DRAFT REPORT FOR CONSULTATION

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Radiological protection education and training for healthcare staff and students

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Abstract

The number of diagnostic and interventional medical procedures using ionising radiations is steadily rising, and procedures resulting in higher patient and staff doses are being performed more frequently. The need for education and training of medical staff (including medical students) and other healthcare professionals in the principles of radiation protection is therefore now even more compelling that in the past.

The Commission has made basic recommendations for such education and training of these individuals in Publications 103 and 105. The present publication expands considerably on these basic recommendations with regard to various categories of medical practitioners, and other healthcare professionals that perform or provide support for diagnostic and interventional procedures utilising ionizing radiation. It provides guidance regarding the necessary radiological protection education and training for use by:

- cognizant regulators, health authorities, and professional bodies with responsibility for radiological protection in medicine;
- the industry that produces and markets the equipment used in these procedures; and
- Universities and other academic institutions responsible for the education of professionals involved in the use of ionizing radiation in healthcare.

In the context of this publication, the term education refers to imparting knowledge and understanding on the topics of radiation health effects, radiation quantities and units, principles of radiological protection, radiological protection legislation and the factors in practice that affect patient and staff doses. Such education should be part of the curriculum in pursuit of medical, dental and other healthcare degrees, and for specialists such as radiologists, medical physicists and radiographers as part of the curriculum of postgraduate degrees. The term

training refers to providing instruction with regard to radiological protection for the justified application of the specific ionizing radiation modalities (e.g. CT, fluoroscopy) that a medical practitioner or other healthcare or support professional will utilize in that individual's role during medical practice.

Advice is also provided on the accreditation and certification of the recommended education and training. In the context of this publication, the term accreditation means that an organization has been approved by an authorised body to provide education or training on the radiological protection aspects of the use of diagnostic or interventional radiation procedures in medicine. The accredited organization is required to meet standards that have been set by the authorised body. The term certification means that an individual medical or clinical professional has successfully completed the education or training provided by an accredited organization for the diagnostic or interventional procedures to be practiced by the individual. The individual must demonstrate competence in the subject matter in a manner required by the accredited body.

Chapter 1: Introduction

The number of diagnostic and interventional medical procedures using ionising radiations is steadily rising, and procedures requiring higher patient doses are being performed more frequently. Thus the reason that medical staff and other healthcare professionals should be educated in radiological protection (RP) is more compelling. Yet in most countries RP training particularly for medical professionals is deficient. In this chapter the need for education of different groups, including those who prescribe radiological procedures and medical students is discussed. It is recommended that this education should cover both deterministic and stochastic effects of ionising radiation with specific examples of RP factors that must be considered, and especially should cover the need to manage radiation dose according to the principles of radiation protection. Although recommendations have been made before by the Commission, this is the first report to specifically address the topic of the delivery of education and training for medical staff and other healthcare professionals involved in use of ionising radiation for diagnostic (radiography, fluoroscopy and nuclear medicine) and interventional (fluoroscopically guided) procedures.

1.1 The need for a greater awareness of radiological protection

Many people are exposed to ionizing radiation from diagnostic and interventional medical procedures. The radiation doses to individual patients can be among the highest from human activities, even when radiotherapy is excluded. In some countries with advanced healthcare systems, the mean number of diagnostic medical procedures utilizing ionizing radiation approaches or exceeds one per year per member of the population. Furthermore radiation doses to patients from diagnostic x-ray examinations differ widely between centres suggesting that there is a widespread need for the optimisation of RP (UNSCEAR, 2000).

In order to avoid unnecessary risk, radiological procedures should only be undertaken when they are expected to influence the management of the patient. Ensuring that all medical radiation procedures are justified requires that awareness is raised among those who prescribe about both the benefits and the risks of such procedures. Recent increases in the number, variety and complexity of interventional procedures can result in radiation doses to patients being sufficiently high to induce deterministic effects, and doses to the medical professionals conducting the procedures can come close to occupational dose limits (ICRP, 2000 b). Therefore particular attention to the management (reduction) of doses to both patients and professionals in interventional procedures is important.

Optimization of RP for patients and medical personnel in diagnostic and interventional medical procedures requires the conviction, engagement and competent performance of the medical, radiographic, physics and technical personnel involved. Planned education and training programmes for the personnel involved are necessary *sine qua non* to ensure reasonable RP of patients and workers.

It is accepted that RP education and training is deficient in many countries for almost all types of medical professionals requesting or performing diagnostic and interventional procedures. There are also deficiencies for some other professionals involved in medical exposures. This view is now largely shared by radiology and RP professionals, who also agree about the importance of training medical staff in order to improve the situation.

The present document makes recommendations on training in RP for medical practitioners, radiographers, physicists, and technicians who perform or provide support for diagnostic and interventional procedures utilising ionizing radiation. It sets out guidance that should be considered by the cognizant regulators, health authorities, and professional bodies with responsibility for RP in medicine, as well as the industry that produces and markets the equipment used in these procedures. This guidance should also be considered by universities and other academic institutions responsible for the education of professionals involved in the use of radiation in healthcare. Guidance is given on education requirements in RP for those who prescribe diagnostic and interventional procedures, and medical and dental students who will prescribe in the future, to aid in the selection of content for medical degrees and postgraduate medical studies. Other than aspects of nuclear medicine therapy, this document does not address radiation therapy,modalities which should only be prescribed by medical staff who have specialized in the relevant disciplines.

One of the principal unresolved issues for accomplishing education and training in RP for medical professionals is establishment of methods for delivery that focus on relevant content and highlight practical issues. For the medical professional in particular, it is essential that courses are perceived as relevant and necessary, and require only a limited commitment of time so that individuals can be persuaded of the advantages of attending. Some information on the content of courses and on websites from which material can be obtained is given in Annexes A, B and C.

1.2 Education and Training in RP

In the context of this document **education** and **training** in RP should be understood as follows.

Education refers to the imparting of knowledge and understanding on basic topics such as radiation hazards, radiation quantities and units, principles of RP, radiation legislation and RP factors affecting patient and staff doses. A basic level of instruction should be given during medical, dental and other healthcare degree courses. More in-depth education on these topics for specialists such as radiologists, medical physicists and radiographers should be given during postgraduate degrees.

Training refers to instruction and practice relating to the ionizing radiation modalitites (e.g. CT, fluoroscopy) used by the individual in medical practice. It should include imparting of specialist knowledge required for optimization of RP and should involve a significant element of practical skills.

RP education and training for medical staff should be promoted by Regulatory and Health Authorities. RP education programmes should be implemented by the heathcare providers and Universities and coordinated at local and national levels to provide courses based on agreed syllabuses and similar standards. Scientific and professional societies should contribute to the development of the syllabuses and to the promotion and support of the education and training. Scientific congresses should include refresher courses on RP, attendance at which could be a requirement for continuing professional development for professionals using ionizing radiation.

Since almost all physicians and dentists will need to request medical exposures, it is appropriate that the basic RP education is included in medical and dental degrees. The inclusion of RP in the syllabuses of medical and dental schools requires inter-sector cooperation at local and national level (e.g. universities, ministries of education). In some Countries, the requirement to train all physicians is less important, since the physician refers the patient, but does not make the decision regarding the justification of the exposure. Here the physician is termed a referrer, rather than a prescriber and in these cases the amount and type of training may therefore be different.

Professionals involved more directly in the use of ionizing radiation should receive education and training in RP at the start of their career, and the education process should continue throughout their professional life as the collective knowledge of the subject develops. It should include specific training on related RP aspects as new equipment or techniques are introduced into a centre.

Medical Physicists have a central role in all education and training programmes on RP. They know about the nature and type of radiation and the RP requirements for the application of ionizing radiation and should work closely with their medical specialist colleagues in setting up and conducting the training programmes.

The radiological equipment manufacturers have an important role to play in the optimization of RP. They have a responsibility to make users aware of the dosimetric implications of the procedures, and to inform them about the proper application of dose-reduction technology.

1.3 The knowledge that RP education and training should provide

1.3.1 Potential health effects from radiation exposure

The purpose of managing radiation dose in diagnostic and interventional procedures is to avoid deterministic health effects and to reduce the probability of stochastic health effects of ionizing radiation.

- Deterministic effects (harmful tissue reactions such as moderate and severe radiation-induced skin injuries) occur when many cells in an organ or tissue are affected. The effects will be clinically observable only if the radiation dose is above some threshold. These thresholds can be reached in localized regions of a patient's skin as a result of complex fluoroscopically guided interventional procedures (ICRP, 2000 b). It is at present a matter of debate whether the threshold for injury to the lens of the eye is sometimes reached in operators performing interventional procedures, leading to an increased frequency of cataracts.

- Stochastic effects (e.g. cancer and heritable effects) can occur due to radiation-induced damage in the DNA of cells which can cause the transformation of cells that are still capable of reproduction, and this can in turn lead to a malignant condition. If the initial damage is inflicted to the germ cells in the gonads, heritable effects may occur. It is likely that the probability of such effects increases proportionally with dose, for the levels of ionizing radiation experienced in diagnostic and interventional procedures. The increase in the probability for cancer induction is influenced by age at exposure, gender and genetic susceptibility to cancer (ICRP, 2007 b).

- Effects on the embryo and fetus: There is potential for radiation effects in the embryo/fetus which are related to the stage of fetal development and the absorbed dose (ICRP, 2003b, 2007 b). Possible deterministic effects include resorption of the embryo during the pre-implantation period, although this is likely to be very infrequent, and malformations which may occur in various organs from the 3rd to the 8th week (organogenesis). Damage to the developing central nervous system may occur in the early fetal period, particularly from the 8th to the 15th week after conception and to a lesser extent between the 16th and 25th week after conception. These deterministic effects have relatively high threshold radiation doses (>100 mSv) and should not occur for optimized diagnostic procedures. With regard to stochastic effects, there is an increase in the probability of leukaemias and other cancers that may occur later in childhood from irradiation during all stages of fetal development. These effects are stochastic in nature and therefore it is likely that there is no threshold dose, so they may occur after low doses, although the probability is small.

If the staff is properly educated and trained in RP, doses from diagnostic procedures and for the most part from fluoroscopically guided interventional procedures should not approach the threshold for deterministic effects. The probability of stochastic effects cannot be totally eliminated, so the appropriate approach is to prescribe or conduct procedures only when they are justified and to take all reasonable steps to manage the patient and staff doses from such procedures to ensure optimization of RP.

1.3.2 Examples of the need to manage radiation dose

Some practical examples of the need for education and training in RP are:

- With regard to pregnant patients (ICRP, 2000a) …
  - The fact that a patient is pregnant must be considered in the justification of procedures for individual patients.

    - The manner in which an examination of a patient is performed depends on whether the embryo/fetus will be in the direct beam and whether the procedure requires a relatively high dose.

- With regard to interventional procedures (ICRP, 2000b)…
    - Fluoroscopically guided interventional procedures are being used by an increasing number of clinicians and many interventionists are not aware of the potential for injury from these procedures and the simple methods for decreasing their incidence. Occasionally, severe radiation-induced skin injuries have occurred.
    - Patients undergoing difficult procedures need to be counselled on the radiation risks, and followed clinically when the associated radiation doses may lead to injury. The patient's personal physician should be informed when there is a possibility of radiation effects.

