostic imaging K38. Describe the appearance of normal anatomical structures in radiographs K39. Describe the radiological appearances of pathoses affecting the teeth and jaws K40. Explain principles of projection and its influence on image interpretation	S23. Recognise the appearance of normal anatomy on dental imaging examinations, including normal variants S24. Recognise the signs of pathoses on dental radiological examinations S25. Interpret dental radiological images and construct and record a report	C17. Implement practices that put optimal patient care at the centre of dental imaging

6 LEARNING OUTCOMES FOR RADIOGRAPHERS

In a modern health service the roles and tasks performed by radiographers are many and varied. In order to address this, and to avoid confusion created by different professional and national titles, a definition of a radiographer was developed and approved by the EFRS General Assembly in 2010 [1].

Within the scope of this document the term 'Radiographer' will be used to refer to professional roles in the fields of diagnostic imaging, NM, IR and radiation therapy.

Radiographers [1]:

- are the healthcare professionals responsible for performing safe and accurate procedures, using a wide range of sophisticated technology within medical imaging, radiotherapy, NM, and IR;
- are professionally accountable for the patients' physical and psychosocial well-being, prior to, during and following diagnostic and radiotherapy procedures;
- take an active role in justification and optimisation of medical imaging and radio-therapeutic procedures;
- are key persons in the radiation safety of patients and other persons in accordance with the ALARA principle and relevant legislation.

In NM, the title NM Technologists (NMT) is recognised by EANM and the IAEA. NMTs perform highly specialised work alongside other healthcare professionals to fulfil responsible roles in patient care and management and radiation protection in diagnostic and therapeutic procedures. They have non-imaging roles within the radiopharmacy and laboratory, and are also involved with PET/CT-aided radiation therapy planning [2].

In Radiation Oncology practices, other than Therapeutic NM practices, the title Radiation TherapisTs (RTTs) is recognised in the core curriculum published by ESTRO [3] and the IAEA. RTTs are the professionals with direct responsibility for the daily administration of radiotherapy to cancer patients. This encompasses the safe and accurate delivery of the radiation dose prescribed, the clinical and the supportive care of the patient on a daily basis throughout the treatment preparation, treatment and immediate post-treatment phases [4].

It is essential whilst carrying out clinical practice in diagnostic and therapy procedures, that radiographers use current knowledge in order to secure, maintain or improve the health and well-being of the patient [5].

While performing their role, radiographers also have a responsibility for radiation protection, patient care and QA during medical imaging or radio-therapeutic procedures.

Radiographers act as the interface between patient and technology in medical imaging and radiation therapy. They are the gatekeepers of patient and staff radiological protection, having a key role in optimisation at the time of exposure to radiation [6].

Radiographers work in a diverse range of areas and each area demands its own specific KSC. These areas include: radionuclide production, which involves cyclotrons and generators; radio-labelling of compounds and living structures (e.g. cells); diagnostic imaging (e.g. X-ray, PET, and NM); radiotherapy (teletherapy, brachytherapy and unsealed source radionuclide therapy); and imaging arising from therapy procedures (e.g. IMRT).

The radiation protection learning outcomes for radiographers provides a set of core learning outcomes together with specific sets of learning outcomes pertinent to diagnostic radiography, NM and radiation therapy [2, 3, 7, 10].

6.1 Radiation protection professional entry requirements

According to the Tuning Template for Radiography, developed under the EU project HENRE (Higher Education Network for Radiography in Europe) [7], the professional entry requirements for radiographers should be equivalent to EQF level 6 [8]. Radiation protection is a major subject for radiographers and should be at the same level as their professional entry-level requirements in the EQF.

6.2 Continuous professional development in radiation protection

Through their careers radiographers advance to EQF level 7 and in some cases even higher, especially for sophisticated diagnostic and therapeutic radiological procedures and this should be through CPD activities that enhance their KSC to higher levels [9]. Special emphasis should be given to new diagnostic and therapeutic systems and the acquisition of skills in the practical use of such systems.

References

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Table 6.1: Core learning outcomes in radiation protection for radiographers

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Core Learning outcomes in radiation protection	K1. Explain physical principles of radiation generation, interaction, modification and protection K2. Explain radiation physics, radiation hazards, radiation biology and dosimetry K3. Understand risk: benefit philosophy and principles involved in all aspects of radiography K4. Identify current national and international radiation protection legislation and regulations relating to staff, patients, carers and the wider general public K5. Explain the physics underpinning non-ionising imaging techniques, including magnetic resonance imaging and ultrasound along with associated safety considerations K6. Describe professional roles and responsibilities in terms of aspects of justification and optimisation K7. Explain QA and QC practices to include: legislation, regulations and guidelines, test equipment and methodologies, programme design and implementation and reporting to ensure the provision of an effective, safe and efficient service K8. Understand occupational risks to health and safety that may be encountered such as safe moving and handling of patients and equipment K9. Describe the importance of audit, research and evidence-based practice to include: the stages in the research process, research governance, ethics, statistics and statistical analysis to facilitate a deeper understanding of research findings and clinical audit K10. Identify the different determinants of radiation risk perception; know the pit-falls of communication on radiation risks	S1. Use the appropriate medical devices in an effective, safe and efficient manner S2. Use effective, safe and efficient radiation protection methods in relation to staff, patients and the general public applying current safety standards, legislation, guidelines and regulations S3. Critically review the justification of a given procedure and verify it in the light of appropriateness guidelines and when in doubt consult the responsible specialist S4. Use and undertake clinical audits S5. Identify the principles of evidence-based practice and the research process S6. Critically reflect on and evaluate one's own experience and practice S7. Participate in CPD S8. Recognise the complicated situation pertaining to radiation protection regarding scientific knowledge on the one side and societal concern and personal emotions on the other side S9. Identify different image quality standards for different techniques S10. Apply the concepts and tools for radiation protection optimisation	C1. Practise effectively, accurately and safely and within the guidance of legal, ethical and professional frameworks C2. Use the appropriate and correct form of identification, address and treatment of the patient (and any accompanying carer if appropriate) C3. Avoid unnecessary exposure and minimise necessary exposure as part of optimisation C4. Seek consent for any examination/treatment to proceed C5. Carry out work in a safe manner when using ionising radiation, taking into account current safety standards, guidelines and regulations C6. Participate in the process of creating and guaranteeing maximum safety for the patient, oneself and others during examinations /treatments involving ionising radiation and maintain the ALARA principle C7. Refuse to accept or carry out a request or referral which, in one's professional opinion, is dangerous or inadvisable C8. Recognise the limitations to one's own scope of competence and seek advice and guidance accordingly C9. When taking decisions about care for (individual) patients be able to make use of relevant national and international (scientific) insights, theories, concepts and research results and integrate these approaches into one's own professional actions (evidence-based practice)

