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Education and Training in Radiological Protection for Diagnostic and Interventional Procedures

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Published on behalf of the International Commission on Radiological Protection

Aims and Scope

The International Commission on Radiological Protection (ICRP) is the primary body in protection against ionising radiation. ICRP is a registered charity and is thus an independent non-governmental organisation created by the 1928 International Congress of Radiology to advance for the public benefit the science of radiological protection. The ICRP provides recommendations and guidance on protection against the risks associated with ionising radiation, from artificial sources widely used in medicine, general industry and nuclear enterprises, and from naturally occurring sources. These reports and recommendations are published approximately four times each year on behalf of the ICRP as the journal *Annals of the ICRP*. Each issue provides in-depth coverage of a specific subject area.

Subscribers to the journal receive each new report as soon as it appears so that they are kept up to date on the latest developments in this important field. While many subscribers prefer to acquire a complete set of ICRP reports and recommendations, single issues of the journal are also available separately for those individuals and organizations needing a single report covering their own field of interest. Please order through your bookseller, subscription agent, or direct from the publisher.

ICRP is composed of a Main Commission, a Scientific Secretariat, and five standing Committees on: radiation effects, doses from radiation exposure, protection in medicine, the application of ICRP recommendations, and protection of the environment. The Main Commission consists of a Chair and twelve other members. Committees typically comprise 10–15 members. Biologists and medical doctors dominate the current membership; physicists are also well represented.

ICRP uses Working Parties to develop ideas and Task Groups to prepare its reports. A Task Group is usually chaired by an ICRP Committee member and usually contains a number of specialists from outside ICRP. Thus, ICRP is an independent international network of specialists in various fields of radiological protection. At any one time, about one hundred eminent scientists and policy makers are actively involved in the work of ICRP. The Task Groups are assigned the responsibility for drafting documents on various subjects, which are reviewed and finally approved by the Main Commission. These documents are then published as the *Annals of the ICRP*.

The membership of the Task Group that prepared this report was:

Full Members
E. Vañó (Chairman)
M. Rosenstein
J. Liniecki
M. Rehani

Corresponding Members
C.J. Martin
R.J. Vetter

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Education and Training in Radiological Protection for Diagnostic and Interventional Procedures

Editor
C.H. CLEMENT

Authors
E. Vañó , M. Rosenstein, J. Liniecki, M. Rehani,
C.J. Martin, R.J. Vetter

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Education and Training in Radiological Protection for Diagnostic and Interventional Procedures

ICRP PUBLICATION 113

Approved by the Commission in October 2010

Abstract–The number of diagnostic and interventional medical procedures using ionising radiations is rising steadily, and procedures resulting in higher patient and staff doses are being performed more frequently. As such, the need for education and training of medical staff (including medical students) and other healthcare professionals in the principles of radiation protection is even more compelling than in the past.
The Commission has made basic recommendations for such education and training of these individuals in ICRP *Publications 103* and *105* (ICRP, 2007a,b). The present publication expands considerably on these basic recommendations with regard to various categories of medical practitioners and other healthcare professionals who perform or provide support for diagnostic and interventional procedures utilising ionising radiation and nuclear medicine therapy. It provides guidance regarding the necessary radiological protection education and training for use by:

- cognisant regulators, health authorities, medical institutions, 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 ionising radiation in health care.

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, radiography and other health care degrees, and for specialists such as radiologists, nuclear medicine specialists and medical physicists 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 ionising radiation modalities (e.g. computed tomography, fluoroscopy) that a medical practitioner or other healthcare or support professional will utilise 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 organisation 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 organisation 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 organisation for the diagnostic or interventional procedures to be practised by the individual. The individual must demonstrate competence in the subject matter in a manner required by the accredited body.

Keywords: Education; Training; Radiological protection; Health care; Medical

References

ICRP, 2007a. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2–4).

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

ICRP Publication 113

Guest Editorial

RADIOLOGICAL PROTECTION EDUCATION IN MEDICINE: AN ESSENTIAL BUT OFTEN MISSING ELEMENT

Publications 103 and *105* (ICRP, 2007a,b) clearly identify the two key elements in radiation protection: justification and optimisation. In medicine, in order to maximise benefit vs risk, one needs to know what the risk is, as well as the means with which to minimise it. Justification means ordering the right procedure for a specific clinical indication, and optimisation means using the correct dose.

The rapid increase in the uses and frequency of medical radiation procedures worldwide, and particularly in developed countries, is obvious. ICRP Committee 3 has produced a number of reports which have detailed the issue of stochastic effects and deterministic injuries from current medical technology, as well as methods to reduce risk.

The impetus for this report was the realisation that many of the millions of medical personnel using radiation-producing equipment or those ordering procedures involving ionising radiation have little knowledge or appreciation of potential radiation effects or optimisation methodology. With the rapid expansion of medical procedures, education and training in this area have become urgent priorities.

There are, however, two major hurdles to implementation. The first is the lack of consensus regarding what training should be given or is required, who should get it, or how much time is needed. Clearly, there is major variation in tasks, equipment, and complexity of radiation uses in medicine. Significant variation occurs as many countries have differing occupational titles and responsibilities. This means that educational programmes need to have many different levels as well as varying content. The second hurdle is the availability of knowledgeable faculty and training material.

Over the last two decades, as medicine has become more complex, those wanting to teach radiation protection have found it increasingly difficult to compete with other topics, given only a specific amount of time in the medical curriculum. The rapid changes in medical technology [from the advances in hybrid positron emission tomography/computed tomography (CT) and CT-guided radiotherapy] have also made it extremely difficult for a faculty member to keep up to date without having a central repository of easily available and expertly prepared material.

Contained in this report is a comprehensive approach to the education and training of radiological protection in medicine. It includes suggested content, objectives, management approaches, and the approximate time needed to educate and train a wide variety of medical professionals and staff. The report does not include specific training material; however, it does include the details of selected websites that offer free downloadable expert material that can be used by teachers and trainers. It remains the responsibility of professional bodies and competent authorities to devise and implement an appropriate programme of training and continuing education.

FRED A. METTLER JR, MD, MPH
ICRP MAIN COMMISSION MEMBER EMERITUS

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ICRP, 2007a. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2–4).
ICRP, 2007b. Radiological protection in medicine. ICRP Publication 105. Ann. ICRP 37 (6).

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PREFACE

Over the years, the International Commission on Radiological Protection (ICRP), referred to below as 'the Commission', has issued many reports providing advice on radiological protection and safety in medicine. ICRP *Publication 105* is a general overview of this area (ICRP, 2007b). These reports summarise the general principles of radiation protection, and provide advice on the application of these principles to the various uses of ionising radiation in medicine and biomedical research.

Most of these reports are of a general nature, and the Commission wishes to address some specific situations where difficulties have been observed. It is desirable that reports on such problem areas be written in a style which is accessible to those who may be directly concerned in their daily work, and that every effort is taken to ensure wide circulation of such reports.

A first step in this direction was taken at the Commission's meeting in Oxford, UK in September 1997. At that time, on the recommendation of ICRP Committee 3, the Commission established several Task Groups to produce reports on topical issues in medical radiation protection.