- With regard to computed tomography procedures (ICRP, 2000c; 2007a)…
    - Computed tomography (CT) procedures can involve relatively high doses to patients, particularly for modern CT scanners that employ multiple rows of detector arrays that allow rapid scanning and wider scan coverage. Doses from multiple procedures often approach or exceed the levels known from epidemiological studies to increase the probability of cancer.
    - The referring physician should evaluate whether the result of each CT procedure will affect the clinical management of the patient, and the radiologist should concur that the procedure is justified. This includes an understanding of the classification of the clinical indications into those requiring higher-dose procedures and those for which lower-dose procedures will be sufficient.
    - The radiologist and CT scanner operator should be aware of the possibilities for managing patient doses by adapting the technical parameters to each patient and the specific procedure, with special attention being paid to paediatric patients.
    - There is potential for dose reduction with all CT systems. It is important that radiologists, cardiologists, medical physicists and CT scanner operators understand the relationship between patient dose and image quality, and that images of the highest quality that require higher doses are not essential for all diagnostic tasks.

  - Operators of CT scanners should have an understanding of the reduction that can be made in exposure by applying specific factors for paediatric patients. Many children have been examined using adult factors and given unnecessarily high doses in the past.

- With regard to digital radiology procedures (ICRP, 2003a)…
  - Digital techniques have the potential to improve the practice of radiology, but higher doses than necessary may be delivered without any corresponding improvement in image quality.
  - Different medical imaging tasks require different levels of image quality. The use of more radiation to give a higher level of image quality should be avoided where this has no additional benefit for the clinical purpose.
  - It is very easy to obtain (and delete) images with digital fluoroscopy systems, and there may be a tendency to obtain more images than necessary.
  - Industry should promote tools to inform radiologists, radiographers, and medical physicists about the recommended exposure parameters and the resultant patient doses associated with digital systems.

- With regard to doses to operators (ICRP 2000a, ICRP 2000b)
  - If a medical professional participating in procedures utilizing radiation declares to her employer that she is pregnant, additional controls have to be considered in order to attain a level of protection for the embryo/fetus broadly similar to that provided for members of the public.
  - Interventionalists with heavy procedure workloads may be exposed to high doses. Sometimes it may be necessary to limit the practice of specific individuals to avoid risk of radiation injury.
  - Different positions adjacent to the x-ray table expose staff to higher or lower dose rates. Staff should be educated about how dose rates vary adjacent to interventional x-ray equipment.
  - The Commission has stated in its Publication 103 (paragraph 249) that "However, new data on the radiosensitivity of the eye with regard to visual impairment are expected. The Commission will consider these data and their possible significance for the equivalent dose limit for the lens of the eye when they become available. Because of the

uncertainty concerning this risk, there should be particular emphasis on optimisation of RP in situations of exposure to the eyes.

1.4 Recommendations in Publications 103 and 105

The underlying objective for the RP training of medical professionals performing diagnostic and interventional procedures is to increase the proficiency of the medical professionals in managing patient and staff doses so that radiation doses are commensurate with the clinical task. ICRP Publication 103 [paragraph 328] and Publication 105 (ICRP, 2007c) [paragraphs (106), (107), (108) and (110)] provide the following recommendations concerning this training:

Publication 103

(328) The physicians and other health professionals involved in the procedures that irradiate patients should always be trained in the principles of RP, including the basic principles of physics and biology. The final responsibility for the medical exposure of patients lies with the physician, who therefore should be aware of the risks and benefits of the procedures involved.

Publication 105

(106) There should be RP training requirements for physicians, dentists and other health professionals who order, conduct, or assist in medical or dental procedures that utilise ionising radiation in diagnostic and interventional procedures, nuclear medicine and radiation therapy. The final responsibility for the radiation exposure lies with the physician, who should therefore be aware of the risks and benefits of the procedures involved.

(107) Relative to radiation use in medicine, three distinct categories of physicians can be identified:

- physicians that are trained in the ionising radiation medical specialties (e.g., radiologists, nuclear medicine physicians, radiation oncologists);

- other physicians that utilise ionising radiation modalities in their practice (e.g., cardiologists, vascular surgeons, urologists); and
- physicians that prescribe medical procedures that use ionising radiation.

N.B. These categories are expanded in Chapter 2 of this report and more detailed recommendations on the amounts of training for each category are given in Chapter 3.

(108) Education and training, appropriate to the role of each category of physician, should be given at medical schools, during the residency and in focused specific courses. There should be an evaluation of the training, and appropriate recognition that the individual has completed the training successfully. In addition, there should be corresponding RP training requirements for other clinical personnel that participate in the conduct of procedures utilising ionising radiation, or in the care of patients undergoing diagnosis or treatments with ionising radiation.

(110) One important need is to provide adequate resources for education and training in RP for future professional and technical staff who request or partake in radiological practices in medicine. The training programme should include initial training for all incoming staff, regular updating and retraining, and certification of the training.

The present report is limited to RP training for diagnostic and interventional procedures, and nuclear medicine therapy.

1.5 Training in interpretation of images

An important element that determines if a medical exposure is justified is whether the images obtained can provide the information required for the clinicnal task. Thus the clinicians for whom the images are provided must have appropriate training in order to interpret relevant details in the images. The interpretation of images will frequently be done by radiologists who have undergone extensive training, but many images will be interpreted by other medical staff and it is important that they receive sufficient training in their medical degree or specialty training for the level of interpretation that they will be required to perform. Training in interpretation of images is not the subject of this document, but is mentioned because that interpretation makes up an important aspect of the justification process for any clinical exposure.

Chapter 2: The healthcare professionals to be trained

Limited awareness of the risks from radiation among physicians is leading to the over-prescription of radiation procedures in many countries. Physicians need to understand the nature of the risks so that they can take these into account when requesting medical exposures. When dealing with pregnant patients the correct balance must be achieved between effective treatment, minimisation of risks, and the avoidance of unnecessary termination. Interventional medical procedures carry a risk of deterministic effects. In order to provide some information on the amount of education and training in RP that is appropriate, 15 categories of healthcare professionals have been identified, eight representing different groups of physicians and dentists, and seven other healthcare professionals involved in the use of radiation. Recommendations on the training for the different categories are discussed, including those for medical students and physicians who prescribe medical procedures using ionising radiation.

2.1 Consequences of failure to deliver training in RP

The rapid expansion in medical procedures using radiation during the last decade has resulted in radiation doses from medical exposures becoming a significant and in some countries the major component of radiation exposure to the population [UNSCEAR 2000]. It is important that the medical profession and other healthcare professionals understand the hazards in order to avoid the creation of unnecessary risks to the population as a whole. The basic rule should be that all exposures are justified in terms of the influence that they will have on management of the patient. Lack of knowledge may result in more imaging tests being requested when other non-radiation tests could be performed or when different lower dose imaging tests could be carried out.

There are many different consequences that can arise from poor awareness and understanding of radiation hazards by medical practitioners apart from over-prescription. A number of physicians have recommended termination of pregnancy following any medical imaging exam that their pregnant patient may have received, a practice that again results from a lack of understanding of the risks from radiation exposure. The lack of knowledge may also lead to pregnant women not receiving the medical care that they need because of exaggerated fears of the risks from fetal exposures.

Those directly involved in exposures need RP training to ensure that procedures are optimized with regard to RP, so that radiation doses to individual patients are not higher than necessary. There are continual new challenges as techniques are developed. For example, digital radiology has the potential to reduce patient doses, but can significantly increase them and the medical professionals need to be trained to use this technology effectively. Experience has shown that as many radiology departments have made the transition to digital equipment, patient doses have not been reduced but have increased measurably. ICRP Publication 93 (ICRP, 2003a) is a dedicated report on the proper management of radiation dose in digital radiology, and includes Section 2.5 on training needs for radiologists and radiographers and Appendix C with an outline for education and training.

Several medical specialties using ionizing radiation as part of their clinical work need to have some knowledge in RP. The level of education and training will be different depending on the uses, the workload and the level of risk (radiation doses) involved. The need for medical doctors employing fluoroscopically guided procedures to be both trained and certified for this practice is very important to avoid unnecessary exposures. There are other groups of healthcare professionals who may have extensive or limited involvement with radiation exposures who also require to be trained.

2.2 Categories of medical and healthcare professionals requiring education and training

In order to facilitate specification of the RP training required by different medical and healthcare professionals, categories that cover the majority of those involved are listed below.

1. *Radiologists (DR)*: Physicians who are going to take up a career in which the major component involves the use of ionizing radiation in radiology.
2. *Nuclear Medicine Specialists (NM)*: Physicians who are going to take up a career in which the major component involves the use of radiopharmaceuticals in nuclear medicine for diagnosis and treatment.

3. *Cardiologists (CD)*: Physicians whose occupation involves a fairly high level of ionizing radiation use, although it is not the major part of their work, such as interventional cardiologists.
4. *Other Medical Specialists using X-rays (MDX)*: Physicians whose occupation involves the use of x-ray fluoroscopy in urology, gastroenterology, orthopaedic surgery, neurosurgery or other specialties.
5. *Other Medical Specialties using Nuclear Medicine (MDN)*: Physicians whose occupation involves prescription and use of a narrow range of nuclear medicine tests.
6. *Other Physicians who assist with radiation procedures (MDA)*: Physicians such as Anaesthetists who have involvement in fluoroscopy procedures directed by others, and Occupational Health Physicians who review records of radiation workers.
7. *Dentists (DT)*: Dentists who take and interpret dental x-ray images routinely.
8. *Medical Prescribers (MD)*: Physicians who request examinations and procedures involving ionizing radiations and medical students who may prescribe examinations in the future.
9. *Radiographers, Nuclear Medicine Physicists and Medical Physics Technologists (RDNM)*: Individuals who are going to take up a career in which a major component is involved with operating and/or testing x-ray or radionuclide imaging equipment, including those carrying out performance tests on a range of x-ray units in different hospitals.
10. *Maintenance engineers (ME)*: Individuals with responsibilities for maintaining the x-ray and imaging systems (including nuclear medicine).
11. *Other Healthcare Professionals (HCP)*: Other professionals such as Podiatrists, Speech Therapists, and Chiropractors who may be involved in the use of radiology techniques to assess patients.
12. *Nurses (NU)*: Nursing staff and other healthcare professionals assisting in diagnostic and interventional x-ray fluoroscopy procedures, injecting radiopharmaceuticals, or assisting in the care of nuclear medicine patients.
13. *Dental Nurses and assistants (DN)*: Dental nurses and dental assistants who take dental radiographs and process images.

14. *Radionuclide Laboratory Staff (RL)*: Individuals who use small quantities of radionuclides for diagnostic purposes such as radioimmunoassay.

15. *Regulators (REG)*: Individuals with responsibility for enforcing ionizing radiation legislation.

2.3 Training for healthcare professionals

2.3.1. Medical professionals involved directly with the use of radiation

Diagnostic radiologists and nuclear medicine specialists in some countries are given an extensive formal training programme and certification during their residency involving typically 30 h – 50 h training in RP. These specialist groups need a high level of understanding of the hazards and RP for many different scenarios. Similar levels of training are required in all countries.

Interventional procedures can involve high doses of radiation and the special radiological risk needs to be taken into account if deterministic effects on the skin are to be avoided. ICRP has proposed in Publication 85 (ICRP, 2000b) a second level of RP training for interventional radiologists and cardiologists:

(50) Interventional procedures are complex and demanding. They tend to be very operator dependent with each centre having slightly different techniques. It is particularly important in these circumstances that individuals performing the procedures are adequately trained in both the clinical technique and in knowledge of RP. A second, specific, level of training in RP, additional to that undertaken for diagnostic radiology, is desirable. Specific additional training should be planned when new x-ray systems or techniques are implemented in a centre. A quality assurance programme for interventional radiology facilities should include RP training and assessment of dose control technique.