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Core Learning outcomes in radiation protection	K15. Understand the particular protection aspects of pregnant women (includes pregnant radiographer/employee), carers and children and knows how to take care of these persons K16. Describe the risk to pregnant women and foetus involved in radiotherapy, NM, and diagnostic and IR K17. Explain dose, quantities and units and their relevance to own professional practice K18. Explain the management of accidental/unintended exposures K19. Explain the concepts and tools for radiation protection optimisation		C10. Recognise the radiation hazards associated with one's work and take measures to minimise them C11. Monitor radiation exposure with the use of a personal dosimeter C12. Establish safe working conditions according to the recommendations and the statutory requirements of European, national, regional legislation, where applicable C13. Instruct other personnel participating in matters relating to appropriate radiation protection practices C14. Carry out short-term and practice-oriented research or clinical audit, either independently or in collaboration with colleagues, to improve the quality of care C15. Participate in clinical audit and applied research for the further development of professional practice and its scientific foundation C16. Place radiation risks in relation to other risks within a societal context C17. Reflect on one's own radiation risk perception C18. Evaluate the results of routine QA tests

Table 6.1.1: Additional learning outcomes in radiation protection for radiology radiographers

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Additional for radiology	K1. Explain the relationship of exposure factors to patient exposure K2. Understand how patient position affects image quality and dose to radiosensitive organs K3. Understand the effect of filter type in diagnostic X-ray systems K4. Understand the purpose and importance of patient shielding K5. Understand post-processing possibilities for CR and DR systems (filters, noise, magnification, raw data manipulation) K6. Know recommendations and legal requirements applying to medical, occupational, and public exposure	S1. Perform the medical procedure with the appropriate X-ray equipment suited and optimised for the specific medical procedure (adult, paediatric, projection possibilities, adjustments for longer procedure time, etc.) S2. Operate according to Good Medical Practice in order to minimise overall fluoroscopy time S3. Put into practice the basic principles of preventing (unnecessary) exposure (time, distance, shielding) S4. Programme the use of beam filters in mammography and conventional radiography (proper use of additional filtration) S5. Use and record the integrated dose meter (DAP) and checks the measured values against DRLs and/or threshold doses for deterministic effects in order to prevent deleterious effects on patients whenever possible S6. Identify various types of patient shielding and state the advantages and disadvantages of each type S7. Use the appropriate method of shielding for a given radiographic procedure S8. Identify difference between continuous and pulsed fluoroscopy and use each mode when appropriate S9. Explain and communicate effectively the nature and magnitude of radiation risk and benefits, in order to obtain informed consent	C1. Take responsibility for use of proper exposition parameters according to type of modality and to radiological procedure C2. Identify the appropriate image receptor that will result in an optimum diagnostic image with the minimum radiation exposure to the patient C3. Identify proper C-arm position regarding occupational doses C4. Discuss added and inherent filtration in terms of the effect on patient exposure C5. Compare dose measurements (DAP, DLP, KAP, ESD, CTDI, glandular dose) readings or equivalent to National or European DRLs C6. Participate in the optimisation of all parameters to create protocols regarding to National or European DRL. C7. Optimise radiological procedure to fit pregnant women and use appropriate paediatric protocols C8. Take responsibility for choosing post-processing tools and change exposure parameters to obtain lower dose for clinical diagnostic images C9. Advise on the proper use of personal protection. C10. Optimise the use of radiology equipment according to ALARA principles

Table 6.1.2: Additional learning outcomes in radiation protection for nuclear medicine technologists

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Additional for nuclear medicine	K1. Explain the physical principles of how radionuclides can be generated K2. Explain how radionuclides can be physically shielded (gamma, beta, positron) K3. For the range of therapy and diagnostic procedures, explain the biological basis on which radiopharmaceutical localisation occurs K4. Understand the risk-benefit philosophy as applied to NM procedures K5. State which QC tests should be applied to which pieces of NM equipment. Explain why and how, and state what their frequency should be K6. Explain the legal and clinical basis on which NM procedures, both diagnostic and therapeutic, are requested and justified K7. Identify which non-ionising radiation diagnostic examinations can be used as possible alternatives to NM procedures K8. Explain how doses for children can be varied from those of adults K9. Indicate which diagnostic examinations carry radiation risk to breast feeding infants; indicate the contingencies which might apply K10. For diagnostic procedures, explain what practical steps can be taken to minimise radiation risk to radiosensitive organs (e.g. thyroid) K11. Understand interactions, pharmacology and adverse reactions of drugs commonly encountered within NM with a particular emphasis on radiopharmaceuticals and X-ray contrast agents K12. Understand biological and physical half-lives of the radiopharmaceuticals used for diagnostic and therapeutic procedures K13. Outline how developments in imaging technology can be used to minimise dose, and therefore risk, from diagnostic NM procedures	S1. Acquire and process images and data that have clinical relevance within NM, observing the principles of exposure optimisation and dose management (e.g. PET/CT) S2. Use devices which can be used to monitor and also minimise radiation dose S3. Use all relevant laboratory equipment S4. Translate guidance and local rules into practical working routines so as to minimise dose to staff, patients and the public S5. Be able to work very fast when handling radionuclides but not at the expense of incurring an adverse incident S6. Be able to communicate effectively with patients and carers so that diagnostic examination requirements are met but not at the expense of compromising the patient experience S7. Be able to discuss with the medical referrer on whether the requested NM procedure is appropriate in part or in whole S8. Be aware of the fact that after a radioactive injection a patient should be separated from other patients S9. Be able to prepare, manipulate and administer radioisotopes, to patients, assuring prior and post-administration radioprotection measures S10. Perform laboratory tests (e.g. GFR) S11. Perform and interpret QC tests to determine whether NM equipment is within manufacturer specification S12. Draw up the correct quantity of radiopharmaceutical for administration S13. Obtain patient consent for diagnostic procedures; explain procedures to the patient and respond appropriately to questions	C1. Take responsibility for conforming to national regulations for all handling of unsealed radioactive substances C2. Take responsibility for conforming to local standards and standard SOPs while handling unsealed radioactive substances C3. Take responsibility for handling unsealed radioactive substances in a manner that accidental / unintended exposure of oneself as well as co-workers is avoided C4. Comply with good manufacturing practice when working within the radiopharmacy C5. Take responsibility for interpreting QC tests to determine whether NM equipment is within manufacturer specification C6. Take responsibility for drawing up the correct quantity of radiopharmaceutical for administration, taking into account DRLs C7. Working within a devolved framework, justify the diagnostic NM procedure C8. Take responsibility for obtaining patients' consent for diagnostic procedures; for explaining procedures to the patient and responding appropriately to their questions C9. Take responsibility for the administration of radiopharmaceuticals which are used for diagnostic procedures C10. Take responsibility for appropriate radiation protection advice to patients undergoing diagnostic NM procedures C11. Take responsibility for providing appropriate care for patients whilst at the same time minimising personal radiation dose