Several such reports have already appeared in print as *Publications 84, 85, 86, 87, 93, 94, 97, 98, 102*, and *112* (ICRP, 2000a,b,c,d, 2003, 2004, 2005a,b, 2007a, 2009) and *Supporting Guidance 2* (ICRP, 2001). The present report continues this series of concise and focused documents, and several more advisory reports are being prepared.

At their meeting in Albuquerque, New Mexico in 2003, the Commission decided that there would be value in developing guidance on radiological protection training and education for healthcare staff and students. Given other priorities at the time, work on this started in earnest in 2008.

The membership of the Task Group drafting this report was as follows:

E. Vañó (Chair)	J. Liniecki
M. Rosenstein	M.M. Rehani

The corresponding members were:

C.J. Martin R.J. Vetter

In addition, Jacques Lochard, ICRP Main Commission member, made an important contribution as critical reviewer.

The membership of Committee 3 during the period of final preparation of this report was:

E. Vañó (Chair)	M.M. Rehani (Secretary)	M.R. Baeza
J.M. Cosset	L.T. Dauer	I. Gusev
J.W. Hopewell	P.-L. Khong	P. Ortiz López
S. Mattsson	D.L. Miller	K. Åhlström Riklund
H. Ringertz	M. Rosenstein	Y. Yonekura
B. Yue		

This report aims to serve the purposes described above. In order to be as useful as possible for these purposes, its style differs in a few respects from the usual style of the Commission's publications in the *Annals of the ICRP*.

The report was approved for publication by the Commission in October 2010.

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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. Prevention of accidents to patients undergoing radiation therapy. ICRP Publication 86. Ann. ICRP 30 (3).

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

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

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ICRP, 2005a. Prevention of high-dose-rate brachytherapy accidents. ICRP Publication 97. Ann. ICRP 35 (2).

ICRP, 2005b. Radiation safety aspects of brachytherapy for prostate cancer using permanently implanted sources. ICRP Publication 98. Ann. ICRP 35 (3).

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

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

ICRP, 2009. Preventing accidental exposures from new external beam radiation therapy technologies. ICRP Publication 112. Ann. ICRP 39 (4).

ICRP, 2001. Radiation and your patient – a guide for medical practitioners. ICRP Supporting Guidance 2. Ann. ICRP 31 (4).

EXECUTIVE SUMMARY

(a) This guidance should be considered by regulators, health authorities, medical institutions, and professional bodies with responsibility for radiological protection (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 health care.

(b) 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 (ICRP, 2007a).

1. Training requirements for healthcare professionals

1.1. Training objectives

(c) 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.

(d) 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 ionising radiation 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 computed tomography scans which involve relatively high doses to patients.

(e) 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 or other regulated healthcare practitioner providing the justification for the exposure being carried out, who therefore should be aware of the risks and benefits of the procedures involved (ICRP, 2007b).

1.2. Medical referrers

(f) Education in RP needs to be given to referrers of imaging techniques using ionising radiation, and to medical and dental students. Referrers need to be familiar with referral criteria appropriate for the range of examinations that they are likely to request.

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

1.3. Medical and other healthcare professionals using radiation techniques

(h) Professionals involved more directly in the use of ionising 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. These staff should be registered on a continuing professional development scheme.

(i) 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. In ICRP *Publication 85* (ICRP, 2000) ICRP proposed a second level of RP training for interventional radiologists and cardiologists, in addition to the training recommended for other physicians who use X-rays. This should also be applied to other medical doctors conducting interventional fluoroscopy-guided procedures (e.g. vascular surgeons).

(j) Training in RP given to interventional cardiologists and other medical doctors conducting interventional fluoroscopy-guided procedures (e.g. vascular surgeons) in most countries is limited. The Commission considers that provision of more RP training for these groups should be a priority.

1.4. Medical physicists

(k) Medical physicists working in RP, nuclear medicine, and diagnostic radiology should have the highest level of training in RP as they have additional responsibilities as trainers in RP for most clinicians.

(l) Medical physicists should have proven knowledge and professional competency by way of professional certification or state registration before they are allowed to practice independently and to teach other medical professionals. They should also enter into a continuing professional development scheme.

1.5. Healthcare professionals working in an environment where radiation is used

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

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

(o) 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.

2. RP training and courses for non-radiation specialists

2.1. Course requirements

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

(q) Training activities in RP should be followed by an evaluation of the knowledge acquired from the training programme. This will allow the accreditation 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.

(r) Education and training in RP should be complemented by formal examination systems to test competency before the person is awarded certification.

(s) If certification in RP is required for some practices (e.g. interventional cardiology), the certificate should be obtained before a professional is involved in practising the specialty at a specific centre. 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.

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

2.2. Training programmes

(u) 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.

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

(w) A key component in the success of any training programme is to convince the engaged personnel about the importance of the principle of optimisation 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.

(x) 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 ICRP *Supporting Guidance 2*, Radiation and your patient: a Guide for medical practitioners (ICRP, 2001).

(y) 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 that in which the participants will be practising.

(z) The need for adequate resources for education and training in RP for future professional and technical staff that 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 accreditation of the training (ICRP, 2007b).

(aa) The minimum requirements for accreditation of a training programme should take account of all the aspects involved. These should include sufficient administrative support; guarantees for the archiving of files, diplomas, etc. for a minimum number of years; sufficient 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.

2.3. Lecturers and trainers

(bb) The primary trainer in RP should be a person who is an expert in RP in the practice with which he or she is dealing. This means a person who, in addition to having a detailed understanding of radiological protection, has knowledge about the clinical practice in the use of radiation.

(cc) Lecturers in training courses should be competent in RP; this is best demonstrated by professional certification, state registration, or an equivalent professional recognition system. They must also have experience in RP in medical installations and in practical work in a clinical environment (e.g. medical physicists, radiographers, etc.).

(dd) Training of those using radiation imaging equipment should be provided by a team involving radiological professionals, each of whom bring their specific knowledge.

(ee) Trainers participating in these activities should meet the local requirements and demonstrate sufficient knowledge in the RP aspects of the procedures performed by the medical specialists involved in the training activity.

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

2.4. Continuing education

(gg) Lectures and training programmes organised by professional bodies, universities, and other medical institutions will play a key role in enabling continuing professional development.

(hh) 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.

(ii) RP training should be updated when there is a significant change in radiology technique or radiation risk, and at intervals not exceeding 36 months.

3. Responsibilities for training provision

3.1. Roles of different organisations

(jj) RP education and training for medical staff should be promoted by the regulatory and health authorities, and by professional bodies and scientific societies. RP education programmes should be implemented by healthcare providers and universities, and co-ordinated at local and national levels to provide courses based on agreed syllabuses and similar standards.

3.2. Universities

(kk) Education and training should be given at medical schools during the medical studies and later, appropriate to the role of each category of physician, 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 diagnoses or treatments with ionising radiation (ICRP, 2007b).

3.3. Regulatory authorities

(ll) Regulatory and health authorities have the capability to enforce 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 co-ordinate the preparation of training material, and, in some cases, to maintain a register of the certified professionals.

(mm) Critical issues that have to be taken into account by the regulatory bodies and health authorities when requiring certification in RP for medical professionals are the available infrastructure for organisation of the training programmes and the financial requirements.