Training in RP given to interventional cardiologists in most countries is limited. The Commission considers that provision of more RP training for this group should be a priority.

The training given to other medical specialists such as vascular surgeons, urologists, endoscopists and orthopedic surgeons before they direct fluoroscopically guided invasive techniques is significantly less. The times allocated for this RP training depend on previous knowledge of the basis of radiation physics and radiobiology, but typically should be at least 15 h (taking into account formal courses and on the job training). A similar amount of RP training, but with a different emphasis is recommended for physicians involved in the delivery of a narrow range of nuclear medicine tests relating to their specialty.

Other medical specialties not directly operating the x-ray units or administering radionuclides, but closely involved with the specialist operator, such as anesthetists, will require some training on the basic aspects of RP [e.g. what is scattered radiation, how equipment use affects their exposure, radiation units, radiobiology, and risks during pregnancy and breast feeding (if open radiation sources are used)]. For these personnel, a combination of seminars and practical demonstrations is likely to be the best arrangement for their RP training.

Occupational health doctors who review dose and health records of radiation workers will also require education in RP. They may have to decide whether individuals should continue to work with radiation after high exposures or if they have particular pathologies or if they are pregnant.

2.3.2 Medical and healthcare professionals prescribing diagnostic exposures and medical students

The vast majority of medical professionals will need to prescribe diagnostic examinations and procedures involving the use of ionizing radiations. A similar level of education in RP needs to be given to:

- prescribers of imaging techniques using ionizing radiation
- medical (and dental) students

The information that these groups need to know is the basis of biological effects of ionizing radiation, a basic idea of the radiological quantities and units, and the relationship between radiation dose and the increase in probability of stochastic effects. Specific risks during pregnancy should also be included. The European Commission has published Guidelines on this issue (EC, 2000b).

Prescribers need to be familiar with referral criteria appropriate for the range of examinations that they are likely to request. It is recommended that “Referral guidelines for imaging”, such as those published by radiology societies are consulted. These are updated periodically as more collective experience is gained, so it is important to recheck criteria periodically, particularly when new techniques are involved.

Education in RP for future prescribers could be included in a dedicated short course or integrated into education on the fundamentals of diagnostic techniques with ionizing radiation in the medical degree.

Other healthcare professionals, such as nurse practitioners in casualty departments and podiatrists may request medical exposures for specific conditions, and will require some instruction in radiation hazards although this can be more limited because of the narrower scope of practice.

2.3.3 Other healthcare professionals

Training for healthcare professionals in RP will be related to their specific jobs and roles. Medical Physicists working in RP and diagnostic radiology should have the highest level of training in RP as they have additional responsibilities as trainers in RP for most of the clinicians.

Radiographers, nuclear medicine technologists and x-ray technologists will all require substantial training in RP as this represents a core aspect of their work.

Maintenance engineers with responsibilities for imaging systems require training in RP, not only related to their personal roles, but also in RP of patients so that they understand how the settings of the x-ray systems and adjustments that they may make influence the radiation doses to patients.

Nurses and other healthcare professionals assisting in fluoroscopic procedures require knowledge of the risks and precautions to minimize their exposure and that of others. There is evidence of a risk of lens opacities among those working in cardiac catheterization laboratories where RP has not been optimized.

Chapter 3: Priorities in topics to be included in the training

The objectives of RP education and the topics that should be included in RP training are considered in this chapter. The need to engage those undergoing the training and make them aware of the radiation hazards and risks associated with the techniques that they are using is stressed. It is not an easy task to achieve effective training with a realistic approach to the use of radiation. Recommended content of courses on radiation hazards, risks and applications for all physicians is given. This material might be covered in medical and other healthcare degrees. Other topics which will differ depending on the role of the physician or healthcare professional are also considered. Recommendations on the amounts of training and the subject matter that is more or less important for each group are given in tables at the end of the chapter.

3.1 Objectives of training

A key component in the success of any training programme is to convince the engaged personnel about the importance of the principle of optimization in RP so that they implement it in their routine practice. In order to achieve this, the material must be relevant and presented in a manner that the clinicians can relate to their own situation.

Priority topics to be included in the training will depend on the involvement of the different professionals in medical exposures. For example some operational aspects are important for radiologists and nuclear medicine specialists, but these are not relevant for prescribers. But most medical specialists will require knowledge of basic topics such as radiation hazards and risks. Interventional operators must be aware that deterministic effects have to be avoided by managing the doses to patients (and personnel) in such a way that they are kept well below the threshold values.

Deterministic effects can be perceived readily by those with a basic understanding of RP principles, as this is a simple process of killing cells. The teaching programmes for interventional radiologists and cardiologists should provide data on dose-response relationships for deterministic effects, how these are affected by secondary factors, and the magnitudes of threshold doses for different organs.

The mechanisms involved in the induction of stochastic effects, on the other hand, and the frequency of their occurrence as a function of dose may not be obvious to all medical and healthcare professionals. Whereas increased incidence and mortality from malignancies after high doses is commonly known and not questioned (e.g. atomic bomb survivors and many other groups) the situation at low doses (< 0.1 Sv) is a different matter, as the postulated risk is derived by extrapolation from higher doses, and is based on a hypothesis. In addition, the magnitude of the risk (probability of occurrence) in the low-dose domain is small, delayed in time, and cannot be attributed directly to an exposure.

The risk of death or serious health impairment in the daily practice of clinical medicine is several orders of magnitude higher than that which can be linked to a stochastic phenomenon resulting from a diagnostic or interventional radiation procedure. Moreover, the delay in manifestation is quite large, so it is not surprising that for many physicians and their helpers the danger of stochastic phenomena is only a second or third order concern, in spite of the fact that the consequences, when they do occur, may result in great suffering and loss of life. It is also usually forgotten, that there are certain patients who undergo radiological diagnostic procedures frequently, with the consequence of a much higher than average risk of cancer induction by medical irradiation.

The education and training should aim to achieve the clear and convincing transfer of the current knowledge and recommendations on the subject that are accepted at the time. The approach recommended by the ICRP for its RP system is to assume no threshold dose for stochastic effects and that the risk of stochastic effects is proportional to organ or tissue dose.

The other extreme in the reaction to radiation exposure, which frequently distorts the reasonable approach to the risk, is usually linked with ignorance of real consequences and their frequency. The most common example is the exaggeration of the dangers from intrauterine exposure, related to induction of malformations. Individuals are often unaware that these effects are deterministic in nature and so will not occur when the dose to the embryo is low, as is the case in diagnostic procedures. The whole subject is dealt with thoroughly and clearly in ICRP Publication 84.

Clear presentation of the basic principles of radiobiology and the consequences of exposure to ionizing radiation should convince trainees that optimization of RP is correct both logically and ethically. It should also provide convincing evidence that diagnostic and interventional medical procedures utilizing ionizing radiation provide health benefits that usually substantially exceed the potential detrimental consequences of the radiological risk attributed to them when RP operational principles are properly applied.

3.2 Course topics

The challenge for medical education is to identify what information physicians need to know for everyday practice. However, courses on RP in medical degrees are limited. This, despite the fact that many of these students will become physicians using x-ray equipment in their practice, ordering radiation imaging tests, or having to respond to questions from their patients about the safety of radiation. Education on RP could be linked to courses on the applications of medical imaging and to training in interpretation of x-rays images in the medical degree.
A useful orientation on some of the topics to be included in this education programme on RP for medical students could be the ICRP Publication "Radiation and your patient: a Guide for medical practitioners" http://www.icrp.org/docs/Rad_for_GP_for_web.pdf.

The core content for these programmes should include (in addition to other local requirements):

1) Properties of ionizing radiation (x rays, beta particles and electrons).
2) How to quantify the amount of radiation. Radiological quantities and units.
3) Radiation mechanisms of interaction with biological materials.
4) Classification of radiation effects: deterministic and stochastic.
5) Magnitude of the risks for cancer and hereditary effects.
6) The use of radiation in diagnostic radiology, interventional radiology, nuclear medicine and radiotherapy.
7) Principles of justification of radiological procedures, optimization of RP and dose limitation.
8) Recommendations and legal requirements applying to medical, occupational, and public exposure.
9) Typical doses from medical diagnostic procedures and comparisons with effective doses from other sources.
10) The importance of diagnostic reference levels in managing the exposure of patients.
11) The appropriate role of effective dose in medicine.
12) Doses that can induce deterministic effects (interventional procedures).

13) The information that different imaging techniques can provide and the relative values of the alternative techniques.

14) How to obtain guidance on referral criteria for different examinations.

15) The principle of only carrying out diagnostic radiological investigations when they will influence patient management.

16) The risks from radiation therapy, nuclear medicine, and diagnostic and interventional radiology.

17) When children and pregnant women require special consideration in diagnostic and interventional procedures.

18) Risks to pregnant women (as patients or staff) and fetuses involved in radiotherapy, nuclear medicine, and diagnostic and interventional radiology.

19) When patients treated with radiation can endanger other people.

20) Commonly asked questions and suggested answers.

21) Legal issues and litigation.

3.3 Training recommendations for various categories of medical staff

The different groups of topics and the level of training recommended for different categories of medically qualified staff and other healthcare professionals are included in Tables 1 and 2 respectively. These have been developed based on current and the existing guidelines (e.g. European Guidelines RP-116). The course content has been expanded and the lists extended to provide a more complete breakdown for categories of staff involved with different aspects of radiation exposures.

The areas and levels suggested in the tables should be considered as core knowledge. More detailed additional training for some of the groups could be required. The practical application of RP specific to a relevant modality should be included in "operational RP”. Training programmes should include procedures that must be followed after accidental or unintended doses to patients from radiological practices have occurred and related ethical issues.

The number of hours indicated in the table should be considered as an indication of the amount of training. It could contain components from different periods of education and training, such as basic residency programmes and special training courses.

Medical physics experts in RP should know all the training areas at the highest level, in addition to physics and all relevant aspects of quality assurance programmes, as they will play a major role in advising others on optimization of RP and delivering the training lectures. This group will need to maintain their competence to ensure that they keep up to date with the current knowledge of radiation hazards and risks, developments in techniques and equipment, and legislative requirements. They will require substantially more training than the other categories considered here.

The length of training programmes (theory and practical work) will depend on the previous knowledge of radiation physics, radiobiology, etc., among the various groups of health professionals in the different countries. A good tool for defining the number of hours needed for training could be the use of guidelines containing specific educational objectives. The components of the course should be adapted to achieve the objectives and realistic times determined.

Practical exercises and practical sessions should be included in the RP training programmes for those directly involved in procedures. A minimum of a 1-2 hour practical session in a clinical installation is recommended for the simplest training programmes, while 20-40% of the total time scheduled may be devoted to practical exercises in more extensive courses.

Some examples of course content for different groups involved in medical exposures are given in Annex A. Radiologists and radiographers involved in paediatric radiology, screening mammography and computed tomography will require some specific training in related RP issues for these examinations. Specific objectives of courses for those working in paediatric radiology are given in the Annex B.