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Additional for nuclear medicine	K14. Outline the role of the physicist and physician in relation to adverse radiation incidents (e.g. administration of a dose to the wrong patient) K15. Outline the role of the physicist in minimising dose to the environment and humans K16. Explain the radiation protection principles, legal requirements and practical solutions which can be used to enhance safe storage, handling and disposal of radioactive materials used within NM K17. State the range of additional radiation protection requirements imposed for patients who are to undergo NM therapy procedures K18. For the radio-labelling of human products (e.g. white cells) explain how good manufacturing practice principles can be applied to minimise the incidence of radiation accidents K19. State how time, distance, shielding, monitoring and audit can be used to minimise dose received by staff, patients and public K20. With good practice in mind, explain how a radioactive spill should be dealt with K21. Explain how doses to pregnant females can be minimised when a diagnostic NM procedure must be carried out K22. Explain how a radionuclide dose should be administered such that no, or very little, residue is left within the dispensing device (e.g. syringe) K23. For hybrid procedures involving X-ray CT explain the practical measures that should be carried out to minimise dose to staff, patient and members of the public K24. Explain DNA damage K25. Describe the cellular effects, mechanisms of cell death	S14. Administer radiopharmaceuticals that are used for diagnostic procedures S15. Assist the physician with the administration of radiopharmaceuticals used for therapeutic procedures S16. Offer appropriate radiation protection advice to patients undergoing diagnostic NM procedures S17. Care for patients who require a high level of care whilst at the same time minimising personal radiation dose S18. Organise clinical workflow so that radioactive patients have minimal contact with at risk individuals (e.g. pregnant females) S19. Decontaminate radioactive spills in a safe and efficient manner	C12. Take responsibility for performing the diagnostic procedure to a suitable standard, ensuring that no repeat examination is required because of technical deficiency C13. Supervise the clinical workflow such that the risk of exposure to individuals (e.g. pregnant females) from other patients is minimised C14. Take responsibility for dealing with radioactive spills in a safe and efficient manner

Table 6.1.3: Additional learning outcomes in radiation protection for radiotherapy technologists

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Additional for radiotherapy	K1. Understand biomedical physics underpinning the scientific, effective, safe and efficient use of medical devices used in radiation therapy, including medical imaging devices used for tumour localisation and treatment planning K2. Knowledge and understanding of the radiation physics underpinning radiation therapy treatments and medical imaging examinations for tumour localisation and treatment planning to include: nuclear structure, radioactive decay, interaction with matter, electromagnetic radiation, particle radiation, sources of radiation, tissue in homogeneity, wedges, weigh factors, beam shape and properties K3. Knowledge and understanding of radiation protection underpinning radiation therapy treatments and medical imaging examinations for tumour localisation and treatment planning to include: radiation hazards, radiation shielding, detection methods, current national and international radiation protection legislation and regulations relating to staff, patients and the general public K4. Knowledge and understanding of the radiobiology underpinning radiation and cytotoxic therapy treatments, and medical imaging examinations for tumour localisation and treatment planning to include: cell biology, effects of ionising and non-ionising radiation, radiation risks, radio sensitivity, side effects of radiation therapy treatments K5. Explain DNA damage K6. Describe the cellular effects, mechanisms of cell death K7. Explain the cell survival curves K8. Describe the normal tissue, solid tumour and leukaemia systems K9. Explain the effects of oxygen, sensitizers and protectors K10. Explain the effect of time-dose fractionation, LET and different radiation modalities and interaction between cytotoxic therapy and radiation K11. Knowledge and understanding of Digital Reconstructed Radiograph (DRR) K12. Knowledge and understanding of Beams Eye View (BEV) K13. Knowledge and understanding of Gross Target Volume (GTV), Clinical Target Volume (CTV) and Planning Target Volume (PTV) K14. Knowledge and understanding of Organs at Risk (OAR) K15. Knowledge and understanding of Dose-Volume Histograms (DVH)	S1. Use medical devices in radiation therapy, including medical imaging devices, used for tumour localisation and treatment planning in a safe and effective manner S2. Analyse the properties of particle and electromagnetic radiation S3. Apply treatment planning including 3D planning, virtual and CT simulation and apply these procedures to plan patients' treatments S4. Prepare treatment plans using IMRT and other techniques such as stereotactic, particle and IGRT S5. Define the target and OAR using ICRU terminology S6. Describe how DVHs are created and used to evaluate plans S7. Relate the influence of changing planning parameters on DVHs S8. Use radiation protection methods relating to staff, patients and the general public, taking into account current safety standards, guidelines and regulations S9. Justify and optimise all procedures effectively S10. Recognise OAR on medical images for tumour localisation and treatment planning S11. Recognise the signs and symptoms associated with treatment in different sites	C1. Able to take into account, from the perspective of the patient, the technical and clinical aspects of the treatment while it is being conducted C2. Able to select and argue for a suitable treatment on the basis of one's own analysis of a question and/or indication, give an account of this and advise accordingly C3. Work in an independent, methodical and evidence-based manner in terms of quality, complete the treatment and report accordingly C4. Able to work in a safe manner when carrying out treatments with ionising radiation, taking into account current safety standards, guidelines and regulations C5. Critically evaluate the dose distribution and DVHs C6. Optimise and evaluate the plan options C7. Assess the daily physical and psychological status of the patient prior to treatment C8. Record all side effects and advise the patient on their management in accordance with department protocol C9. Calculate/check monitor units and treatment times C10. Check treatment prescription calculations for accuracy and alert clinician of any discrepancies

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Additional for radiotherapy	K16. Explain the collimating systems K17. Describe Brachytherapy systems K18. Explain absorbed dose K19. Define target-absorbed dose specification in external RT K20. Define target-absorbed dose specification in brachytherapy K21. Illustrate algorithms for 3D dose calculations K22. Explain applications of conformal RT, IMRT, IGRT, stereotactic RT and particle therapy K23. Describe radiation weighting factor K24. Explain the risk of induction of secondary tumours K25. Explain equivalent dose – tissue weighting factor K26. Knowledge and understanding of the scientific basis of the range of radiation therapy techniques and medical imaging techniques for tumour localisation and treatment planning across the range of technology / equipment used along with the operational and maintenance, for professional purposes, so that equipment can be operated at the highest level of understanding K27. Knowledge and understanding of positioning, immobilisation and beam shielding devices used in radiation therapy K28. Knowledge and understanding of radiation therapy verification systems K29. Knowledge and understanding related to the technical appraisal of diagnostic images for tumour localisation and treatment planning, to facilitate judgements on acceptability and quality	S12. Identify the side effects associated with the individual treatment S13. Define the effects of concomitant treatment S14. Analyse stochastic and deterministic effects S15. Define the parameters routinely used S16. Recognise the critical structures on the verification images S17. Identify the imaging protocol S18. Identify the daily entrance and exit dose and dose level of critical organs S19. Be familiar with reporting systems and reporting protocols S20. Describe the radiation hazards and how they are managed S21. Effective, safe and efficient use of positioning, immobilisation and beam shielding devices used in radiation therapy S22. Use radiation therapy verification systems safely, effectively and efficiently S23. Perform, record and analyse QC activities S24. Approach occupational risks to health and safety such as safe moving and handling of patients and equipment in a safe and effective manner	C11. Check decay tables/exposure rates for Cobalt units are updated C12. Apply safety procedures when using brachytherapy sources C13. Assess patients undergoing external beam radiotherapy and brachytherapy and refer them to the radiation oncologist or other health professional as appropriate C14. Assess the practical problems associated with machine and accessory equipment limitations and respond accordingly C15. Optimise and evaluate plan options C16. Carry out manual calculations C17. Engage in QA and follow safety policies C18. Check if all parameters, devices and settings are correct C19. Carry out in vivo dosimetry C20. Evaluate results, take corrective action as per protocol and report any inconsistency C21. Analyse and record the results and report any deviations C22. Report incidents and near incidents to the multidisciplinary team C23. Examine any incident or near incident and how they can be prevented in the future C24. Routinely inspect the area to ensure that radiation protection measures are in place and functional

7 LEARNING OUTCOMES IN RADIATION PROTECTION FOR MEDICAL PHYSICISTS/ MEDICAL PHYSICS EXPERTS

The KSC requirements in radiation protection for the medical physicist (MP) working with ionising radiation and the medical physics expert (MPE) are given in the 'Guidelines on the Medical Physics Expert' published by the EC as part of the radiation protection series [1]. These guidelines are based on the provisions regarding the MPE to be found in the revised Euratom BSS [2].