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

3.4. Professional bodies and scientific societies

(oo) Scientific and professional societies should contribute to the development of syllabuses to ensure a consistent approach, and to the promotion and support of 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 ionising radiation.

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

(qq) Professional bodies are encouraged to promote lectures on RP relevant to their specialty in medical congresses to facilitate continuing professional development.

3.5. Equipment manufacturers

(rr) The radiology equipment manufacturers have an important role to play 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.

(ss) Equipment manufacturers have a responsibility to develop and make available appropriate tools that are built into radiological equipment to facilitate easy and convenient determination and recording of exposure with reasonable accuracy.

(tt) Equipment manufacturers should ensure that maintenance engineers with responsibilities for imaging systems and clinical applications specialists have training in RP of patients. It is important that they understand how the settings of the x-ray systems and adjustments that they may make influence the radiation doses to patients.

4. References

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

ICRP, 2001. Radiation and your patient – a guide for medical practitioners. ICRP Supporting Guidance 2. Ann. ICRP 31(4).

ICRP, 2007a. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37(2–4).

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

1. INTRODUCTION

(1) The number of diagnostic and interventional medical procedures using ionising radiations is rising steadily, and procedures requiring higher patient doses are being performed more frequently. As such, the need for medical staff and other healthcare professionals to be educated in radiological protection (RP) is more compelling. However, in most countries, RP training, particularly for medical professionals, is deficient. In this chapter, the need for education of different groups, including those who refer for 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 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 delivery of education and training for medical staff and other healthcare professionals involved in the use of ionising radiation for diagnostic [radiography, fluoroscopy, computer tomography (CT) and nuclear medicine], interventional (fluoroscopically guided), and nuclear medicine therapy procedures.

1.1. Need for a greater awareness of radiological protection

(2) Many people are exposed to ionising 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 utilising ionising 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 (ICRP, 2000).

(3) In order to avoid unnecessary risk, radiological procedures should only be undertaken when they are expected to influence patient management. In order to ensure that all medical radiation procedures are justified, awareness needs to be raised about both the benefits and the risks of such procedures among those clinicians who request them. 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, 2000b). Therefore, particular attention to the management (reduction) of doses to both patients and professionals in interventional procedures is important.

(4) Optimisation 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 these personnel are essential to ensure reasonable RP of patients and workers.

(5) 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.

(6) The present report makes recommendations on training in RP for medical practitioners, radiographers, physicists, dentists, technologists, and other healthcare professionals who perform or provide support for diagnostic and interventional procedures utilising ionising radiation. It sets out guidance that should be considered by the regulators, health authorities, medical institutions, 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 health care. Guidance is given on education requirements in RP for those who refer for diagnostic and interventional procedures, and medical and dental students who will refer in the future, to aid in the selection of content for medical degrees and postgraduate medical studies. This report does not address radiation therapy, except as it concerns some aspects of nuclear medicine therapy.

(7) One of the principal unresolved issues for accomplishing education and training in RP for medical professionals is the 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 only require limited time commitment so that individuals can be persuaded of the advantages of attending. The use of e-learning structures would allow professionals to complete training at convenient times, and to pace their learning according to their previous knowledge. 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 radiological protection

(8) In the context of this report, education and training in RP should be understood as follows.

(9) The term '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. Specific training in RP should be guaranteed in radiographers' education. More in-depth education on these topics for other specialists, such as radiologists and medical physicists, should be given during postgraduate degrees.

(10) The term 'training' refers to instruction and practice relating to the ionising radiation modalities (e.g. CT, fluoroscopy) used by the individual in medical

practice. It should include imparting of specialist knowledge required for optimisation of RP, and should involve a significant element of practical skills.

(11) RP education and training for medical staff should be promoted by regulatory and health authorities. RP education programmes should be implemented by the healthcare providers and universities, and co-ordinated at local and national levels to provide courses based on agreed syllabuses and similar standards. Scientific and professional societies have a major role to play in ensuring the delivery of consistent education and training. They should contribute to the development of syllabuses, and to the promotion and support of 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 ionising radiation.

(12) Since almost all physicians and dentists will need to request medical exposures, it is appropriate to include basic RP education in medical and dental degrees. The inclusion of RP in the syllabuses of medical and dental schools requires intersector co-operation at local and national level (e.g. universities, ministries of education). The definition of a referrer is a medical doctor, dentist, or other health professional who is entitled to refer individuals for medical exposures to a practitioner, in accordance with national requirements. The referring clinician forms part of the justification process because he/she has full knowledge of the patient's clinical history, although the final decision regarding justification of the exposure is made by the practitioner, who takes clinical responsibility for the exposure because of his/her greater depth of knowledge and training in RP and imaging techniques. In situations where the justification of referrals is not confirmed by a radiation specialist, the referrer will need to have substantially more training in radiological techniques and radiation risks in order to enable them to become a practitioner.

(13) Professionals involved more directly in the use of ionising 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 medical devices or techniques are introduced into a centre.

(14) Medical physicists have a central role in all education and training programmes on RP as they know about the nature and type of radiation, and the RP requirements for the application of ionising radiation. Medical physicists, radiographers, and radiologists should work closely with their medical specialist colleagues in establishing and conducting training programmes.

(15) The radiological equipment manufacturers have an important role to play in the optimisation 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. Equipment manufacturers also have a responsibility to develop and make available appropriate tools that are built into radiological equipment to facilitate easy and convenient determination and recording of exposure with reasonable accuracy.

1.3. Knowledge that radiological protection education and training should provide

1.3.1. Potential health effects from radiation exposure

(16) The purpose of managing the radiation dose in diagnostic and interventional procedures is to avoid deterministic health effects, and to keep the probability of stochastic health effects of ionising radiation as low as reasonably achievable, taking into account the needs of the medical procedure.

(17) 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 only be clinically observable if the radiation dose is above a certain threshold. These thresholds can be reached in localised regions of a patient's skin as a result of complex fluoroscopically-guided interventional procedures (ICRP, 2000b). At present, it is 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.

(18) 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. This can 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 ionising 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, 2007b).

Effects on the embryo and fetus

(19) 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, 2007b). 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 third week to the eighth week after conception (organogenesis). Damage to the developing central nervous system may occur in the early fetal period, particularly from the eighth week to the 15th week after conception, and to a lesser extent between the 16th week and the 25th week after conception. These deterministic effects have relatively high threshold radiation doses ($>$100 mSv) and should not occur for optimised diagnostic procedures. With regard to stochastic effects, there is an increase in the probability of leukaemia 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; as such, they may occur after low doses, although the probability is small.

(20) If staff are properly educated and trained in RP, doses from diagnostic procedures and, for the most part, fluoroscopically-guided interventional procedures should not approach the threshold for deterministic effects. The probability of

stochastic effects cannot be eliminated totally, so the appropriate approach is only to refer for and conduct procedures when they are justified, and to take all reasonable steps to manage the patient and staff doses from such procedures to ensure optimisation of RP.

1.3.2. Examples of the need to manage radiation dose

(21) A needs assessment should be carried out to identify learning objectives for every group. Some practical examples of the need for education and training in RP are given below.

(22) 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.