Table 1 Recommended RP training requirements for different categories of physicians and for dentists

Training Area	1 DR	2 NM	3 CD	4 MDX	5 MDN	6 MDA	7 DT	8 MD
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	l	l	l	l	l
Physical characteristics of the x-ray machines	m	l	m	m	l	l	l	-
Fundamentals of radiation detection	l	h	l	l	m	-	l	-
Fundamentals of radiobiology, biological effects of radiation	h	h	m	m	m	l	l	l
Risks of cancer and hereditary disease and effective dose	h	h	m	m	m	l	m	m
Risk of deterministic effects	h	m	h	m	l	l	l	l
General principles of RP	h	h	h	m	m	m	m	l
Operational RP	h	h	h	m	h	m	m	l
Particular patient RP aspects	h	h	h	h	h	m	m	l
Particular staff RP aspects	h	h	h	h	h	m	m	l
Typical doses from diagnostic procedures	h	h	l	l	l	l	l	m
Risks from fetal 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	10-15	10-15	5-10

DR – Diagnostic Radiology Specialists
NM – Nuclear Medicine Specialists
CD – Interventional Cardiologists
MDX – Other Medical Doctors using x-ray systems
MDN – Other Medical Doctors using radiopharmaceuticals
MDA – Other Medical Doctors assisting with fluoroscopy procedures such as anaesthetists and occupational health physicians
DT – Dentists
MD – Medical Doctors prescribing medical exposures and Medical Students

Level of knowledge
l – low level of knowledge
m- medium level of knowledge
h – high level of knowledge

Table 2 Recommended RP training requirements for different categories of healthcare professionals other than physicians or dentists

Training Area	9 RD NM	10 ME	11 HCP	12 NU	13 DN	14 RL	15 REG
Atomic structure, x-ray production and interaction of radiation	m	m	l	-	l	m	l
Nuclear Structure and radioactivity	m	m	-	-	-	m	l
Radiological quantities and units	m	m	l	l	l	m	m
Physical characteristics of the x-ray machines	m	h	m	-	l	l	l
Fundamentals of radiation detection	m	h	l	l	l	m	l
Fundamentals of radiobiology, biological effects of radiation	m	l	m	l	l	m	l
Risks of cancer and hereditary disease and effective dose	m	l	m	l	m	m	m
Risks of deterministic effects	m	-	l	l	l	l	m
General principles of RP	h	m	m	m	m	m	m
Operational RP	h	m	m	m	m	h	m
Particular patient RP aspects	h	m	h	m	m	-	m
Particular staff RP aspects	h	m	h	m	m	h	m
Typical doses from diagnostic procedures	h	l	l	-	l	-	l
Risks from fetal exposure	h	l	m	l	l	m	l
Quality control and quality assurance	m	h	l	-	m	l	m
National regulations and international standards	m	h	m	l	l	m	h
Suggested number of training hours	40-100	40-60	15-20	10-15	10-15	20-40	15-20

RDNM – Radiographers, nuclear medicine physicists and technologists, medical physics technologists
HCP – Healthcare professional involved in x-ray procedures
NU – Nurses assisting in procedures
DN – Dental nurses or assistants
ME – Maintenance engineers
RL – Radionuclide laboratory staff
REG – Regulators

Chapter 4: Training opportunities and suggested methodologies

Recommendations on the training for a selection of the categories of staff are made. This is followed by discussion of the focus for courses and suggestions about the individuals who would normally deliver the lectures and provide the training. Medical Physicists and other practitioners will give much of the RP training, but the medical and healthcare professionals who perform the radiation procedures will themselves have an important role. The themes of the method of delivery and the amount of training are developed and the need for the continuation of the training throughout the career of each individual as part of their continuing professional development is discussed.

4.1 Training Programmes

Training programmes need to be devised for a variety of different categories of medical and clinical staff with greater or lesser involvement with medical exposures.

In general the professions in categories 1 and 2 (Table 1), and 8 and 9 (Table 2) shall have formal education in RP and a formal examination system to test competency before the person is awarded a degree that entitles him/her to practice the profession. Education and training in RP is generally included as part of the dental degree for category 7 and may be included in specific training courses for dental nurses and dental care assistants (category 13).

For the other medical professionals in categories 3, 4 and 5 (Table 1), who are directly involved in procedures using radiation, the Commission is aware that there has been a considerable lack of education and training in a large part of the world and this needs to be corrected. The Commission recommends that the levels of education and training should be commensurate with the level of usage of radiation. Physicians, nurses and other healthcare professionals (categories 6 and 12) who are involved in radiation procedures but do not influence patient doses directly also need some training in RP.

The training needs in RP of Category 8, physicians who prescribe or request medical exposures, have remained largely unaddressed. It is unfortunate that RP training in the past has been linked with staff safety alone and issues of patient safety neglected. This category of personnel has a direct influence on patient safety and their training is important. Among the ICRP's principles of RP for justification, optimization and dose limitation, prescribing physicians have a significant role in the justification of medical examinations.

There are substantial differences in the numbers of medical exposures carried out in developed countries that might be regarded as having a similar level of health care. Although some of these variations may result from the use of more advanced procedures, more important contributory factors are differences in the level of control on the prescription and justification of the exposures and in the methods of delivery and funding of health care. Surveys have shown the level of knowledge that medical prescribers have of RP to be relatively poor. It has also been identified that few of those responsible for prescribing or performing examinations were familiar with the units used to specify the amount of radiation or the level of risk from common procedures. Therefore, the Commission recommends that a stronger emphasis is placed on transfer of knowledge of RP and its application to prescribers. This recommendation applies particularly to practitioners and medical specialists outside radiological specialisations. Since all medical professionals are likely to prescribe medical exposures, the Commission recommends that the basic education in RP for physicians (category 8) is given as part of the medical degree. The Commission also urges professional societies for relevant medical and RP staff to work together to develop continuing education in collaboration with healthcare providers.
The issue of transfer of knowledge for current medical prescribers is more difficult to address. In addition to the basic information on RP and radiation doses derived from the different procedures imparted to all medical students, international RP organisations and professional bodies are encouraged to facilitate this transfer to current prescribers by making appropriate material readily available and providing learning opportunities. Possible alternative methods might include distribution of printed material on RP, perhaps linked to booklets on referral guidelines, promotion of short E-learning packages aimed specifically at prescribers, and inclusion of lectures on RP in conferences for general medical practitioners and other medical specialties.

Maintenance engineers currently receive some training in RP, but this may be primarily focussed on RP of staff and training on RP for patients needs to be expanded, particularly in relation to digital radiology and new equipment.

The RP authorities should not confuse radionuclide laboratory workers (category 14) with other categories as the risk of radiation exposure is only for staff rather than both staff and patients. The RP requirements will be less for work with some radionuclides than with others and the amount of education and training needs to be judged on the basis of merit. In many cases there may be no need to have personnel monitoring. However, the Commission recommends definite training for laboratory staff, which may be of rather longer duration as staff members may be involved on a full time basis and some of the staff may be exempted from personnel monitoring because it is inappropriate for the type of radiation emitted from the radioactive material handled.

In some cases legislative control may make regulatory authorities exercise powers without due understanding and appreciation of practicalities. Thus staff from the enforcing authority (category 15) will also need to receive a limited amount of training. This should include aspects of optimisation of RP, and practical RP, in addition to dose levels and risks and is likely to require at least 15h-20h of instruction.

4.2 Delivery of Training

The objective of any training in a hospital setting is to acquire a) knowledge and b) skills, and there are many approaches to achieve this. Conventional training programmes utilise a structure that is curriculum based. There is a fundamental difference between training methodologies employed in non-medical subjects and in medical or rather clinical ones. While much of the training in sciences such as physics or biology is based on knowledge transmission, there is much greater emphasis in clinical training on imparting skills to solve day-to-day problems. A training programme in RP for healthcare professionals has to be oriented towards the type of training to which the target audience is accustomed. Lectures should deal with essential background knowledge and advice on practical situations, and the presentations should be tailored to clinical situations to impart skills in the appropriate context. Practical training should be in a similar environment to the one in which the participants will be practising and provide the knowledge and skills required for performing clinical procedures. It should deal with the full range of issues that the trainees are likely to encounter.

The primary trainer in RP should normally be a person who is an expert in RP in the practice with which he or she is dealing (normally a medical physicist). That means a person having knowledge about the clinical practice in the use of radiation, the nature of radiation, the way it is measured, how it interacts with the tissues, what kind of effects it can lead to, principles and philosophies of RP, and international and national guidelines. Since RP is covered by legislation in almost all countries of the world, awareness about national legislations and the responsibilities of individuals and organizations is essential.

The RP trainer, in many situations, may lack the knowledge of practicalities and thus talk from an unrealistic standpoint relating to idealised situations. The foremost point in any successful training is that the trainer should have a clear perception about the practicalities in the work that the training has to cover. It should deal with what people can practice in their day to day work. Many trainers in RP cannot resist the temptation of dealing with basic topics such as radiation units, interaction of radiation with matter, and even structure of the atom and atomic radiations in more depth than is appropriate. Such basic topics while being essential in educational programmes should be dealt with only to a level such that they make sense. A successful trainer will not be ego-centric about definitions which are purely for academic purposes but will be guided by the utility of the information to the audience. The same applies to regulatory requirements. The trainer should speak the language of users to convey the necessary information without compromising on the science and regulatory requirements. Health professionals who use radiation in day-to-day work in hospitals and impart the radiation dose to patients have knowledge about practical problems in dealing with patients who may be very sick. They understand problems with the radiation equipment they deal with, the constraints of time they have in dealing with large numbers of patients and the lack of radiation measuring and RP tools. Inclusion of lectures from practising clinicians in courses for categories 1-8, is strongly recommended. It may be useful for the RP trainer to be on hand during such lectures to comment and discuss any issues raised.

4.3 The Amount of Training

Another point to be considered is “How much training?” Most people and organizations follow the relatively easy route of prescribing the number of hours. This document gives some recommendations on the number of hours of education and training in Tables 1 and 2 which should act as a simple guideline rather than be applied rigidly. This has advantages in terms of implementation of training and monitoring the training activity, but is only a guide.

The issue of how much training is given should be linked with the evaluation methodology. One has to be mindful about the educational objectives of the training, i.e. acquiring knowledge and skills. Many programmes are confined to providing training without assessing the achievement of the objectives. Although some programmes have pre and post training evaluations to assess the knowledge gained, fewer training programmes assess the acquisition of practical skills. Using modern methodologies of online examination, results can be determined instantaneously.

It may be appropriate to encourage development of questionnaire and examination systems that assess the knowledge and skills, rather than prescribing the number of hours of training. Because of the magnitude of the requirement for RP training, it may be worthwhile for organizations to develop online evaluation systems. The Commission is aware that such online methods are currently available mainly from organizations that deal with large scale examinations. The development of self-assessment examination systems is encouraged to allow trainees to use them in the comfort of the home, on a home PC or anywhere where the internet is available. The Commission recommends that evaluation should have an important place.

The amount of training depends upon the level of radiation employed in the work and the probability of occurrence of over-exposures either to the patient or to staff. For example radiotherapy employs delivery of several gray of radiation per patient and a few tens of gray each day to groups of patients. Interventional procedures could also deliver skin doses in the range of a few gray to specific patients. The level of radiation employed in radiography practice is much lower than the above two examples and also the probability of significant over-exposure is lower, unless a wrong patient or wrong body part is irradiated. The radiation doses to patients from CT examinations are also relatively high and thus the need for RP is correspondingly greater. Another factor that should be taken into account is the number of times a procedure such as CT may be repeated on the same patient.

The practice of interventional cardiology involves high localised radiation doses to patients which may induce skin injuries. Therefore, it has been suggested that as the amount of radiation usage in cardiology grows to match that in interventional radiology, the standards of training on radiation effects, radiation physics and RP in interventional cardiology should also match those in interventional radiology.