Member States shall ensure that in medical radiological practices, a medical physics expert is appropriately involved, the level of involvement being commensurate with the radiological risk posed by the practice. In particular:

- *I. in radiotherapeutic practices other than standardized therapeutic nuclear medicine practices, a medical physics expert shall be closely involved;*
- *II. in standardized therapeutical nuclear medicine practices as well as in radiodiagnostic and interventional radiology practices, involving high doses as referred to in Article 60(1)(c), a medical physics expert shall be involved;*
- *III. for other medical radiological practices not covered by (a) and (b), a medical physics expert shall be involved, as appropriate, for consultation and advice on matters relating to radiation protection concerning medical exposure.'*

Within the health-care environment, the MPE should act or give specialist advice on matters relating to radiation physics as applied to medical exposure and non-medical imaging exposure using medical equipment. Depending on the medical radiological practice, the MPE takes responsibility for dosimetry, including physical measurements for evaluation of the dose delivered to the patient and other individuals subject to medical exposure, gives advice on medical radiological equipment, and contributes, in particular, to the following:

'(a) optimization of the radiation protection of patients and other individuals subjected to medical exposure, including the application and use of diagnostic reference levels;

(b) the definition and performance of quality assurance of the medical radiological equipment;

(c) acceptance testing of medical radiological equipment;

(d) the preparation of technical specifications for medical radiological equipment and installation design;

(e) the surveillance of the medical radiological installations;

(f) the analysis of events involving, or potentially involving, accidental or unintended medical exposures;

(g) the selection of equipment required to perform radiation protection measurements;

(h) the training of practitioners and other staff in relevant aspects of radiation protection:

The following mission statement from the 'Guidelines on the MPE' document aims to make the role of the MP/MPE more understandable to decision-makers and managers of healthcare institutions and provide direction for those in other roles:

"*Medical Physics Experts 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/control and optimised clinical use of medical radiological* *devices and regarding patient risks from associated ionising radiations including radiation protection and the prevention of unintended or accidental exposures; 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, carers and comforters*" [1].

The key activities of the MP/MPE are: scientific problem-solving, dosimetry measurements, patient safety/risk management (including volunteers in biomedical research, carers, comforters and persons subjected to non-medical imaging exposure), occupational and public safety/risk management (when there is an impact on medical exposure or personal safety), clinical medical device management, 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. These key activities are defined and elaborated in the 'Guidelines on the Medical Physics Expert' [1].

Owing to the special and wide-ranging involvement of MP/MPE in radiation protection the KSC inventory for these professionals is very extensive and cannot be reproduced here; the reader should refer to the aforementioned guidelines; the KSC for MP/MPE in the 'Guidelines on the Medical Physics Expert' are subdivided into:

a) a Core KSC inventory common to all three specialties of medical physics, which involve ionising radiation, namely diagnostic radiology, IR, NM and radiation oncology,

b) three additional KSC inventories each of which consist of the KSC specific to one of the above three specialties.

Further guidance can be found here [3-9].

7.1 Radiation protection professional entry requirements

The entry level certification requirement in radiation protection for MPs in a given specialty is EQF level 7 in all Core KSC, and the KSC specific to that particular specialty[8] [1].

7.2 Continuous professional development in radiation protection

In the case of MPs, the term CPD has a special meaning which is advanced education, training and experience for the achievement of MPE status in their particular specialty of medical physics. The certification requirement in radiation protection for achievement of MPE status in a given specialty of medical physics is an EQF Level 8 in all the Core KSC and the KSC specific to that specialty [1].

References

[1] EC, 2014, RP174. Guidelines on Medical Physics Expert. Directorate-General Energy, Luxembourg (in Press).

8 The reader is referred to section 1.6 for more information.

[2] Council of the European Union. (2013). Council Directive 2013/59/Euratom laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom. Official Journal L-13 of 17.01.2014.

[3] Jacob Geleijns, Éamann Breatnach, Alfonso Calzado Cantera, John Damilakis, Philip Dendy, Anthony Evans, Keith Faulkner, Renato Padovani, Wil Van Der Putten, Lothar Schad, Ronnie Wirestam, Teresa Eudaldo, "Core Curriculum for Medical Physicists in Radiology, Recommendations from an EFOMP/ESR Working Group", June 2011, http://www.efomp.org/images/docs/policy/CC%20radiology%20physics%20JUN_%202011.pdf (Last time accessed was on the 14th of December 2012).

[4] IAEA, 2010, Training Course Series No. 47. Clinical Training of Medical Physicists specialising in Diagnostic Radiology. IAEA, Vienna, http://www-pub.iaea.org/books/IAEABooks/8574/Clinical-Training-of-Medical-Physicists-Specializing-in-Diagnostic-Radiology (Last time accessed was on the 14th of December 2012).

[5] Alberto Del Guerra, Manuel Bardies, Nicola Belcari, Carmel J. Caruana, Stelios Christofides, Paola Erba, Cesare Gori, Michael Lassmann, Markus Nowak Lonsdale, Bernhard Sattler, Wendy Waddington, "Curriculum for education and training of Medical Physicists in Nuclear Medicine. Recommendations from the EANM Physics Committee, the EANM Dosimetry Committee and EFOMP", Physica Medica (2012), http://dx.doi.org/10.1016/j.ejmp.2012.06.004 (Last time accessed was on the 14th of December 2012).

[6] IAEA,2011, Training Course Series No. 50. Clinical Training of Medical Physicists specialising in Nuclear Medicine. IAEA, Vienna, http://www-pub.iaea.org/books/IAEABooks/8656/Clinical-Training-of-Medical-Physicists-Specializing-in-Nuclear-Medicine (Last time accessed was on the 14th of December 2012).

[7] Eriksen JG, et al., "The updated ESTRO core curricula 2011 for clinicians, medical physicists and RTTs in radiotherapy/radiation oncology", Radiotherapy and Oncology 2012 Apr;103(1):103-8, http://www.estro-education.org/courses/Documents/The%20updated%20ESTRO%20core%20curricula%202011%20for%20clinicians,%20medical%20physicists%20and%20RTTs.pdf (Last time accessed was on the 14th of December 2012).

[8] Guidelines for Education and Training of Medical Physicists in Radiotherapy (updated 2nd edition. Feb.2011), http://www.estro-education.org/europeantraining/Documents/2nd%20finalised%20edition%20European%20CC%20Physics_16%2002%202011.pdf (Last time accessed was on the 14th of December 2012).

[9] IAEA, 2009, Training Course Series No. 37. Clinical Training of Medical Physicists Specialising in Radiation Oncology. IAEA, Vienna, http://www-pub.iaea.org/books/IAEABooks/8222/Clinical-Training-of-Medical-Physicists-Specializing-in-Radiation-Oncology (Last time accessed was on the 14th of December 2012).