(23) 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.
- Interventional procedures are complex and demanding. They tend to be very operator dependent with each centre having slightly different techniques. Individuals performing the procedures must be adequately trained in both the clinical technique and in knowledge of radiation protection. A second, specific, level of training in radiation protection, additional to that undertaken for diagnostic radiology, is essential.
- 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.

(24) With regard to CT procedures (ICRP, 2000c, 2007a):

- 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.
- CT with single photon emission CT (SPECT) in SPECT/CT scanners and positron emission tomography (PET) in PET/CT scanners often combine a high-dose nuclear medicine procedure with a CT scan and so result in particularly high doses.

- 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 radiographer should be aware of the possibilities for managing patient doses by adapting the technical parameters to each patient and the specific procedure, with particular 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 radiographers understand the relationship between patient dose and image quality, and that not all diagnostic tasks require high-quality images.
- Radiographers 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.
- Operators of SPECT/CT and PET/CT scanners should take into account that the CT component is often primarily for anatomical identification of the site where the radiopharmaceutical is localised, so lower levels of image quality and lower dose options may be appropriate.

(25) 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.
- Industry should co-operate closely with radiologists, radiographers, and medical physicists to develop procedures and optimise protocols in order to minimise doses given to patients.

(26) With regard to doses to operators (ICRP, 2000a,b):

- If a medical professional participating in procedures utilising 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 reduce the risk of radiation injury.
- Different positions adjacent to the patient couch expose staff to higher or lower dose rates. Staff should be educated about how dose rates vary adjacent to interventional x-ray equipment.
- In *Publication 103* (ICRP, 2007b, Para. 249), the Commission stated 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 ICRP *Publications 103* and *105*

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

(28) *Publication 103*

> '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' (ICRP, 2007b, Para. 328).

(29) *Publication 105*

> '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' (ICRP, 2007c, Para. 106).
>
> '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' (ICRP, 2007c, Para. 107).

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.

> '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' (ICRP, 2007c, Para. 108).

> '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' (ICRP, 2007c, Para. 110).

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

1.5. Training in interpretation of images

(31) An important element that determines if a medical exposure is justified is whether the images obtained can provide the information required for the clinical 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. However, 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 report, but is mentioned because interpretation represents an important aspect of the justification process for any clinical exposure.

1.6. 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.

2. HEALTHCARE PROFESSIONALS TO BE TRAINED

(32) 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 them into account when requesting medical exposures. When dealing with pregnant patients, the correct balance must be achieved between effective clinical benefit, 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 appropriate amount of education and training in RP, 15 categories of healthcare professionals have been identified: eight representing different groups of physicians and dentists, and seven representing other healthcare professionals involved in the use of radiation. Recommendations on training for the different categories are discussed, including those for medical students and physicians who refer for medical procedures using ionising radiation.

2.1. Consequences of failure to deliver training in radiological protection

(33) The rapid expansion in medical procedures using radiation over 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 ionising radiation imaging tests being requested when other non-radiation tests could be performed, or when different lower-dose imaging tests could be carried out.

(34) In addition to over-prescription, there are many other consequences that can arise from poor awareness and understanding of radiation hazards by medical practitioners. In pregnant women, a number of physicians have recommended termination of pregnancy following any medical imaging examination. This practice 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.

(35) Those directly involved in exposures need RP training to ensure that procedures are optimised 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 also increase doses significantly; medical professionals need to be trained to use this technology effectively. Experience has shown that many radiology departments have made the transition to digital equipment, but patient doses have not reduced and some have increased measurably. *Publication 93* (ICRP, 2003) is a

dedicated report on the proper management of radiation dose in digital radiology, and includes Section 2 on training needs for radiologists and radiographers, and Annex C with an outline for education and training.

(36) Several medical specialties using ionising radiation as part of their clinical work need to have some knowledge of RP. The level of education and training will differ 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 need to be trained.

2.2. Categories of medical and healthcare professionals requiring education and training

(37) 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.

- Category 1 – radiologists: physicians who are going to take up a career in which the major component involves the use of ionising radiation in radiology. This includes those performing interventional radiology procedures.
- Category 2 – nuclear medicine specialists: 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 including PET or PET/CT.
- Category 3 – cardiologists and interventionalists from other specialties: physicians whose occupation involves a fairly high level of ionising radiation use, although it is not the major part of their work, such as interventional cardiologists. The specialties involved vary around the globe, but may include vascular surgeons and neurosurgeons.
- Category 4 – other medical specialists using x rays: physicians whose occupation involves the use of x-ray fluoroscopy in urology, gastroenterology, orthopaedic surgery, neurosurgery, or other specialties.
- Category 5 – other medical specialties using nuclear medicine: physicians whose occupation involves prescription and use of a narrow range of nuclear medicine tests.
- Category 6 – other physicians who assist with radiation procedures: physicians such as anaesthetists who have involvement in fluoroscopy procedures directed by others, and occupational health physicians who review records of radiation workers.
- Category 7 – dentists: dentists who take and interpret dental x-ray images routinely.

- Category 8 – medical referrers: physicians who request examinations and procedures involving ionising radiations, and medical students who may refer for examinations in the future.
- Category 9 – medical physicists: medical physicists specialising in RP, nuclear medicine, or diagnostic radiology.
- Category 10 – radiographers, nuclear medicine technologists, and x-ray technologists: individuals who are going to take up a career in which a major component is involved with operating and/or testing x-ray units, including those carrying out some tests on a range of x-ray units in different hospitals and operating radionuclide imaging equipment.
- Category 11 – maintenance engineers and clinical applications specialists: individuals with responsibilities for maintaining the x-ray and imaging systems (including nuclear medicine), or advising on the clinical application of such systems.
- Category 12 – other healthcare professionals: other professionals such as podiatrists, physiotherapists, and speech therapists who may be involved in the use of radiology techniques to assess patients.
- Category 13 – nurses: nursing staff and other healthcare professionals assisting in diagnostic and interventional x-ray fluoroscopy procedures, radiopharmaceutical administration, or the care of nuclear medicine patients.
- Category 14 – dental care professionals: dental hygienists, dental nurses, and dental care assistants who take dental radiographs and process images.
- Category 15 – chiropractors: chiropractors and other healthcare professionals who may refer for, justify, and take radiographic exposures.
- Category 16 – radiopharmacists and radionuclide laboratory staff: radiopharmacists and individuals who use radionuclides for diagnostic purposes such as radioimmunoassay.
- Category 17 – regulators: individuals with responsibility for enforcing ionising radiation legislation.

2.3. Training for healthcare professionals

2.3.1. Medical professionals involved directly with the use of radiation

(38) Diagnostic radiologists and nuclear medicine specialists in some countries are given an extensive formal training programme and certification during their residency, typically involving 30–50 h of 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.

(39) 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. In *Publication 85* (ICRP, 2000), ICRP proposed a second level of RP training for interventional radiologists and cardiologists:

> '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' (ICRP, 2000, Para. 50).

(40) Training in RP given to interventional cardiologists and those directing cardiac CT in most countries is limited. The Commission considers that provision of more RP training for this group should be a priority.

(41) Significantly less training is given to other medical specialists such as vascular surgeons, urologists, endoscopists, and orthopaedic surgeons before they direct fluoroscopically-guided invasive techniques. The times allocated for this RP training depend on previous knowledge 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.