4.4 Continuing Medical Education

With many medical schools using computer-based tools for their curricula as well as continuing education, it seems reasonable that the same approach could be employed for continuing education on radiation biology and radiation exposures in medicine. According to studies of medically-related online learning, there are several key factors to consider when designing material for this environment, three of which are: user requirements, available support by the developing organization, and adaptability to varying contexts

Chapter 5: Certification of the training

This chapter gives recommendations for the accreditation of organisations who give the training and advice on the certification of individuals. This includes information on the minimum requirements and the experience necessary for the course lecturers. The importance of obtaining feedback from participants about such courses is stressed in order to ensure that the training is suitable for their level of responsibility. The need to evaluate the knowledge gained from the training is discussed and examples of tests that could be used are given. It is recommended that universities and scientific societies collaborate in the organisation and accreditation of courses in order to ensure that appropriate training programmes are in place. The regulatory authorities will have a role in enforcement to encourage participation. International organisations can provide training material suitable for use on RP courses. The radiology equipment suppliers are well placed to play an important role in providing training relating to the effective use of new imaging systems.

5.1 Terminology

The medical and other healthcare professionals involved with medical exposures will need to attend formal accredited training courses. They may receive some components of training, particularly practical aspects from local centres and all the training received should be formally recorded. The formal courses will need to provide certification for the individuals trained.

In the context of this document, the terms **accreditation** and **certification** should be understood in the following way:

Accreditation - means that an organization has been approved by an authorised body to provide training to medical professionals on the RP aspects of the use of diagnostic or interventional radiation procedures in medicine. The accredited organization is required to meet standards that have been set by the authorised body for such training.

Certification - means that an individual medical or clinical professional has successfully completed training provided by an accredited organization on the RP aspects of the diagnostic or interventional procedures to be practiced by the individual. The individual must demonstrate competence in the subject matter in a manner required by the accredited body.

The standards that an accredited body must meet, and the manner in which a certified individual demonstrates competence will differ for different types of medical and clinical professionals, for different medical modalities, for different methods of training, and for different countries. This document does not intend to state the standards (for accreditation) or the methods to demonstrate competency (for certification), but provides guidance on the requirements.

5.2 Criteria for accreditation of organizations to provide training in RP

Minimum requirements:

The minimum requirements for accreditation of a training programme should take account of all the aspects involved. These should include enough administrative support, guarantees for the archiving of files, diplomas, etc. for a minimum number of years, enough didactic support (classroom, audio-visual support, etc.), teachers qualified in the topics to be taught and with experience in hospital medical physics, instrumentation for practical exercises, and availability of clinical installations for practical sessions. Locations where practical training is provided should be medical installations and not only laboratory or computer based simulation exercises.

Lecturers experience:

Lecturers in the training courses must have previous experience in RP in medical installations and in practical work in a clinical environment (normally a medical physicist). Trainers participating in these activities should meet the local requirements and demonstrate enough knowledge in the RP aspects of the procedures performed by the medical specialists involved in the training activity (e.g. to train cardiologists in RP, trainers should demonstrate previous practical experience in the RP aspects in cardiac laboratories). This experience may be obtained through observation and working with medical staff to optimize technique with regard to radiation dose, but it could require in some countries or regions, the organization of some activities to “train the trainers”. Attendance at lectures given by medical staff in RP courses and involvement in discussion during the courses may also be a useful component in the development of the trainer’s knowledge of techniques and practices.

Feedback from participants

Part of the follow up to maintain the accreditation of the organizations providing the training should be analyses of results from surveys of participant responses at the end of the training courses or training activities. These surveys should include aspects on the educational content, methodology, training material, practical work, duration of the training, and appropriateness of the lecturers to train in the specific topics.

5.3 Assessment to confirm successful completion of training

Training activities in RP should be followed by an evaluation of the knowledge acquired from the training programme. This will allow the certification of the training for the attendants (required in some countries by the Regulatory or Health Authorities), and verify and improve the quality and the appropriateness of the lectures and the training programme (audit of the training activity). In some training Institutions this audit is already a routine included in the quality management system.

Several evaluation methods can be considered. A simple test of multiple-choice questions may be used to evaluate the knowledge of the attendants and score some of the key aspects to identify the possible weaknesses in the training programmes. This method has the advantage of needing only 30-60 min and of allowing easy processing of the results with conventional computer software. Other classical evaluation methods such as written examinations, personal interview, automatic computer evaluation answering a set of questions, continuous assessment during the training programme, etc, can also be considered.

In some countries, a system for accrediting RP training programmes could be established at national or regional level. This process may be undertaken by the Regulatory or Health Authorities, with the help of Academic Institutions (Universities) and scientific or professional societies or by the academic institution or professional societies themselves. A register of accredited bodies should also be established.

Diplomas

Basic details should be given in the diplomas or certificates awarded to those attending a training programme in RP. This should include the centre conducting the training, the number of accredited training hours, process of accreditation: examination or other form of assessment, date of the training, and the name of the academic staff member(s) with responsibility for the training programme.

The state of knowledge of RP evolves, and the radiation techniques used develop, change and expand with time. Therefore certification in RP should be limited in time and renewal should require staff to participate in periodic refresher activities.

5.4 Roles of Various Organisations in RP Training

5.4.1 Universities, Training Institutions and Scientific Societies

Universities, Training Institutions and Scientific Societies may all have an important role in the promotion, organization and accreditation of the training activities in RP for medical exposures. They have the scientific knowledge, the experience, the infrastructure and the capability to select the best lecturers for such courses or seminars. The involvement of the relevant medical, radiology, nuclear medicine and medical physics scientific societies is a key factor in attracting different clinicians to the training programmes. These societies also have the capability to include refresher courses on RP in their scientific congresses with a high impact on the audience. Societies of radiology, nuclear medicine, interventional cardiology, vascular surgery, and other relevant specialties should offer and promote refresher courses on RP during major scientific congresses.

5.4.2 Regulatory and Health Authorities

Regulatory and Health Authorities have the capability of enforcing some levels of RP training and certification for those involved in medical exposures and to decide if a periodic update could be necessary for some groups of specialists. They also have the capacity to direct resources for these training programmes, to promote and coordinate the preparation of training material, and in some cases, to maintain a register of the certified professionals.

5.4.3 International Organizations

Some international organizations (e.g. ICRP, IAEA, WHO, EC, etc) can give recommendations on the content (including educational specific objectives) and number of hours of recognized training for the different professional groups and criteria for accreditation and certification. They can also produce or coordinate the preparation of training material and offer it at the WEB sites of the Organizations.

5.4.4 The Radiology Industry

The radiology industry has an important role in RP training for the new technologies. The industry should produce training material in parallel with the introduction of new x-ray or imaging systems, to promote the advances in RP of patients and to alert operators about the impact on patient doses if the new modalities are not used properly.

5.4.5 Organization and financing of the training

A critical issue that has to be taken into account by the regulatory bodies and health authorities when requiring certification in RP for medical professionals is the available infrastructure for organization of the training programmes and the financial requirements.

In some countries or regions, the cooperation of international organizations (e.g. IAEA, WHO, PAHO, EC, etc) could be helpful in initiating the activities through the organization of pilot courses and provision of training material to train the trainers. Later, RP training could be extended with the cooperation of universities, research centers and scientific or professional societies (e.g. medical physics, radiology, nuclear medicine, cardiology, etc).

Provision of financial support for training is a critical issue. If certification in RP is required for some practices (e.g. interventional cardiology), the certificate should be required before a professional is involved in practicing the specialty at a specific center. If the requirement is introduced in a country once the professionals are already working in the specialty, the different healthcare providers will need to make the resources available to train their own professionals in RP.

Summary of ICRP recommendations

1) This guidance should be considered by the cognizant regulators, health authorities, and professional bodies with responsibility for RP in medicine, as well as the industry that produces and markets the equipment used in medical x-ray and nuclear medicine procedures. This guidance should also be considered by universities and other academic institutions responsible for the education of professionals involved in the use of radiation in healthcare.

2) The physicians and other health professionals involved in the procedures that irradiate patients should always be trained in the principles of RP, including the basic principles of physics and biology (from ICRP-103).

3) There should be RP training requirements for physicians, dentists and other health professionals who request, conduct or assist in medical or dental procedures that utilise ionising radiation in diagnostic and interventional procedures, nuclear medicine and radiation therapy. The final responsibility for the radiation exposure lies with the physician providing the justification for the exposure being carried out, who therefore should be aware of the risks and benefits of the procedures involved (from ICRP-105).

4) Education and training, appropriate to the role of each category of physician, should be given at medical schools, during the residency and in focused specific courses. There should be an evaluation of the training, and appropriate recognition that the individual has successfully completed the training. In addition, there should be corresponding RP training requirements for other clinical personnel that participate in the conduct of procedures utilising ionising radiation or in the care of patients undergoing diagnoses or treatments with ionising radiation (from ICRP-105).

5) The need for adequate resources for the education and training in RP for future professional and technical staff who request or partake in radiological practices in medicine must be recognised. Training programmes should include initial training for all incoming staff, regular updating and retraining, and certification of the training (from ICRP-105).

6) It is important that the medical profession and other healthcare professionals understand the hazards from radiation in order to avoid the creation of unnecessary risks to the population as a whole. Lack of knowledge may result in more imaging tests being

requested when other non-radiation tests could be performed or when different lower dose imaging tests could be carried out. This is particularly important for CT scans which involve relatively high doses to patients.

7) The basic rule in prescription of any medical exposure is that it must be justified in terms of the influence it will have on the management of the patient and this should always be followed.

8) It is essential that courses on RP for medical professionals are perceived as relevant and necessary, and require only a limited commitment of time so that individuals can be persuaded of the advantages of attending.

9) RP education and training for medical staff should be promoted by the Regulatory and Health Authorities. RP education programmes should be implemented by the heath care providers and Universities and coordinated at local and national levels to provide courses based on agreed syllabuses and similar standards.

10) Scientific and professional societies should contribute to the development of the syllabuses, and to the promotion and support of the education and training. Scientific congresses should include refresher courses on RP, attendance at which could be a requirement for continuing professional development for professionals using ionizing radiation.

11) Professionals involved more directly in the use of ionizing radiation should receive education and training in RP at the start of their career, and the education process should continue throughout their professional life as the collective knowledge of the subject develops. It should include specific training on related RP aspects as new equipment or techniques are introduced into a centre.

12) Interventional procedures can involve high doses of radiation and the special radiological risk needs to be taken into account if deterministic effects on the skin are to be avoided. ICRP has proposed in its Publication 85 a second level of RP training for interventional radiologists and cardiologists, additional to that undertaken for diagnostic radiology.

13) Training in RP given to interventional cardiologists in most countries is limited. The Commission considers that provision of more RP training for this group should be a priority.

14) Education in RP needs to be given to prescribers of imaging techniques using ionizing radiation and to medical and dental students. Prescribers need to be familiar with referral criteria appropriate for the range of examinations that they are likely to request.

15) Training programmes need to be devised for a variety of different categories of medical and clinical staff with greater or lesser involvement with medical exposures.

16) Training for healthcare professionals in RP should be related to their specific jobs and roles.

17) Medical Physicists working in RP and diagnostic radiology should have the highest level of training in RP as they have additional responsibilities as trainers in RP for most of the clinicians.

18) Nurses and other healthcare professionals assisting in fluoroscopic procedures require knowledge of the risks and precautions to minimize their exposure and that of others.

19) Maintenance engineers currently receive some training in RP, but this may be primarily focussed on RP of staff. Training on RP of patients needs to be expanded, particularly in relation to digital radiology and new equipment.