Table 7.1: Learning outcomes in radiation protection for medical physicists/medical physics experts

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
	For a comprehensive list of learning outcomes in radiation protection for medical physicists/medical physics experts, please refer to the EC's publication RP174, 'Guidelines on Medical Physics Expert', Directorate-General Energy, Luxembourg (in Press).		

8 LEARNING OUTCOMES FOR NURSES AND OTHER HEALTHCARE WORKERS NOT DIRECTLY INVOLVED IN THE USE OF IONISING RADIATION

It is essential that nurses and other healthcare workers not directly involved in the use of ionising radiation who work within a clinical area where ionising radiation is used are aware of the potential radiogenic risk.

When a nurse or other healthcare worker has any concerns relating to radiation protection, which are of an occupational nature, these should be referred to the radiation protection officer who would, if necessary, liaise with the RPE. If the concerns relate to patient protection they should be referred to the MPE.

Education and training in radiation protection for all such workers is essential [1]. This should be described in their professional charter or profile. The appropriate learning outcomes for these workers are given in table 8.1.

8.1 Radiation protection professional entry requirements

Radiation protection education and training is a minor subject for general ward nurses and should be part of their professional training. Such training should cover the core radiation protection education and training as specified in chapter two.

Nurses working in areas where ionising radiation is used should be specifically educated and trained in radiation protection at the level required for their duties in such areas. In most cases EQF level 5 is sufficient, but in some cases (e.g. IR and radiotherapy) this must be EQF level 6[9].

For other healthcare workers working in areas where ionising radiation is used, their radiation protection KSC should be at the level appropriate to their roles and duties within the specific areas where they work.

8.2 Continuous professional development in radiation protection

Nurses and other healthcare workers must maintain and advance their KSC through appropriate CPD activities essential for maintaining good practice.

References

[1] ICRP, 2009. Education and Training in Radiological Protection for Diagnostic and Interventional Procedures. ICRP Publication 113. Ann. ICRP 39 (5).

9 The reader is referred to section 1.6 for more information.

Table 8.1: Learning outcomes in radiation protection for nurses and other healthcare workers

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Radiation protection	K1. Know the basic physical principles of radiation generation, interaction, modification and protection K2. Basic radiation physics, radiation hazards, radiation biology and dose quantities and units K3. Know the dose distribution around the patient K4. Current national and international radiation protection legislation and regulations relating to workers K5. Occupational risks, health and safety that may be encountered K6. List and explain radiation protection aspects with respect to staff K7. Radiation risks to the unborn child during pregnancy K8. Radiation risks to the breastfeeding infant K9. Basic principles of shielding and its relation to minimising occupational risks K10. Knowledge about the particular protection of body areas such as the gonads, eye lenses and thyroid gland	S1. Follow the instructions of radiation professionals S2. Put into practice the basic principles of preventing unnecessary exposure (time, distance, shielding) S3. Be aware of issues relating to continual care of patients who undergo NM or brachytherapy procedures S4. Observe the rules relating to distance when caring for patients undergoing NM, fluoroscopy or brachytherapy procedures	C1. Recognise the radiation hazards associated with one's work and take measures to minimise them C2. Recognise the limits of one's own knowledge on radiation protection C3. Supervise untrained (re. radiation protection) colleagues (nurses and other health care workers) and prevent them from entering the controlled areas while radiation is active

9 LEARNING OUTCOMES FOR MAINTENANCE ENGINEERS AND MAINTENANCE TECHNICIANS

Preventive Maintenance (PM) is a necessary activity to ensure radiological equipment functions according to its specifications [1]. PM is carried out by engineers, or technicians, specifically trained to maintain and repair radiological equipment.

Whenever new radiological equipment is introduced in a healthcare facility, specific training should be provided by the manufacturer's engineers before the equipment is put into clinical use [2]. This training should be part of the commissioning process of the new radiological system. It is important to consider the manufacturer's responsibility to make complete and comprehensible maintenance and repair instructions available in the local language.

The background education and training of maintenance engineers and technicians is usually electrical or mechanical engineering without any radiation protection education and training content. Their KSC in radiological equipment maintenance and repair is acquired through the radiological equipment manufacturer's dedicated maintenance and repair training courses, specific to the type and model of the radiological equipment. These courses take place at the manufacturer's facilities and include theoretical and practical training on the maintenance and repair of the equipment without any specific emphasis on staff or patient radiation protection.

To safeguard the safety of the equipment users and patients after equipment maintenance, it is very important for maintenance engineers and technicians to follow a written procedure of handing over the equipment for clinical use after each preventive maintenance or repair. This procedure should be agreed together with the MPE and the hospital management.

The general radiation protection education and training of radiological equipment maintenance engineers and technicians should cover the core learning outcomes for radiation protection, as outlined in table 2.2. Furthermore, additional radiation protection education and training is required according to the complexity of the radiological equipment for which the maintenance engineers and technicians are responsible for maintaining and repairing, and they should be, at least, at EQF level 5. They should also include the additional KSC outlined in table 9.1.

9.1 Radiation protection professional entry requirements

The radiation protection professional entry requirements for maintenance engineers and technicians should be equivalent to EQF[10] level 5, and should consist of at least the core learning outcomes from chapter two. Additional learning outcomes are necessary for the specific radiological equipment for which they are responsible for maintaining and repairing.

9.2 Continuous professional development in radiation protection

Maintenance engineers and technicians must maintain and advance their KSC through appropriate CPD activities, which are essential to maintain the proper functioning of the radiological equipment, which they are responsible for maintaining and repairing.

[10] The reader is referred to section 1.6 for more information.

References

[1] WHO, 2011. WHO Medical device technical series, "Medical equipment maintenance programme overview", WHO, Geneva, 2011.

[2] EC, 2000, RP 116. Guidelines on Education and Training in Radiation Protection for Medical Exposures. Directorate-General Environment, Luxembourg. http://ec.europa.eu/energy/nuclear/radiation_protection/doc/publication/116.pdf (Last time accessed was on the 14th of December 2012).

Table 9.1: Additional learning outcomes in radiation protection for maintenance engineers and maintenance technicians

	Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
Radiation protection	K1. Explain the basic physical principles of radiation generation, interaction with matter and modification K2. Explain occupational risks, health and safety that may be encountered and associated protection measures K3. Explain basic principles of shielding and its relation to minimising occupational risks K4. Describe the equipment handover procedure	S1. Apply the basic principles of preventing unnecessary exposure (time, distance, shielding) in their practice S2. Apply the equipment handover procedure	C1. Take responsibility for recognition of the radiation hazards associated with one's work and take measures to minimise them C2. Recognise the limits of one's own knowledge on radiation protection and seek advice from the RPE C3. Coordinate the equipment hand over procedure

10 ACCREDITATION, CERTIFICATION AND RECOGNITION OF MEDICAL EDUCATION AND TRAINING IN RADIATION PROTECTION

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

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

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

Certification is a process that recognises an individual medical professional who has demonstrated special knowledge and expertise in medical radiation protection, and has successfully completed the education or training provided by an accredited organisation. 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 optimise medical procedures and provide better patient care. Certification should not be issued for an unlimited period of time. Recertification is required after a specific time span, usually three to five years. Recertification programmes should be based on CPD models.