(42) Other medical specialties not directly operating the x-ray units or administering radionuclides but closely involved with the specialist operator, such as anaesthetists, will require some training on the basic aspects of RP [e.g. 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. E-learning programmes incorporating videos and other technical aids can enhance the learning experience.

(43) 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, if they have particular pathologies, or if they are pregnant.

2.3.2. Medical and healthcare professionals prescribing diagnostic exposures and medical students

(44) The vast majority of medical professionals will need to refer for diagnostic examinations and procedures involving the use of ionising radiations. A similar level

of education in RP needs to be given to present and future potential referrers with particular emphasis on paediatrics.

(45) The information that these groups need to know is the basis of biological effects of ionising 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, 2000).

(46) Referrers 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, should be 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.

(47) Education in RP for future referrers could be included in a dedicated short course or integrated into education on the fundamentals of diagnostic techniques with ionising radiation in the medical degree.

(48) 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. In some countries, nurse practitioners and other healthcare professionals are permitted to practice independently and refer for a limited range of medical exposures, and these individuals should be required to have the same training and certification as those in Category 8.

2.3.3. Other healthcare professionals

(49) Training for healthcare professionals in RP will be related to their specific jobs and roles. Medical physicists working in RP and other radiation specialists should have the highest level of training in RP as they have additional responsibilities as trainers in RP for most clinicians.

(50) Radiographers, nuclear medicine technologists, and x-ray technologists will all require substantial training in RP as this represents a core aspect of their work and they will contribute to the training of others.

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

(52) Nurses and other healthcare professionals assisting in fluoroscopic procedures require knowledge of the risks and precautions to minimise their exposure and that of others. There is evidence of a risk of lens opacity among those working in cardiac catheterisation laboratories where RP has not been optimised.

2.4. References

EC, 2000. Referral Criteria for Imaging. Radiation Protection 118. European Commission, Directorate General for the Environment, Luxembourg, 2000 <http://ec.europa.eu/energy/nuclear/radioprotection/publication/doc/118_en.pdf>. (accessed March 1, 2011).

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

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

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.

3. PRIORITIES IN TOPICS TO BE INCLUDED IN TRAINING

(53) 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. The 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 amount of training and the subject matter that is more or less important for each group are given in Tables 3.1 and 3.2.

3.1. Objectives of training

(54) A key component in the success of any training programme is to convince the engaged personnel about the importance of the principle of optimisation 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.

(55) 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 referrers. However, 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.

(56) Deterministic effects can be perceived readily by those with a basic understanding of RP principles, as this is a simple process of cell killing. 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 tissues.

(57) The mechanisms involved in the induction of stochastic effects, on the other hand, and the probability 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.

(58) 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

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

Training area	Category							
	1 DR	2 NM	3 CDI MDI	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	m	m	l	l	l
Physical characteristics of x-ray machines	m	l	m	m	l	l	m	–
Fundamentals of radiation detection	m	h	l	l	m	–	l	–
Principle and process of justification	h	h	h	h	h	h	h	m
Fundamentals of radiobiology, biological effects of radiation	h	h	m	m	m	l	l	l
Risks of cancer and hereditary disease	h	h	m	m	m	l	m	m
Risk of deterministic effects	h	h	h	m	l	l	m	l
General principles of RP including optimisation	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	h	l
Particular staff RP aspects	h	h	h	h	h	m	h	l
Typical doses from diagnostic procedures	h	h	m	m	m	m	m	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	8– 12	10–15	5– 10

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

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

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

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

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. 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 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.

(59) 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 intra-uterine 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 *Publication 84* (ICRP, 2000).

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

3.2. Course topics for medical students and medical practitioners

(61) The challenge for medical education is to identify the information that physicians need to know for everyday practice. However, courses on RP in medical degrees are limited, 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-ray images in the medical degree.

(62) A useful orientation on some of the topics to be included in the education programme on RP for medical students is ICRP *Supporting Guidance 2*, Radiation and your patient: a Guide for medical practitioners (ICRP, 2001).

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

- properties of ionising radiation (x rays, beta particles and electrons);
- how to quantify the amount of radiation, and radiological quantities and units;
- radiation mechanisms of interaction with biological materials;

- classification of radiation effects: deterministic and stochastic;
- magnitude of the risks for cancer and hereditary effects;
- the use of radiation in diagnostic radiology, CT, interventional radiology, nuclear medicine, PET/CT, and radiotherapy;
- recommendations and legal requirements applying to medical, occupational, and public exposure;
- principles and methods of protection of patients and staff in diagnostic and interventional radiology;
- principles of justification of radiological procedures, optimisation of RP, and dose limitation;
- typical doses from medical diagnostic procedures;
- application of risk in the justification process;
- the importance of the principle of optimisation and the use of diagnostic reference levels in managing the exposure of patients;
- the appropriate role of effective dose in medicine;
- doses that can induce deterministic effects (interventional procedures);
- the information that different imaging techniques can provide and the relative usefulness of the alternative techniques;
- how to obtain guidance on referral criteria for different examinations;
- the principle of only carrying out diagnostic radiological investigations when they will influence patient management;
- the risks from radiation therapy, nuclear medicine, and diagnostic and interventional radiology;
- when children and pregnant women require special consideration in diagnostic and interventional procedures;
- risks to pregnant women (as patients or staff) and fetuses involved in nuclear medicine (including therapy), and diagnostic and interventional radiology;
- when patients treated with radiation or undergoing diagnostic nuclear medicine or PET examinations can endanger other people;
- knowledge and skills for counselling patients on radiation risks before and after medical exposures;
- commonly asked questions and suggested answers;
- national and international legislation, guidelines, and institutions; and
- legal issues and litigation.

3.3. Training recommendations for various categories of medical staff

(64) 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 3.1 and 3.2, respectively. These have been developed based on existing guidelines, such as those of the European Commission (EC, 2000). 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.

(65) It is recognised that the division of tasks between professionals varies in different countries. Thus training requirements will vary depending on the roles of individuals, and the amount of education and training should be determined by an assessment of the need and identification of specific training objectives. The groups identified in Tables 3.1 and 3.2 are exemplars. An individual may be part of more than one category. For example, an interventional cardiologist who also refers for and evaluates nuclear cardiology examinations must meet requirements of both Categories 3 and 5, although there will be common elements that only need to be covered once.

(66) 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 have occurred from radiological practices, as well as some aspects on ethical issues. A useful approach in development of the structure for training courses and material may be to create separate modules relating to the different roles of referrer, operator, and practitioner.

(67) The number of hours indicated in the tables 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.

(68) Medical physicists 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 optimisation of RP and delivering the training lectures. This group will need to maintain their competence to ensure that they keep up to date with 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.

(69) 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 should be determined.

(70) Practical exercises and practical sessions should be included in the RP training programmes for those directly involved in procedures. A practical session in a clinical installation lasting at least 1–2 h 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.

(71) 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 CT will require some specific training in related RP issues for these examinations. Specific training objectives for those working in paediatric radiology are given in Annex B.

3.4. References

EC, 2000. 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.