20) The Commission recommends training for radionuclide laboratory staff related to their practice. This may be of rather longer duration as staff members may work with radionuclides on a full time basis.

21) Staff from the enforcing authority will need to receive a limited amount of RP training. This should include aspects of optimisation and practical RP.

22) Education and training in RP should be complemented by formal examination systems to test competency before the person is awarded a certification that entitles him/her to practice the activity using ionizing radiation.

23) The Commission recommends that a stronger emphasis is placed on transfer of knowledge of RP and its application to prescribers. This recommendation applies particularly to practitioners and medical specialists outside radiological specialisations. Since all medical professionals are likely to prescribe medical exposures, the Commission recommends that basic education in RP for physicians be given as part of the medical degree.

24) A key component in the success of any training programme is to convince the engaged personnel about the importance of the principle of optimization in RP so that they implement it in their routine practice. In order to achieve this, the training material must

be relevant and presented in a manner that the clinicians can relate to their own situation.

25) Priority topics to be included in the training will depend on the involvement of the different professionals in medical exposures. A useful orientation on some of the topics to be included in the education programme on RP for medical students could be the ICRP Publication “Radiation and your patient: a Guide for medical practitioners”.

26) A training programme in RP for healthcare professionals has to be oriented towards the type of training to which the target audience is accustomed. Practical training should be in a similar environment to the one in which the participants will be practising.

27) The Commission urges professional societies for relevant medical and RP staff to work together to develop continuing education in collaboration with healthcare providers.

28) The primary trainer in RP should normally be a person who is an expert in RP in the practice with which he or she is dealing (normally a medical physicist). That means a person having knowledge about the clinical practice in the use of radiation,

29) Lecturers in training courses must have previous experience in RP in medical installations and in practical work in a clinical environment. Trainers participating in these activities should meet the local requirements and demonstrate enough knowledge in the RP aspects of the procedures performed by the medical specialists involved in the training activity.

30) Training activities in RP should be followed by an evaluation of the knowledge acquired from the training programme. This will allow the certification of the training for the attendants. Basic details should be given in the diplomas or certificates awarded to those attending a training programme in RP.

31) Because of the magnitude of the requirement for RP training, it may be worthwhile for organizations to develop online evaluation systems. The Commission is aware that such online methods are currently available mainly from organizations that deal with examinations carried out on a large scale. The development of self-assessment examination systems is also encouraged.

32) With many medical schools using computer-based tools for their curricula as well as continuing education, it seems reasonable that the same approach could be employed for continuing education on radiation biology and radiation exposures in medicine.

33) The minimum requirements for accreditation of a training programme should take account of all the aspects involved. These should include enough administrative support, guarantees for the archiving of files, diplomas, etc. for a minimum number of years, enough didactic support, teachers qualified in the topics to be taught and with experience in hospital medical physics, instrumentation for practical exercises, and availability of clinical installations for practical sessions.

34) Part of the follow up to maintain the accreditation of the organizations providing the training should be analyses of results from surveys of participant responses at the end of the training courses or training activities.

35) Regulatory and Health Authorities have the capability of enforcing some levels of RP training and certification for those involved in medical exposures and to decide if a periodic update could be necessary for some groups of specialists. They also have the capacity to direct resources for these training programmes, to promote and coordinate the preparation of training material, and in some cases, to maintain a register of the certified professionals.

36) The radiology equipment manufacturers have an important role in RP training for new technologies. The radiology industry should produce training material in parallel with the introduction of new x-ray or imaging systems, to promote the advances in RP of patients. The equipment manufacturers should alert operators about the impact of their technologies on patient doses if the equipment is not used properly.

37) A critical issue that has to be taken into account by the regulatory bodies and health authorities when requiring certification in RP for medical professionals is the available infrastructure for organization of the training programmes and the financial requirements.

38) If certification in RP is required for some practices (e.g. interventional cardiology), the certificate should be required before a professional is involved in practicing the specialty at a specific center. If the requirement is introduced in a country once the professionals are already working in the specialty, the different healthcare providers will need to make the resources available to train their own professionals in RP.

References

ICRP, 2000a. Pregnancy and medical radiation. ICRP Publication 84. Ann ICRP 30(1).

ICRP, 2000b. Avoidance of radiation injuries from medical interventional procedures. ICRP Publication 85. Ann. ICRP 30(2).

ICRP, 2000c. Managing patient dose in computed tomography. ICRP Publication 87. Ann. ICRP 30(4).

ICRP, 2003a. Managing patient dose in digital radiology. ICRP Publication 93. Ann. ICRP 34(1).

ICRP, 2003b. Biological effects after prenatal irradiation (embryo and fetus). ICRP Publication 90. Ann ICRP 33(1/2).

ICRP, 2007a. Managing patient dose in multi-detector computed tomography. ICRP Publication 102. Ann. ICRP 37(1).

ICRP, 2007b. The 2007 recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37(2-4).

ICRP, 2007c. Radiological protection in medicine. ICRP Publication 105. Ann. ICRP 37(6).

UNSCEAR, 2000. Sources and Effects of Ionising Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation Report to the General Assembly with Scientific Annexes, United Nations, New York, NY.

Annexes

A. **Examples of suggested content for training courses.**

B. **Outline of specific objectives for paediatric exposures**

C. **Sources of training material.**

D. **References containing information of interest for the present report**

Annex A. Examples of suggested content for training courses

Examples of material that is recommended for inclusion in RP training relating to different types of medical exposures are given. The style and arrangement of the content varies, but different approaches are included to provide ideas and examples. This material will be in addition to the core content outlined at the end of Chapter 2.

A.1 Nuclear Medicine [Category 2 (Table 1) and 9 (Table 2)]

The following subjects should be included in the training and education regarding optimization of RP while administering radiopharmaceuticals to patients for purposes of diagnosis:

a. Justification of exposure, assuring a positive balance of benefit versus risk. Decisions should be based on scientific evidence and clinical experience that appropriate indications fulfill the above condition. Existing guidance, e.g. that prepared by the EU [EC, 200b] on indications for the use radiology procedures is a good example. Training should include information on the proportion of cases for which there is a possibility of using other imaging modalities, not exposing the patient to ionizing radiation.

b. Activities of radiopharmaceuticals used for specific diagnostic procedures, taking into account diagnostic reference levels.

c. Choice of the radiopharmaceutical from the standpoint of clinical indications

d. Organ and effective doses from different radiopharmaceutical examinations, and the effect of age (mSv/MBq).

e. Magnitude of risk as a function of age.

f. Choice of the radiopharmaceutical from the standpoint of magnitude of organ or tissue and effective dose

g. Choice of the radiopharmaceutical from the standpoint of economic considerations and availability (logistics).

h. Specific conditions for identification of pregnant patients and limitations placed on nuclear medicine diagnostics in pregnancy.

i. Modifications of activity to be administered, related to body mass and/or age (infants, children, adolescents).

j. Possible relaxation of the restriction on the amount of activity administered in oncology diagnostics.

k. Enhancing elimination of radiopharmaceuticals in order to reduce exposure.

l. Special protection of the fetus in nuclear medicine diagnostics of the mother; indications and contraindications for some procedures.

m. Nuclear medicine diagnostics in breast feeding females; temporal and/or complete abandoning of breast feeding as a function of the radiopharmaceutical and administered activity.

n. Action to be taken following misadministration

o. Exposure of volunteers in medical research, involving administration of radiopharmaceuticals – justification, conditions, requirements – ethical and legal.

p. Role of quality management and control in optimization of RP.

q. Requirement for adherence to authorized procedures.

r. Purpose and scope of audits – internal and external.

s. Recommendations for patients leaving nuclear medicine units after diagnostic procedures (very limited).

Additional RP aspects for Therapeutic Nuclear Medicine procedures

(This is included since nuclear medicine specialists will not usually attend RP courses for radiotherapy.)

a. Protection of patients undergoing therapy with radiopharmaceuticals and personnel preparing and administering radiopharmaceuticals.

b. Indications and adherence to authorized procedures. In research: acceptance by the ethical commission.

c. Clinical consequences of administration to a pregnant patient or a patient becoming pregnant in the weeks following a radionuclide therapy.

d. Periods for which female should avoid conception following radionuclide therapy.

e. Treatment of the mother with radionuclide therapy during pregnancy – dilemmas and limitations (exclusions).

f. Instructions to patients leaving the nuclear medicine unit after therapy with radiopharmaceuticals, particularly with ^{131}I iodides administered for treatment of thyroid cancer and hyperthyroidism.

Protection of personnel in nuclear medicine.

a. General rules for work with unsealed sources,

b. Special protection of hands (fingers) of radiopharmacists in labeling the ligands with high activities of ^{99m}Tc.

c. Monitoring of finger doses and protection while injecting patients for diagnostic purposes.

d. Potential risks of high doses from handling of therapeutic radionuclide (high energy beta emitters)

e. Risks from handling alpha-emitting radionuclides (where this is carried out)

f. Monitoring of exposure of the personnel dealing with high activities of ^{131}I.

g. Reasons for exclusion of pregnant workers from activity in controlled areas.

RP for personnel working in PET/CT

Overall objective: To become familiar with PET/CT technology, operational principles, safe design of facilities, dosimetry relating to staff and patients and the RP considerations relating to the use of this emerging technique.

a. Basic PET/CT technology including cyclotron, PET scanners, CT scanners and the merging of the two technologies into PET/CT

b. National and international requirements for medical exposure in PET/CT: responsibilities, training, justification, optimization of RP, diagnostic reference levels, and dose calculations

c. PET/CT procedures from the patient perspective, including patient preparation, administration of the radiopharmaceutical, imaging and discharge of the patient.

d. Factors that influence patient dose especially for paediatric and female patients.

e. Factors taken into account to minimize staff and member of the public doses when designing a new PET/CT and/or cyclotron facility, including shielding and layout issues

f. Protective equipment (and its efficacy) for reduction of staff doses in cyclotron and PET/CT facilities: from shielding to handling devices and personal protective equipment (PPE).

g. Personal and workplace monitoring; type of monitors, where, who and when to monitor, and decontamination procedures.

h. Staff doses received from PET/CT and how the basic principles of RP can be used to minimize them. This includes pregnant staff, visitors to the unit, and friends and relatives of the patient.

i. Aspects of a PET/CT facility: transport of the radionuclide, accounting, security of sources and waste management at the facility

j. Organization of RP programme, safety / risk assessment, designation of areas, the written procedures and local rules to ensure the safe operation of the PET/CT unit and production facilities and emergency procedures.

k. QC needed on the production of the radiopharmaceutical and optimization of RP with regard to each PET and CT scanner, and their combined usage.

A.2 Interventional Radiology (Category 1, Table 1)

(adapted from EC, 2000a)

Those working in interventional radiology should have the knowledge to do the following.