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 programmes, educational material, teaching methods, administration and archives, course updates 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.

Specifically, in order to plan and provide effective education and training, education providers should have the necessary knowledge and skills in the radiation protection aspects of the procedures carried out by the practitioners involved in the training activity [1]. Training in medical radiation protection is very challenging, considering the rapid technological developments and the complex science involved in modern imaging procedures. For this reason, the development of ‘train-the-trainer’ schemes is of crucial importance to provide the best possible opportunities to MPs and other experts involved in medical radiation protection training.

Scientific programme contents and educational material should be reviewed periodically to ensure that 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 the 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 for examining knowledge in medical radiation protection, including written examinations, oral examinations and research projects. Recertification programmes ensure that certified professionals maintain, develop or improve KSC in the area of medical radiation protection for which they are certified.

There are several initiatives and tools developed by the EC to facilitate the accreditation, certification, validation and recognition of knowledge, as well as to promote the mobility of students, educators and researchers. The EQF for LLL 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. One year of a study programme is equivalent to 60 credits. The ECTS is compatible with the EQF and can help medical radiation protection schools to implement QA 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]. The ECVET credit system allows individuals to obtain a vocational certificate by obtaining units at the most appropriate pace. A difference between the ECTS and ECVET credit systems is that the ECVET credit system is based on learning outcomes, whereas ECTS is based on time spent on an educational activity.

Medical radiation protection education and training courses must be accredited by an external, independent accreditation body with the involvement and representation of the relevant specialists. In accordance with the EQF, guidelines presented in the current document list the required learning objectives in terms of knowledge, skills and competences in table format. Information is provided separately for each medical profession working with ionising radiation. This information can be used by accreditation bodies to evaluate the content of education and training programmes in medical radiation protection offered by organisations such as professional and scientific societies, radiation protection competent authorities, etc. The ECTS can be used not only for the main higher education degrees, but also for LLL activities. The appendix to this section gives an example of how to calculate indicative ECTS using the KSC for radiographers. When using the ECTS for continuing education, the same principles for credit award, accumulation and transfer apply as for credits allocated to higher education programmes [4].

References

[1] ICRP, 2009. Education and Training in Radiological Protection for Diagnostic and Interventional Procedures. International Commission on Radiological Protection (ICRP) Publication 113, Ann ICRP (2009) 39(5).

[2] Accreditation and quality assurance in vocational education and training. Selected European approaches. European Centre for the development of vocational training, CEDEFOP, Luxembourg, 2009.

[3] Recommendation of the European Parliament and of the Council of 23 April 2008 on the establishment of the European Qualifications Framework for lifelong learning (Official Journal C 111, 6.5.2008).

[4] ECTS Users' Guide. European Communities, Brussels, 2009.

[5] The European Credit System for Vocational Education and Training (ECVET). Get to know ECVET better. Questions and Answers. European Commission, 2011.

APPENDIX: SYLLABUS AND ECTS MODEL FOR RADIATION PROTECTION EDUCATION AND TRAINING

Introduction

In 1999, several European Countries (currently 41) signed the Bologna Declaration, which aims to create the European Higher Education Area (EHAE), by harmonising academic degrees and QA standards throughout Europe [1].

To that end, a credit system (ECTS) was introduced [2]. ECTS makes teaching and learning in higher education more transparent, facilitates the recognition of studies, and allows for the transfer of learning experiences between different institutions. It also serves curriculum design and QA.

An academic year corresponds to 60 ECTS, and the first educational cycle (Bachelor level) can vary from 180 to 240 ECTS. The second cycle (Master level) can vary from 90 to 120 ECTS and the third cycle (PhD level) can vary from 180 to 240 ECTS. These three cycles correspond respectively to level 6, 7 and 8 of the European LLL EQF [3].

One ECTS represents a study workload between 25 and 30 hours with all study activities included (e.g.: self-study, attending classes, exams, skills lab, etc.).

ECTS for education and training

In order to assist with the calculation of the corresponding number of ECTS from the KSC specified for each of the professions considered in this document, the KSC for radiographers have been used as an example.

Radiation protection education and training is included in all radiographer education programmes, but there is still lack of harmonisation, not only in terms of syllabus, topic or workload, but also in terms of the different education models used to obtain the KSC in radiation protection, as these can be obtained through several educational and pedagogical methods.

There is no unambiguous or simple tool to convert curriculum items into credits. To solve this, the European Commission developed an ECTS users' guide [2] that gives orientation on the concept and the way to implement the ECTS. In addition, practical information about this guide was published by Richard de Lavigne [4], Counsellor for ECTS and the Diploma Supplement for the EC.

In order to build their new curriculum according to the Bologna Process, using the methodology proposed by Karjalainen A. et al [5] and the credit calculator excel sheet, provided by the same author, a number of Radiographers' higher educational institutes (HEI) surveyed their students and academics regarding the necessary workload for each syllabus or module.

Nevertheless, each model for determining workload is always hypothetical and can only be verified during its practical implementation.

To build this example, Radiographers' HEI were asked about the amount of ECTS dedicated specifically to radiation protection.

The following recommendation represents average values after eliminating 15% of the lowest and highest values:

- 20 ECTS for radiation protection education and training for Radiography;
- Total workload in hours: 540;
- Contact hours: 240 (140 theoretical + 100 practical);
- Independent study hours: 300 (1.25 hours of personal study for each contact hour).

Independent of the model used by the HEI, the students should always be assessed in order to assure that the KSC in radiation protection education and training is obtained.

Only as a suggestion (because the HEI are autonomous in defining their curricula), the recommended syllabuses are given in Table A1 matched with the topics in Table 2.1.

ECTS for continuous professional development

CPD programmes should ideally be developed and organised using ECTS methodology for credit award, not only because it would facilitate the recognition process (at national and international level), but also because it would allow the creation of a quantitative indicator of what health professionals dealing with ionising radiation should obtain during their LLL activities [3].

References

[1] Bologna declaration of June 1999, http://www.bologna-bergen2005.no/Docs/00-Main_doc/990719BOLOGNA_DECLARATION.PDF (Last time accessed was on the 14th of December 2012).

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Table A1: Recommended syllabus and ECTS for radiation protection education and training for radiographers

Syllabus	ECTS	From Table 2.1	
		Topic number	TOPIC
Radiation protection and safety	5	9	General principles of radiation protection
		10	Operational radiation protection
		11	Particular patient radiation protection aspects
		12	Particular staff radiation protection aspects
		16	National regulations and international standards
		19	Justification of imaging examinations
Quality control and optimisation in medical imaging and radiotherapy	5	4	Physical characteristics of X-ray systems
		5	Fundamentals of radiation detection
		15	Quality control and quality assurance in radiation protection
Radiobiology	3	6	Fundamentals of radiobiology, biological effects of radiation
		7	Risks of cancer and hereditary disease and effective dose
		8	Risks of deterministic effects
		14	Risks from foetal exposure to ionising radiation
Radiation physics and dosimetry	4	3	Radiological quantities and units
		13	Typical doses from diagnostic procedures
		17	Dose management of pregnant patients
		18	Dose management of pregnant staff
Nuclear and atomic physics	3	1	Atomic structure, X-ray production and interaction of radiation
		2	Nuclear structure and radioactivity

11 EDUCATION AND TRAINING RESOURCES

When searching the internet hundreds of teaching resources on radiation protection can be found; however, it is not clear whether these resources are accurate and reliable. A list of radiation protection education and training resources verified by the contributors to these guidelines is provided below.