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

ICRP, 2001. Radiation and your patient – a guide for medical practitioners. ICRP Supporting Guidance 2. Ann. ICRP 31 (4).

4. TRAINING OPPORTUNITIES AND SUGGESTED METHODOLOGIES

(72) Recommendations on training for a selection of staff categories are made in this chapter. 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 training throughout the career of each individual as part of their continuing professional development is discussed.

4.1. Training programmes

(73) 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.

(74) In general, the professions in Categories 1 and 2 (Table 3.1), and 9 and 10 (Table 3.2) shall have formal education in RP and a formal examination system to test competency before the person is awarded a degree. Formal training in RP with proven professional competency through professional certification is needed in addition to education before he/she is qualified and entitled to practice the profession and teach others to practice. 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 healthcare professionals (Category 14).

(75) For the other medical professionals in Categories 3, 4, and 5 (Table 3.1), and other healthcare professionals in Category 12 (Table 3.2), 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 13) who are involved in radiation procedures but do not influence patient doses directly also need some training in RP.

(76) The RP training needs of Category 8 professionals, physicians who refer for 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 have been neglected. This category of personnel has a direct influence on patient safety and their training is important. Among ICRP's principles of RP for justification, optimisation, and dose limitation, prescribing physicians have a significant role to play in the justification of medical examinations. Other healthcare professionals who refer patients for a specific group of exposures require a similar amount of training in RP to professionals in Category 8 relating to those exposures.

(77) 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 that medical referrers have a relatively poor level of knowledge about RP. It has also been identified that few of those responsible for prescribing or performing examinations are familiar with the quantities and units used to specify the amount of radiation or the level of risk from common procedures. Therefore, the Commission recommends that a stronger emphasis should be placed on transfer of knowledge of RP and its application to referrers. This recommendation applies particularly to practitioners and medical specialists outside radiological specialisations. Since all medical professionals are likely to refer for medical exposures, the Commission recommends that basic education in RP for physicians (Category 8) should be 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.

(78) The issue of transfer of knowledge for current medical referrers 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 referrers 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 referrers, and inclusion of lectures on RP in conferences for general medical practitioners and other medical specialties.

(79) Maintenance engineers and applications specialists (Category 11) currently receive some training in RP, but this may be primarily focused on RP of staff; training on RP of patients needs to be expanded, particularly in relation to digital radiology and new equipment. Principles and procedures for image quality and dose optimisation should also be emphasised in training of engineers. Some degree of national co-ordination will be required in order to achieve this.

(80) Chiropractors (Category 15) require training to refer for radiographic exposures, but will require extensive additional theoretical and practical training if they justify exposures and operate their own x-ray equipment. Consequently, the range of hours given for this group is larger, and the amount of training obtained needs to be adjusted accordingly.

(81) Radionuclide laboratory workers (Category 16) should not be confused with other categories as the risk of radiation exposure is for staff alone 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 training for laboratory staff be tailored to their needs, which may be of rather longer duration as they may be working with radionuclides on a full time basis, and some may be exempted from personal

monitoring because it is inappropriate for the type of radiation emitted from the radioactive material handled.

(82) Staff from regulatory authorities (Category 17) should be senior medical physicists or equivalent with strong radiation protection competences, but may need to receive some additional training.

4.2. Delivery of training

(83) The objective of any training in a hospital setting is to acquire knowledge and 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, subjects. While non-medical training, particularly in the past, has often been based on knowledge transmission, there has always been great emphasis in clinical training on imparting skills to solve day-to-day problems. Indeed, most training these days is practice-oriented in many non-medical subject areas. 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 given in a similar environment to that in which the participants will be practising, and should 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.

(84) Training in RP should be provided by a team of radiological professionals, each of whom bring their specific knowledge. The primary trainer should be a person who is an expert in RP in the practice with which he or she is dealing. This will normally be a medical physicist, but radiographers and others have an important role. The primary trainer should have 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 type 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 legislation and the responsibilities of individuals and organisations is essential.

(85) 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. Some trainers in RP cannot resist the temptation to deal 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 only be dealt with to a level that is appropriate for the purpose in hand. A successful trainer will be guided by the utility of the information to the

audience, and not include over-complex definitions purely for academic purposes. The same applies to regulatory requirements. The trainer should speak the language of users to convey the necessary information without compromising the regulatory requirements. It is important that RP trainers update their knowledge continually to remain abreast of new clinical techniques and technologies. Radiographers and other 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 ill. They understand problems with the radiation equipment they deal with, the time constraints for dealing with large numbers of patients, and the lack of radiation measuring and RP tools, and can make a valuable contribution to training of other groups. Inclusion of lectures from practising clinicians in courses for Categories 1–8 is strongly recommended. However, to support the practising clinician, who may not always have the necessary updated theoretical and regulatory knowledge, it may be useful for the RP trainer to be on hand during such lectures to comment and discuss any issues raised.

4.3. Amount of training

(86) Another point to be considered is 'How much training?' Most people and organisations follow the relatively easy route of prescribing the number of hours. This report gives some recommendations on the number of hours of education and training in Tables 3.1 and 3.2, but this 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. Too much flexibility in the amount of training should be avoided as this could lead to variations in the standard of practice.

(87) The issue of how much training should be linked with prior knowledge of the trainee and 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 knowledge and skills, rather than prescribing the number of hours of training. Development of evaluation schemes at national level or by professional bodies is to be encouraged as this would ensure consistency of standards. Due to the magnitude of the requirement for RP training, it may be worthwhile for organisations to develop online evaluation systems. The Commission is aware that such online methods are currently available mainly from organisations 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.

(88) The amount of training should take into account the type of radiation work undertaken, the level of risk, the frequency of the procedure, and the probability of occurrence of over-exposures to the patient or to staff. For example, interventional procedures can deliver skin doses of a few gray to specific patients, and the radiation doses to patients from CT examinations are relatively high, so the need for RP is correspondingly greater. Particular consideration should be given to the number of times a procedure such as CT may be repeated on the same patient. Although the level of radiation employed in most imaging procedures is lower than the examples given, care must always be taken to minimise doses as the number of these procedures performed is far higher. Account should also be taken of changes in the level of radiation work that can occur fairly quickly for any medical professionals (e.g. staff movement) and in any medical institution (e.g. introduction of new services), as this may require additional RP training at certain points during a clinician's career.

(89) The practice of interventional cardiology involves high localised radiation doses to patients which may induce skin injuries. Therefore, 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 match those for the interventional aspects of radiology.

4.4. Continuing medical education

(90) RP training should be updated when there is a significant change in radiology technique or radiation risk, and at intervals not exceeding 36 months. Professional bodies are encouraged to promote lectures on RP relevant to their specialty in medical congresses to facilitate this. With many medical schools using computer-based tools for their curricula as well as continuing education, it seems reasonable that the same approach could also 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, including user requirements, available support by the developing organisation, and adaptability to varying contexts.

5. CERTIFICATION OF TRAINING

(91) 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 professional scientific societies should 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

(92) 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.

(93) In the context of this report, the terms 'accreditation' and 'certification' should be understood in the following way.

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

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

(96) The standards that an accredited organisation 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 report does not intend to state the standards (for accreditation) or the methods to demonstrate competency (for certification), but provides guidance on the requirements. The body providing accreditation will need national recognition and should have representation from key players such as the professional bodies representing radiologists, medical physicists, radiographers, and physicians.