1. X-ray systems for interventional radiology.
    a. To explain the effect of high additional filtration (e.g. copper filters) on conventional x-ray beams.
    b. To explain the virtual collimation and the importance of wedge filters.
    c. To explain the operation of continuous and pulsed x-ray emission modes.
    d. To explain the benefits of the grid controlled x-ray tube when using pulsed beams.
    e. To explain the concept of road mapping.
    f. To explain temporal integration and its benefits in terms of image quality.
    g. To analyse changes in the dose rate when varying the distance from image intensifier to patient.
2. Dosimetric quantities specific for interventional radiology.
    a. To define the dose area product (DAP) (or kerma-area product) and its units.
    b. To define entrance dose and entrance dose rate in fluoroscopy.
    c. To understand the cumulative air kerma and its relationship to entrance dose.
    d. To discuss the correlation between entrance surface dose and DAP.
    e. To discuss the relationship between DAP and effective dose.
    f. To correlate the dose upon entry into the patient with the dose at the exit surface and the dose at the intensifier input surface.
3. Radiological risks in interventional radiology.
    a. To describe deterministic effects that may be observed in interventional radiology.

   b. To analyse the risks of deterministic effect induction as a function of the surface doses received by the patients.

   c. To be aware of the probability of these effects in interventional practice

   d. To analyse the relationship between received doses and deterministic effects in the lens of the eye.

   e. To be aware of the likely time intervals between irradiation and occurrence of the different deterministic effects, the required follow-up and control of patients.

   f. To analyse the stochastic risks in interventional procedures and their age dependence.

4. RP of the staff in interventional radiology.

   a. To comment on the most important factors which influence staff doses in interventional radiology laboratories.

   b. To analyse the influence of the x-ray C-arm positioning on occupational doses.

   c. To analyse the effects of using different fluoroscopy modes on occupational doses.

   d. To analyse the effects of using personal protection (e.g. leaded aprons, thyroid collars, lead glasses, gloves, etc.).

   e. To analyse the benefits and drawbacks of using articulated screens suspended from the ceiling.

   f. To understand the benefit of protecting the legs using lead rubber drapes.

   g. To understand the importance of the suitable location of personal dosimeters.

5. RP of patients in interventional radiology.

   a. To analyse the correlation between fluoroscopy time and number of images taken in a procedure and the dose received by patients.

   b. To analyse the effects of using different fluoroscopy modes on patient doses.

   c. To discuss the effects of the focus to skin distance and patient image intensifier input distance.

   d. To analyse the dose reductions attainable by modifying the image rate in digital acquisition or in cine.

   e. To give typical examples of patient entrance dose value per image in different procedures.

   f. To analyse the effect of using different magnifications on patient dose.

   g. To discuss the parameters which should be recorded in the patient history regarding (or with reference to data on) the doses received.

6. Quality assurance (QA) in interventional radiology.

   a. To discuss the difference between equipment performance parameters that usually do not downgrade with time and those that could require periodic control.

   b. To understand how image quality can be assessed.

   c. To discuss the importance of establishing simple criteria to compare doses at the patient or intensifier entrance in different situations.

   d. To note the importance in QA programmes of the periodic control of patient dose and its comparison with "diagnostic reference levels DRLs" (in this case, DRLs are not used in the strict sense of "diagnostic", but for the patient dose derived from the imaging part of the interventional procedure).

   e. Local and international rules for interventional radiology.

   f. To discuss the different national regulations which apply in interventional radiology installations.

   g. To describe the international recommendations for interventional radiology (WHO, IAEA, ICRP, EC, etc.).

   h. To provide information on the international recommendations concerning the limitation of high-dose modes.

7. Procedure optimization with regard to radiation dose in interventional radiology.

   a. To understand the influence of kVp and mA on image contrast and patient dose when using contrast media.

   b. To understand the different features available on radiology equipment.

   c. To note the importance of optimization of RP in interventional radiology radiation procedures.

   d. To discuss the importance of DRLs related to the patient dose at local, national and international levels.

   e. To analyse the importance of periodic patient dose control in each room.

   f. To discuss the possibility of using different C-arm orientations during long procedures in which the threshold for deterministic effects may be attained.

   g. To analyse the importance of recording the dose imparted to every patient.

A.3 Interventional Cardiology (Category 3, Table 1) (see also Rehani 2007)

Those working in interventional cardiology should have the knowledge to do the following.

1. X-ray systems for interventional cardiology.
   a. To explain the effect of high additional filtration (e.g. copper filters) on conventional x-ray beams.
   b. To explain virtual collimation
   c. To explain the operation of continuous and pulsed x-ray emission modes.
   d. To analyse changes in the dose rate when varying the distance from image intensifier to patient.
2. Dosimetric quantities specific for interventional cardiology.
   a. To define the dose area product (DAP) (or kerma-area product) and its units.
   b. To define entrance dose and entrance dose rate in fluoroscopy.
   c. To understand the cumulative air kerma and its relationship to entrance dose.
   d. To discuss the correlation between entrance surface dose and DAP.
   e. To discuss the relationship between DAP and effective dose.
3. Radiological risks in interventional cardiology.
   a. To describe deterministic effects that may be observed in interventional cardiology.
   b. To analyse the risks of deterministic effect induction as a function of the surface doses received by the patients.
   c. To analyse the relationship between received doses and deterministic effects in the lens of the eye.
   d. To be aware of the likely time intervals between irradiation and occurrence of the different deterministic effects, the required follow-up and control of patients.
   e. To analyse the stochastic risks in interventional procedures and their age dependence.
4. RP of the staff in interventional cardiology.
   a. To comment on the most important factors which influence staff doses in interventional cardiology laboratories.
   b. To analyse the influence of the x-ray C-arm positioning on occupational doses.

   c. To analyse the effects of using different fluoroscopy modes on occupational doses.

   d. To analyse the effects of using personal protection (e.g. leaded aprons, thyroid collars, lead glasses, gloves, etc.).

   e. To analyse the benefits and drawbacks of using articulated screens suspended from the ceiling.

   f. To understand the benefit of protecting the legs using lead rubber drapes.

   g. To understand the importance of the suitable location of personal dosimeters.

5. RP of patients in interventional cardiology.

   a. To analyse the correlation between fluoroscopy time and number of images taken in a procedure and the dose received by patients.

   b. To analyse the effects of using different fluoroscopy modes on patient doses.

   c. To discuss the effects of the focus to skin distance and patient image intensifier input distance.

   d. To analyse the dose reductions attainable by modifying the image rate in digital acquisition or in cine.

   e. To give typical examples of patient entrance dose value per image in different procedures.

   f. To analyse the effect of using different magnifications on patient dose.

6. Quality assurance (QA) in interventional cardiology.

   a. To discuss the difference between equipment performance parameters that usually do not downgrade with time and those that could require periodic control.

   b. To understand how image quality can be assessed.

   c. To note the importance in QA programmes of the periodic control of patient dose and its comparison with “diagnostic reference levels DRLs” (in this case, DRLs are not used in the strict sense of “diagnostic”, but for the patient dose derived from the imaging part of the interventional procedure).

   d. To discuss the different national regulations which apply in interventional cardiology installations.

   e. To provide information on the international recommendations concerning the limitation of high-dose modes.

7. Procedure optimization in interventional cardiology.

   a. To understand the different features available on cardiology equipment and their influence on patient dose and image quality.

   b. To note the importance of optimization of RP in interventional cardiology radiation procedures.

c. To discuss the importance of DRLs related to the patient dose at local, national and international levels.

d. To discuss the possibility of using different C-arm orientations during long procedures in which the threshold for deterministic effects may be attained.

e. To analyse the importance of recording the dose imparted to every patient.

A.4 Theatre fluoroscopy using mobile equipment [Category 4 (Table 1) and 11 (Table 2)]

Those involved in the use of mobile fluoroscopy equipment should have the knowledge to do the following. Topics recommended for those who assist in procedures (categories 6 and 12) are marked with an asterisk *.

1. X-ray systems.
    a. To explain the operation of continuous and pulsed x-ray emission modes.
    b. To analyse changes in the dose rate when varying the distance of the x-ray tube from the patient, and the x-ray tube to image receptor distance.
    c. To define the DAP, entrance dose and entrance dose rate and their units.
    d. To discuss the relationship between DAP and effective dose.
    e. To understand the stochastic risks in mobile fluoroscopy
2. RP of the staff.
    a. To analyse the influence of the x-ray C-arm positioning on occupational doses and the implications of using different C-arm orientations. *
    b. To understand the effects of using personal protection (e.g. leaded aprons, gloves, eyeglasses, thyroid protectors, etc.). *
    c. To understand the importance of the suitable location of personal dosimeters. *
3. RP of patients.
    a. To analyse the correlation between fluoroscopy time, number of images taken in a procedure and dose received by patients. *
    b. To analyse the effects of using different fluoroscopy modes on patient doses. *
    c. To understand the influence of the x-ray tube to skin distance on patient skin dose. *
    d. To discuss the parameters which should be recorded in the patient history relating to the doses received.
    e. To discuss the importance of reference levels related to the patient dose at local levels.

Annex B: Outline of specific educational objectives for paediatric radiology

The factors relating to images quality and patient dose are more complex in paediatric radiology because of the variations in patient size. They are also more critical because of the greater radiosensitivity of tissues of paediatric patients. Therefore more detail is included to remind those designing RP courses of the factors that should be included.

(1) General, equipment and installation considerations.

1.1 To justify the requirements concerning the power of the generator and its relationship with the need for short exposure times (3 milliseconds).

1.2 To explain the convenience of high frequency generators in relation to the accuracy and reproducibility of exposures in paediatrics.

1.3 To discuss the advantages and limitations of automatic exposure control (AEC) devices in paediatrics.

1.4 To justify the specific technical requirements of the AEC devices for paediatrics.

1.5 To explain that careful manual selection of exposure factors usually results in lower doses.

1.6 To explain the design aspects to be considered in paediatric x-ray rooms for improving the child's cooperation (control panel with easy patient visibility and contact, etc.).

1.7 To discuss the advantages and limitations of fast film-screen combinations and lower exposure factors for Computed Radiography.

1.8 To discuss the advantages of using low-absorbing materials in cassettes, tables, etc.

1.9 To analyse the limited improvement in image quality when using the anti-scatter grid in paediatrics and the increase in patient dose.

1.10 To analyse the specific technical requirements of anti-scatter grids for paediatrics.

1.11 To explain how the anti-scatter grid should be removable in paediatric equipment, particularly fluoroscopic systems.

1.12 To explain the convenience of using image intensifiers with high conversion factors for reducing patient dose in fluoroscopic systems.

1.13 To justify the convenience of specific kV-mA dose rate curves for automatic brightness control in fluoroscopic systems used for paediatrics.

1.14 To discuss the importance of using specific technical radiographic parameters for CT examinations in paediatrics (lower mAs than for adults, and lower kV in some cases).

1.15 To analyse the special problems with the use of mobile x-ray units in paediatrics.

1.16 To explain the advantages and disadvantages of under-couch and over-couch fluoroscopy units for paediatrics.

1.17 To discuss the advantages and role of pulsed fluoroscopy.

1.18 To compare conventional and digital equipment and the role/use of frame-grab technique in digital imaging.

1.19 To discuss value of cine playback (digital) and video playback (digital/conventional fluoroscopy) in screening examinations.

1.20 To discuss the role of additional tube filtration.

(2) Reduction of exposure

2.1 To analyse the most frequent causes of repeating films in paediatrics – reject analysis, audit and feedback.

2.2 To discuss how immobilisation can reduce the radiographic repeat rate.

2.3 To analyse the different immobilisation devices available for paediatric radiology to make application atraumatic. The role of simple aids such as sticky tape, sponge wedges and sand bags.

2.4 To explain how short exposure times can improve image quality and reduce the number of films repeated.

2.5 To explain the inconvenience of using mobile x-ray units for paediatrics and the difficulty in getting short exposure times.

2.6 To explain the importance of having radiographers with specific training in paediatric radiology.

2.7 To discuss the importance of gonad protection in paediatric radiology and value of having various sizes and types.

2.8 To analyse the importance of the collimation (in addition to the basic collimation corresponding to the film size) in paediatric patients, particularly window protection for hips and lateral collimation devices for follow-up scoliosis.