Most of these resources can be downloaded for free. The resources listed are not exhaustive and were available at the time of print.

11.1 European Commission Radiation Protection

http://ec.europa.eu/energy/nuclear/radiation_protection_en.htm
(Last accessed on the 12th of December 2012).

This is the official website of the EC where all the relevant European radiation protection legislation can be found, as well as a large number of relevant guideline documents.

http://ec.europa.eu/energy/nuclear/radiation_protection/medical/applications_en.htm (Last accessed on the 12th of December 2012).

Recently a 'medical applications' web page was introduced, which is more specific to radiation protection for medical applications. Relevant conferences and workshops are announced, as well as a plethora of other relevant information.

11.2 IAEA Radiation Protection of Patients

https://rpop.iaea.org/RPOP/RPoP/Content/index.htm (Last accessed on the 12th of December 2012).

This is a Web page on the official website of the IAEA where information for healthcare professionals, patients and the public can be found on the Radiation Protection Of Patients (RPOP). It provides educational and training material, recent publications and other relevant information. This can be regarded as a one-stop shop for the radiation protection of patients.

11.3 Image Wisely

http://www.imagewisely.org/About-Us (Last accessed on the 12th of December 2012).

The American College of Radiology (ACR) and the Radiological Society of North America (RSNA) formed a Joint Task Force on Adult Radiation Protection to address concerns about the surge of public exposure to ionising radiation from medical imaging. The Joint Task Force collaborated with the American Association of Physicists in Medicine (AAPM) and the American Society of Radiologic Technologists (ASRT) to create the Image Wisely campaign with the objective of lowering the amount of radiation used in medically necessary imaging studies and eliminating unnecessary procedures.

Image Wisely offers resources and information to radiologists, MPs, other imaging practitioners, and patients.

11.4 Image Gently

http://www.pedrad.org/associations/5364/ig/ (Last accessed on the 12th of December 2012).

The Image Gently campaign is an initiative of the Alliance for Radiation Safety in Paediatric Imaging. The campaign's goal is to change practice by increasing awareness of the opportunities to promote radiation protection in the imaging of children. It provides educational and training material, recent publications and other relevant information.

11.5 International Commission on Radiological Protection (ICRP)

http://www.icrp.org/ (Last accessed on the 12th of December 2012).

The work of the ICRP helps to prevent cancer and other diseases and effects associated with exposure to ionising radiation, and to protect the environment.

The ICRP publish reports on all aspects of radiological protection. Most address a particular area within radiological protection, but a few publications, the so-called fundamental recommendations, describe the overall system of radiological protection. The **International System of Radiological Protection** has been developed by ICRP based on (i) the current understanding of the science of radiation exposures and effects and (ii) value judgements. These value judgements take into account societal expectations, ethics, and experience gained in the application of the system.

11.6 International Radiation Protection Association (IRPA)

http://www.iradiation protectiona.net/ (Last accessed on the 12th of December 2012).

IRPA is recognised by its members, stakeholders and the public as the international voice of the radiation protection profession in the enhancement of radiation protection culture and practice worldwide

11.7 Optimization of Radiation protection for Medical Staff (ORAMED)

http://www.oramed-fp7.eu/en (Last accessed on the 12th of December 2012).

ORAMED (Optimization of RAdiation protection for MEDical staff) aims at the development of methodologies for better assessing and reducing exposure to medical staff during procedures that have potentially large doses or complex radiation fields, such as IR, NM and new developments. It also provides education and training material.

11.8 European Medical ALARA Network (EMAN)

http://www.eman-network.eu/ (Last accessed on the 12th of December 2012).

This is a new European network created for stakeholders within the medical sector to have the opportunity to discuss and exchange information on various topics relating to the implementation of the ALARA principle in the medical field.

This network also supports the EC in its activities relating to the optimisation of radiation protection of individuals submitted to medical exposure.

11.9 European Training and Education in Radiation Protection (EUTERP) Foundation

http://www.euterp.eu/(last accessed on the 27th of January 2013).

The EUTERP Foundation is an independent legal entity set up to provide a centralised European source of information on radiation protection education and training matters. It is a focal point for the discussion and development of European training activities in Radiation Protection in all the fields using ionising radiation, including the medical field.

11.10 Heads of the European Radiological protection Competent Authorities (HERCA)

http://www.herca.org/ (Last accessed on the 12th of December 2012).

HERCA (Heads of the European Radiological protection Competent Authorities) is a voluntary association in which the heads of radiation protection authorities work together in order to identify common issues and propose practical solutions for these issues. HERCA is working on topics generally covered by provisions in the Euratom Treaty. The programme of work of HERCA is based on a common interest in significant regulatory issues.

The goal of HERCA is to contribute to a high level of radiological protection throughout Europe.

11.11 American College of Radiology (ACR)

http://www.acr.org/ (Last accessed on the 12th of December 2012).

The ACR include radiologists, radiation oncologists, MPs, interventional radiologists, NM physicians and allied health professionals. For over three quarters of a century, the ACR has devoted its resources to making imaging safe, effective and accessible to those who need it.

The ACR serves patients and society by maximising the value of radiology, radiation oncology, IR, NM and medical physics.

11.12 Australian Department of Health of Western Australia

http://www.imagingpathways.health.wa.gov.au/includes/index.html (Last accessed on the 12th of December 2012).

This website provides a clinical decision support tool and educational resources for diagnostic imaging.

ABBREVIATIONS

AAPM	American Association of Physicists in Medicine
ACR	American College of Radiology
ALARA	As Low As Reasonably Achievable
ASRT	American Society of Radiologic Technologists
BEV	Beams Eye View
BSS	Basic Safety Standards
CanMEDS	Canadian Medicine Specialists
CIRSE	Cardiovascular and Interventional Radiological Society of Europe
CME	Continuous Medical Education
CPD	Continuous Professional Development
COM	Commission
CT	Computed Tomography
CTDI	Computed Tomography Dose Index
CTV	Clinical Target Volume
DAP	Dose Area Product
DLP	Dose Length Product
DRL	Diagnostic Reference Level
DRR	Digital Reconstructed Radiograph
DVH	Dose Volume Histogram
DSA	Digital Subtraction Angiography
EANM	European Association of Nuclear Medicine
EC	European Commission
ECTS	European Credit Transfer and accumulation System
ECVET	European Credit System for Vocational Education and Training
EI	Educational Institute
EU	European Union
EFRS	European Federation of Radiographer Societies
EFOMP	European Federation of Organisations for Medical Physics
EHAE	European Higher Education Area
EMAN	European Medical ALARA Network
ENETRAP	European Network on Education and Training in Radiation Protection
EQF	European Qualifications Framework
ESD	Entrance Surface Dose
ESR	European Society of Radiology
ESTRO	European Society for Therapeutic Radiology and Oncology