5.2. Criteria for accreditation of organisations to provide training in radiological protection

5.2.1. Minimum requirements

(97) The minimum requirements for accreditation of a training programme should take account of all the aspects involved. These should include sufficient administrative support; guarantees for the archiving of files, diplomas, etc. for a minimum number of years; sufficient 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. Practical training should be provided at medical installations, rather than laboratory- or computer-based simulation exercises.

5.2.2. Lecturers' experience

(98) Lecturers for the training courses should be competent in RP, which is best demonstrated by professional certification, state registration, or an equivalent professional recognition system. They must also have experience in RP in medical installations and in practical work in a clinical environment. Often, medical physicists will lead on this, but other groups such as radiologists, radiographers, and other clinicians with specialist knowledge of techniques may be involved. Trainers participating in these activities should meet the local requirements and demonstrate sufficient 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 optimise technique with regard to radiation dose, but it could require the organisation of some activities to 'train the trainers' in some countries or regions. Attendance at lectures given by medical staff in RP courses and involvement in discussion during the courses may also be useful components in the development of the trainer's knowledge of techniques and practices.

5.2.3. Feedback from participants

(99) Part of the follow-up to maintain the accreditation of organisations providing training should be analyses of results from surveys of participant responses at the end of 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

(100) Training activities in RP should be followed by an evaluation of the knowledge acquired from the training programme. This will allow the accreditation 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 included routinely in the quality management system.

(101) 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 examination, personal interview, automatic computer evaluation answering a set of questions, continuous assessment during the training programme, etc., can also be considered.

(102) 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.

(103) For those in Categories 1–5 and 7 in Table 3.1, and Categories 9–12 and 14–16 in Table 3.2, assessment of competency and practical skills will also be required.

5.3.1. Diplomas

(104) 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, number of accredited training hours, process of accreditation (examination or other form of assessment), date of training, and the name of the academic staff member(s) with responsibility for the training programme.

(105) 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 and continuing professional development programmes.

5.4. Roles of various organisations in radiological protection training

5.4.1. Universities, training institutions, and scientific societies

(106) Universities, training institutions, and scientific societies may all have an important role to play in the promotion, organisation, 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, radiography, 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

(107) Regulatory and health authorities have the capability to enforce 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 co-ordinate the preparation of training material, and, in some cases, to maintain a register of the certified professionals.

5.4.3. International organisations

(108) Some international organisations [e.g. ICRP, Intenational Atomic Energy Agency (IAEA), World Health Organization (WHO), European Commission (EC), etc.] can give recommendations on the content (including educational-specific objectives) and number of hours of recognised training for the different professional groups, and criteria for accreditation and certification. They can also produce or co-ordinate the preparation of training material, and offer it on their websites.

5.4.4. The radiology industry

(109) The radiology industry has an important role to play 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. Organisation and financing of training

(110) Critical issues that have to be taken into account by the regulatory bodies and health authorities when requiring certification in RP for medical professionals are the available infrastructure for organisation of the training programmes and the financial requirements.

(111) In some countries or regions, the co-operation of international organisations (e.g. IAEA, WHO, Pan American Health Organization, EC, etc.) could be helpful in initiating the activities through the organisation of pilot courses and provision of training materials to train the trainers. Later, RP training could be extended with the co-operation of universities, research centres, and scientific or professional societies (e.g. medical physics, radiology, nuclear medicine, cardiology, etc.).

(112) If certification in RP is required for practices such as interventional cardiology, the certificate should be obtained before a professional is involved in practising the specialty at a specific centre. 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.

ANNEX A. EXAMPLES OF SUGGESTED CONTENT FOR TRAINING COURSES

A.1. Nuclear medicine [Categories 2 (Table 3.1) and 10 (Table 3.2)]

(A1) The following subjects should be included in training and education regarding optimisation of RP while administering radiopharmaceuticals to patients for diagnostic purposes.

- Justification of exposure, assuring a positive balance of benefit vs risk. Decisions should be based on scientific evidence and clinical experience that appropriate indications fulfil the above condition. Existing guidance, such as that prepared by the EC (2000b), on indications for the use of 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 ionising radiation.
- Activities of radiopharmaceuticals used for specific diagnostic procedures, taking diagnostic reference levels into account.
- Choice of radiopharmaceutical from the standpoint of clinical indications.
- Organ and effective doses from different radiopharmaceutical examinations, and the effect of age (mSv/MBq).
- Magnitude of risk as a function of age.
- Choice of radiopharmaceutical from the standpoint of magnitude of organ or tissue doses and effective dose.
- Choice of radiopharmaceutical from the standpoint of economic considerations and availability (logistics).
- Specific conditions for identification of pregnant patients, and limitations placed on nuclear medicine diagnostics in pregnancy.
- Modifications of activity to be administered, related to body mass and/or age (infants, children, adolescents).
- Possible relaxation of restriction on the amount of activity administered in oncology diagnostics.
- Enhancing elimination of radiopharmaceuticals in order to reduce exposure.
- Special protection of the fetus in nuclear medicine diagnostics of the mother; indications and contraindications for some procedures.
- Nuclear medicine diagnostics in breastfeeding females; temporal or complete abandonment of breast feeding as a function of the radiopharmaceutical and administered activity.
- Understanding the principles, routine quality assurance, and practical use of dose calibrators.
- Understanding the principles and practice involved in intravenous, oral, and inhaled radiopharmaceutical administrations.
- Action to be taken following misadministration.
- Procedures for dealing with incontinent patients.

- Exposure of volunteers in medical research involving administration of radiopharmaceuticals – justification, conditions, and requirements (ethical and legal).
- Role of quality management and control in optimisation of RP.
- Requirement for adherence to authorised procedures.
- Purpose and scope of audits – internal and external.
- Recommendations for patients leaving nuclear medicine units after diagnostic procedures (very limited).

A.1.1. Additional radiological protection aspects for therapeutic nuclear medicine procedures

(A2) This is included since nuclear medicine specialists will not usually attend RP courses for radiotherapy.

- Protection of patients undergoing therapy with radiopharmaceuticals, and personnel preparing and administering radiopharmaceuticals.
- Indications and adherence to authorised procedures. In research, acceptance by the ethical commission.
- Clinical consequences of administration to a pregnant patient or a patient becoming pregnant in the weeks following a radionuclide therapy.
- Periods for which females should avoid conception following radionuclide therapy.
- Treatment of mothers with radionuclide therapy during pregnancy – dilemmas and limitations (exclusions).
- Safety measures for management of in-patients administered with therapeutic doses of radiopharmaceuticals.
- Instructions to patients leaving nuclear medicine units after therapy with radiopharmaceuticals, particularly with ^{131}I iodides administered for treatment of thyroid cancer and hyperthyroidism.

A.1.2. Protection of personnel working in nuclear medicine

- General rules for work with unsealed sources.
- Special protection of hands (fingers) of radiopharmacists in labelling the ligands with high activities of ^{99m}Tc.
- Monitoring of finger doses, and protection while injecting patients for diagnostic purposes.
- Potential risks of high doses from handling therapeutic radionuclides (high-energy beta emitters).
- Risks from handling alpha-emitting radionuclides (where this is carried out).
- Monitoring of exposure of the personnel dealing with high activities of ^{131}I.
- Reasons for exclusion of pregnant workers from activity in controlled areas.