2.9 To discuss the importance of the correct patient positioning and collimation, particularly for excluding the gonads from the direct beam.

2.10 To discuss the importance of establishing whether adolescent girls might be pregnant when abdominal examinations are contemplated.

2.11 To discuss the fact that motion is a greater problem in children and could require specific adjustment of radiographic techniques.

2.12 To discuss the importance of a proper consultative relationship between the referring physician and the radiologist. Role of agreed protocols and diagnostic pathways.

2.13 To discuss some examples of radiological examination of questionable value in children (like some follow-up chest radiographs in simple pneumonia, abdominal radiographs in suspected constipation, etc.).

2.14 To explain that the repetition of a radiological examination in paediatrics should always be decided by the radiologist.

2.15 To discuss the convenience of using appropriate projections for minimizing dose in high risk tissues (PA projections should replace AP where possible for spinal examinations).

2.16 To discuss the convenience of having additional filters available to enable them to be easily changed (1 mm Al; 0.1 and 0.2 mm Cu should be available).

2.17 To discuss the value of having a dedicated paediatric room or complete sessions dedicated to paediatric radiology. Experienced staff who can obtain the child's confidence and cooperation in a secure and child-friendly environment are of paramount importance in reducing radiation doses in paediatrics.

2.18 To discuss the importance of having specific referral criteria, e.g. for head injury where the incidence of injury is low.

2.19 To discuss referral criteria for all x-ray examination of children, especially those which may be age-related, e.g. scaphoid not ossified, below age of 6 years, nasal bones cartilaginous below age of 3 years.

2.20 To discuss high kV techniques.

2.21 To explain the value of using long focus patient distances.

2.22 To explain the importance of using the light beam diaphragm to move the patient into position rather than screening during overcouch fluoroscopy procedures.

2.23 To discuss the need to adjust exposure factors for CT to suit the size of the patient and have an agreed method for selecting these factors.

2.24 To understand the influence of imaging using lower mAs and kV values for paediatric CT.

2.25 To discuss the role of audit and quality assurance in maintaining or improving image quality and dose.

(3) Risk factors

3.1 To discuss the fact that longer life expectancy in children means a greater potential for manifestation of possible harmful effects of radiation.

3.2 To consider that the radiation doses used to examine young children should generally be smaller than those employed in adults.

3.3 To explain that the risk factor for cancer induction in children is between 2 and 3 times higher than for adults, with emphasis on the developing breast and gonads and the more widespread distribution of red bone marrow in the developing skeleton.

3.4 To discuss the risk factor for genetic effects in children.

3.5 To relate with the natural occurrence of congenital abnormalities.

3.6 To relate with the natural incidence of cancer.

(4) Patient dosimetry. Reference dose values.

4.1 To explain the specific difficulties of measuring patient doses in paediatrics.

4.2 To discuss the dosimetric techniques available for patient dosimetry in paediatrics.

4.3 To discuss how patient dose values are related to patient size.

4.4 To analyse some typical patient reference dose values in paediatrics and their relation with patient size.

4.5 To analyse the reference dose values available for paediatrics.

4.6 To discuss how to use reference dose values in paediatric radiology.

(5) Protection of personnel and parents

5.1 To analyse the possibility of parents cooperating in the radiological examination of their children and the precautions to be taken.

5.2 To clarify that the parents' exposure in this situation can be considered as a medical exposure but that optimisation criteria must be applied.

5.3 To highlight that the parents or helpers should know exactly what is required of them.

5.4 To explain that pregnant women should not be allowed to help during paediatric examinations.

5.5 To explain the importance of using lead aprons and lead gloves (if the hands are in the direct radiation field) in these situations.

(6) International recommendations

6.1 To take into account the existence of relevant documents published by the ICRP, NCRP, EC and WHO concerning RP in paediatric radiology.

(7) Nuclear Medicine considerations

7.1 To explain the importance of having nuclear medicine technologists with specific training in paediatric radiology.

7.2 To discuss the fact that motion is a greater problem in children and could require specific adjustment of nuclear medicine techniques.

7.3 To discuss the importance of a proper consultative relationship between the referring physician and the nuclear medicine specialist.

7.4 To explain that the repetition of a nuclear medicine examination in paediatrics should always be decided by the nuclear medicine specialist.

7.5 To discuss how to determine the amount of activity to be administered to paediatric patients.

Annex C: Examples of some sources of training material

1. Power point slides for free download and direct use: http://rpop.iaea.org/RPOP/RPoP/Content/AdditionalResources/Training/1_TrainingMaterial/index.htm
2. Other educational resources:
   a. Material in the form of specific questions and answers in different diagnostic, interventional and therapeutic modalities at IAEA website on the radiological protection of patients: http://rpop.iaea.org
   b. In the Form of ask Expert at Health Physics website: http://hps.org/publicinformation/ate/faqs/
   c. RSNA: http://www.rsna.org/Education/index.cfm

<u>Web addresses of organizations having training material (in alphabetical order)</u>

ORGANIZATION	ACRONYM	WEBSITE
American Association of Physicists in Medicine	AAPM	http://www.aapm.org/ HTTP://WWW.AAPM.ORG/MEETINGS/VIRTUAL_LIBRARY/
European Commission	EC	http://ec.europa.eu/energy/nuclear/radiation_protection/publications_en.htm MARTIR PROJECT
European Society for Therapeutic Radiology and Oncology	ESTRO	http://www.estro.org/Pages/default.aspx e-TEST RADIOBIOLOGY
International Atomic Energy Agency	IAEA	http://rpop.iaea.org http://www.iaea.org/Publications/ http://www-pub.iaea.org/MTCD/publications/publications.asp
International Commission on Radiological Protection	ICRP	http://www.icrp.org/ educational material for Publication Nos. 84-85-86-87-93 http://www.icrp.org/educational_area.asp
International Radiation Protection Association	IRPA	http://www.irpa.net/ IRPA10, IRPA11 REFRESHER COURSES
Perry Sprawls website		HTTP://WWW.SPRAWLS.ORG/RESOURCES/#RADIATION
Office of Radiation Protection (Division of Environmental Health, USA)		http://www.doh.wa.gov/ehp/rp/factsheets/fsdefault.htm#introfs

ORGANIZATION	ACRONYM	WEBSITE
University of Washington		http://www.ehs.washington.edu/rsotrain/ http://courses.washington.edu/radxphys/PhysicsCourse.html
Image Gently		http://www.pedrad.org/associations/5364/ig/index.cfm?page=369

Annex D: References containing information of interest for the present report

CLASSIC, 2008. Classic K, Carlson S, Vetter RJ, Roessler G. Physician Education: Expansion of the Radiation Protection Practice. IRPA 12 Proceedings. Buenos Aires. Argentina. 2008.

EC, 1997. European Commission. Council directive 97/43 EURATOM on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure, and repealing directive 84/466 EURATOM. Official journal no. L180. Luxembourg, European Commission, 1997; 22–27. http://europa.eu.int/comm/energy/nuclear/radioprotection/legislation_en.htm

EC, 2000a. Guidelines for education and training in radiation protection for medical exposures, Radiation Protection 116, European Commission. Directorate General Environment, Nuclear Safety and Civil Protection. Luxembourg, 2000. Available at: http://europa.eu.int/comm/energy/nuclear/radioprotection/publication/doc/116_en.pdf.

EC, 2000b. Referral Criteria for Imaging. Radiation Protection 118. European Commission. Directorate General for the Environment. Luxembourg, 2000 (and updates from March 2008). Available at: http://ec.europa.eu/energy/nuclear/radioprotection/publication/118_en.htm

González AJ. The 12th congress of the international radiation protection association: strengthening radiation protection worldwide. Health Phys. 2009, 97, 6-49.

Hadley JL, Agola J, Wong P. Potential impact of the American College of Radiology Appropriateness Criteria on CT for trauma. *AJR* 2006; **186**: 937-942

Hendee W, Mettler M Jr, Walsh M, Guleria R, Craven C, Sia S, Durand-Zaleski I, Sheehan M, Czarwinski R, Rehani M, Le Heron J, Boal T, Zaknun J; International Atomic Energy Agency (IAEA). Report of a consultation on justification of patient exposures in medical imaging. Radiat Prot Dosimetry. 2009;135(2):137-44.

Klein LW, Miller DL, Balter S, Laskey W, Haines D, Norbash A, Mauro MA, Goldstein JA and members of the Joint Inter-Society Task Force on Occupational Hazards in the Interventional Laboratory, 2009. Occupational health hazards in the interventional laboratory: Time for a safer environment. Heart Rhythm. 6, 439-434.

MARTIN, 2003. Martin CJ, Dendy PP, Corbett RH. Medical Imaging and Radiation Protection for Medical Students and Clinical Staff.The British Institute of Radiology. UK. 2003.

Mettler, F. A. Jnr. Medical Radiation exposure in the US 2006. Preliminary results of NCRP SC-6-2 Medical Subgroup. Presented at Annual Meeting of NCRP, Crystal City, MD, USA April 2007.NAS/NRC, 2006.

Health risks from exposure to low levels of ionising radiation: BEIR VII Phase 2. Board on Radiation Effects Research. National Research Council of the National Academies, Washington, D.C.

NCRP, 2009. Ionizing radiation exposure of the population of the United States. NCRP Report No. 160. National Council on Radiation Protection and Measurements, Bethesda, Maryland.

PEER, 2005. Peer S, Faulkner K, Torbica P, Peer R, Busch HP, Vetter S, Neofotistou E, Back C, Bosmans H, Vano E. Relevant training issues for introduction of digital radiology: results of a survey. Radiat Prot Dosimetry. 2005;117(1-3):154-61.

PICANO, 2007. Picano E, Vano E, Semelka R, Regulla D. The American College of Radiology white paper on radiation dose in medicine:deep impact on the practice of cardiovascular imaging. Cardiovasc Ultrasound. 2007 Oct 31;5:37.

REHANI, 2005.Rehani, M.M., Ortiz-Lopez, P., 2005. Radiation effects in fluoroscopically guided cardiac interventions - keeping them under control. Int. J. Cardiol. 109, 147-151, 2006.

REHANI 2007. Rehani MM. Training of interventional cardiologists in radiation protection--the IAEA's initiatives. Int J Cardiol. 2007 Jan 8;114(2):256-60.

SHIRALKAR, 2003. Shiralkar S, Rennie A, Snow M, Galland RB, Lewis MH, Gower-Thomas K. Doctors' knowledge of radiation exposure: questionnaire study. BMJ. 2003 Aug 16;327(7411):371-2.

VANO 2001. Vano E, Gonzalez L, Faulkner K, Padovani R, Malone JF. Training and accreditation in radiation protection for interventional radiology. Radiat Prot Dosimetry. 2001;94(1-2):137-42.

VANO 2003. Vano E, Gonzalez L, Canis M, Hernandez-Lezana A. Training in radiological protection for interventionalists. Initial Spanish experience. Br J Radiol. 2003;76(904):217-9.

VANO, 2005. Vano E, Gonzalez L. Accreditation in radiation protection for cardiologists and interventionalists. Radiat Prot Dosimetry. 2005;117(1-3):69-73.

WAGNER, 2004. Wagner LK, Archer BR. Minimizing Risks from Fluoroscopy X-rays (Fourth Edition). Partners in Radiation Management, The Woodlands, TX, USA. 2004.

WHO, 2000. Efficacy and Radiation Safety in Interventional Radiology. WHO 2000. Geneva.