ESVS	European Society for Vascular Surgery
Euratom	European Atomic Energy Community
GFR	Glomerular Filtration Rate
GP	General Practitioner
GTV	Gross Target Volume
HEI	Higher Education Institution
HENRE	Higher Education Network for Radiography in Europe
HERCA	Heads of the European Radiological Protection Competent Authorities
HTA	Health Technology Assessment
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IORT	IntraOperative Radiation Therapy
IR	Interventional Radiology
KAP	Kerma Area Product
KSC	Knowledge, Skills and Competence
LET	Linear Energy Transfer
LLL	Lifelong Learning
LNT	Linear No-Threshold
MED	Medical Exposures Directive
MEDRAPET	Medical Radiation Protection Education and Training
MP	Medical Physicist
MPE	Medical Physics Expert
MS	Member States
NM	Nuclear Medicine
NMT	Nuclear Medicine Technologist
OLINDA/EXM	Organ Level INternal Dose Assessment/EXponentialModeling
OR	Operating Room
OAR	Organs at Risk
ORAMED	Optimization of RAdiation protection for MEDical staff
PET	Positron Emission Tomography
PET/CT	Positron Emission Tomography/Computed Tomography
PM	Preventive Maintenance
PS	Professional Societies
PTV	Planning Target Volume
QA	Quality Assurance
QC	Quality Control
RCR	Royal College of Radiology

RP116	Radiation Protection Report 116
RPA	Radiation Protection Authority
RPE	Radiation Protection Expert
RPOP	Radiation Protection of Patients
RSNA	Radiological Society of North America
RTT	Radiation TherapisTs
SPECT	Single Photon Emission Tomography
SPECT/CT	Single Photon emission Computed Tomography/Computed Tomography
SOP	Standard Operating Procedure
TIPS	Transjugular Intrahepatic Portosystemic Shunt
UEMS	European Union of Medical Specialists
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WHO	World Health Organisation

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Endorsements

ESR	(European Society of Radiology
EFOMP	(European Federation of Organisations for Medical Physicists)
EFRS	European Federation of Radiographers Societies)
EANM	(European Association of Nuclear Medicine)
ESTRO	(European Society for Radiotherapy and Oncology)
CIRSE	(Cardiovascular and Interventional Radiological Society of Europe)
EUTERP	(European Training and Education in Radiation Protection Foundation)
ESVS	European Society for Vascular Surgery

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ANNEX: ICRP 113 TABLES 3.1 AND 3.2

The ICRP 113 tables 3.1 and 3.2 are reproduced below with the kind permission of the ICRP.

Table 3.1. Recommended radiological protection training requirements for different categories of physicians and dentists.

Training area	Category							
	1DR	2NM	3CDIMDI	4MDX	5MDN	6MDA	7DT	8MD
Atomic structure, x-ray production, and interaction of radiation	m	h	l	l	l	l	l	–
Nuclear structure and radioactivity	m	h	l	–	m	–	–	–
Radiological quantities and units	m	h	m	m	m	l	l	l
Physical characteristics of x-ray machines	m	l	m	m	l	l	m	–
Fundamentals of radiation detection	m	h	l	l	m	–	l	–
Principle and process of justification	h	h	h	h	h	h	h	m
Fundamentals of radiobiology, biological effects of radiation	h	h	m	m	m	l	l	l
Risks of cancer and hereditary disease	h	h	m	m	m	l	m	m
Risk of deterministic effects	h	h	h	m	l	l	m	l
General principles of radiation protection including optimisation	h	h	h	m	m	m	m	l
Operational radiation protection	h	h	h	m	h	m	m	l
Particular patient radiation protection aspects	h	h	h	h	h	m	h	l
Particular staff radiation protection aspects	h	h	h	h	h	m	h	l
Typical doses from diagnostic procedures	h	h	m	m	m	m	m	m
Risks from foetal exposure	h	h	l	m	m	l	l	l
Quality control and quality assurance	m	h	m	l	l	–	l	–
National regulations and international standards	m	m	m	m	m	l	m	l
Suggested number of training hours	30–50	30–50	20–30	15–20	15–20	8–12	10–15	5–10

RP, radiological protection; DR, diagnostic radiology specialists; NM, nuclear medicine specialists; CDI, interventional cardiologists; MDI, interventionalists from other specialties; MDX, other medical specialists using x-ray systems; MDN, other medical specialists using nuclear medicine; MDA, other medical doctors assisting with fluoroscopy procedures such as an aesthetists and occupational health physicians; DT, dentists; MD, medical doctors referring for medical exposures and medical students; l, low level of knowledge indicating a general awareness and understanding of principles; m, medium level of knowledge indicating a basic understanding of the topic, sufficient to influence practices undertaken; h, high level of detailed knowledge and understanding, sufficient to be able to educate others.

Table 3.2. Recommended radiological protection training requirements for categories of health care professionals other than physicians or dentists.

Training area	Category								
	9MP	10RDNM	11ME	12HCP	13NU	14DCP	15CH	16RL	17REG
Atomic structure, x-ray production, and interaction of radiation	h	m	m	l	l	m	l	m	l
Nuclear structure and radioactivity	h	m	m	–	–	–	–	m	l
Radiological quantities and units	h	m	m	l	l	l	m	m	m
Physical characteristics of x-ray machines	h	h	h	m	–	l	m	l	l
Fundamentals of radiation detection	h	h	h	l	l	l	l	m	l
Principle and process of justification	h	h	–	l	l	l	h	–	m
Fundamentals of radiobiology, biological effects of radiation	h	m	l	m	l	l	m	m	L
Risks of cancer and hereditary disease	h	h	l	m	l	m	m	m	m
Risks of deterministic effects	h	h	–	l	l	l	m	l	m
General principles of radiation protection including optimisation	h	h	m	m	m	m	m	m	m
Operational radiation protection	h	h	m	m	m	m	m	h	m
Particular patient radiation protection aspects	h	h	m	h	m	m	h	–	m
Particular staff radiation protection aspects	h	h	m	h	m	m	h	h	m
Typical doses from diagnostic procedures	h	h	l	l	–	l	m	–	l
Risks from foetal exposure	h	h	l	m	l	l	m	m	l
Quality control and quality assurance	h	h	h	l	–	m	m	l	m
National regulations and international standards	h	m	h	m	l	l	m	m	h
Suggested number of training hours	150–200	100–140	30–40	15–20	8–12	10–15	10–30	20–40	15–20

RP, radiological protection; MP, medical physicists specialising in radiation protection, nuclear medicine, and diagnostic radiology; RDNM, radiographers, nuclear medicine technologists, and x-ray technologists; HCP, health care professionals directly involved in x-ray procedures; NU, nurses assisting in x-ray or nuclear medicine procedures; DCP, dental care professionals including hygienists, dental nurses, and dental care assistants; ME, maintenance engineers and applications specialists; CH, chiropractors and other healthcare professionals referring for, justifying, and delivering radiography procedures (amount of training depends on range of tasks performed); RL, radiopharmacists and radionuclide laboratory staff; REG, regulators; l, low level of knowledge indicating a general awareness and understanding of principles; m, medium level of knowledge indicating a basic understanding of the topic, sufficient to influence practices undertaken; h, high level of detailed knowledge and understanding, sufficient to be able to educate others.