A.1.3. Radiological protection for personnel working in PET/CT

(A3) The overall objective is 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 technique.

- Basic PET/CT technology including cyclotron, PET scanners, CT scanners, and the merging of the two technologies into PET/CT.
- National and international requirements for medical exposure in PET/CT: responsibilities, training, justification, optimisation of RP, diagnostic reference levels, and dose calculations.
- PET/CT procedures from the patient perspective, including patient preparation, administration of the radiopharmaceutical, imaging, and discharge of the patient.
- Factors that influence patient dose, particularly for paediatric and female patients.
- Factors taken into account to minimise staff and public doses when designing a new PET/CT and/or cyclotron facility, including shielding and layout issues.
- 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.
- Personal and workplace monitoring; type of monitors; where, who and when to monitor; and decontamination procedures.
- Staff doses received from PET/CT and how the basic principles of RP can be used to minimise them. This includes pregnant staff, visitors to the unit, and friends and relatives of the patient.
- Aspects of a PET/CT facility: transport of the radionuclide, accounting, security of sources, and waste management at the facility.
- Organisation of RP programme, safety/risk assessment, designation of areas, written procedures, local rules to ensure safe operation of the PET/CT unit and production facilities, and emergency procedures.
- Quality control needed on production of the radiopharmaceutical and optimisation of RP with regard to each PET and CT scanner, and their combined usage.

A.2. Interventional radiology (Category 1, Table 3.1)

(A4) Those working in interventional radiology should have the knowledge to do the following (adapted from EC, 2000a).

A.2.1. X-ray systems for interventional radiology

- Explain the effect of high additional filtration (e.g. copper filters) on conventional x-ray beams.
- Explain the virtual collimation and the importance of wedge filters.
- Explain the operation of continuous and pulsed x-ray emission modes.
- Explain the benefits of the grid controlled x-ray tube when using pulsed beams.
- Explain the concept of road mapping.

- Explain temporal integration and its benefits in terms of image quality.
- Analyse changes in dose rate when varying the distance from image intensifier to patient.

A.2.2. Dosimetric quantities specific for interventional radiology

- Define the dose area product (DAP) (or kerma area product) and its units.
- Define entrance dose and entrance dose rate in fluoroscopy.
- Understand the cumulative air kerma and its relationship to entrance dose.
- Discuss the correlation between entrance surface dose and DAP.
- Discuss the relationship between DAP and effective dose.
- Correlate the dose upon entry into the patient with the dose at the exit surface and the dose at the intensifier input surface.

A.2.3. Radiological risks in interventional radiology

- Describe deterministic effects that may be observed in interventional radiology.
- Analyse the risks of deterministic effect induction as a function of the surface doses received by patients.
- Be aware of the probability of these effects in interventional practice.
- Analyse the relationship between received doses and deterministic effects in the lens of the eye.
- Be aware of the likely time intervals between irradiation and occurrence of the different deterministic effects, the required follow-up, and control of patients.
- Analyse the stochastic risks in interventional procedures and their age dependence.

A.2.4. Radiological protection of staff in interventional radiology

- Comment on the most important factors which influence staff doses in interventional radiology laboratories.
- Analyse the influence of the x-ray C-arm positioning on occupational doses.
- Analyse the effects of using different fluoroscopy modes on occupational doses.
- Analyse the effects of using personal protection (e.g. leaded aprons, thyroid collars, lead glasses, gloves, etc.).
- Analyse the benefits and drawbacks of using articulated screens suspended from the ceiling.
- Understand the benefit of protecting the legs using lead rubber drapes.
- Understand the importance of a suitable location for personal dosimeters.

A.2.5. Radiological protection of patients in interventional radiology

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

- Analyse the effects of using different fluoroscopy modes on patient doses.
- Discuss the effects of the focus to skin distance and patient image intensifier input distance.
- Analyse the dose reductions attainable by modifying the image rate in digital acquisition or in cine.
- Give typical examples of patient entrance dose value per image in different procedures.
- Analyse the effect of using different magnifications on patient dose.
- Discuss the parameters which should be recorded in the patient history regarding (or with reference to data on) the doses received.

A.2.6. Quality assurance in interventional radiology

- Discuss the difference between equipment performance parameters that do not usually downgrade with time and those that could require periodic control.
- Understand how image quality can be assessed.
- Discuss the importance of establishing simple criteria to compare doses at the patient or intensifier entrance in different situations.
- Note the importance in quality assurance programmes of the periodic control of patient dose and its comparison with diagnostic reference levels that take into account complexity of the interventional procedure (in this case, diagnostic reference levels are not used in the strict sense of 'diagnostic', but for the patient dose derived from the imaging part of the interventional procedure).
- Local and international rules for interventional radiology.
- Discuss the different national regulations which apply in interventional radiology installations.
- Describe the international recommendations for interventional radiology (WHO, IAEA, ICRP, EC, etc.).
- Provide information on the international recommendations concerning the limitation of high-dose modes.

A.2.7. Optimisation of the procedures with regard to radiation dose in interventional radiology

- Understand the influence of kVp and mA on image contrast and patient dose when using contrast media.
- Understand the different features available on radiology equipment.
- Note the importance of optimisation of RP in interventional radiology radiation procedures.
- Discuss the importance of diagnostic reference levels that take into account complexity of the interventional procedure, related to the patient dose at local, national, and international levels.
- Analyse the importance of periodic patient dose control in each room.
- Discuss the possibility of using different C-arm orientations during long procedures in which the threshold for deterministic effects may be attained.
- Analyse the importance of recording the dose imparted to every patient.

A.3. Interventional cardiology (Category 3, Table 3.1)

(A5) Those working in interventional cardiology should have the knowledge to do the following.

A.3.1. X-ray systems for interventional cardiology

- Explain the effect of high additional filtration (e.g. copper filters) on conventional x-ray beams.
- Explain virtual collimation.
- Explain the operation of continuous and pulsed x-ray emission modes.
- Analyse changes in the dose rate when varying the distance from image intensifier to patient.

A.3.2. Dosimetric quantities specific for interventional cardiology

- Define the DAP (or kerma area product) and its units.
- Define entrance dose and entrance dose rate in fluoroscopy.
- Understand the cumulative air kerma and its relationship to entrance dose.
- Discuss the correlation between entrance surface dose and DAP.
- Discuss the relationship between DAP and effective dose.

A.3.3. Radiological risks in interventional cardiology

- Describe deterministic effects that may be observed in interventional cardiology.
- Analyse the risks of deterministic effect induction as a function of the surface doses received by patients.
- Analyse the relationship between received doses and deterministic effects in the lens of the eye.
- Be aware of the likely time intervals between irradiation and occurrence of the different deterministic effects, the required follow-up, and control of patients.
- Analyse the stochastic risks in interventional procedures and their age dependence.

A.3.4. Radiological protection of staff in interventional cardiology

- Comment on the most important factors which influence staff doses in interventional cardiology laboratories.
- Analyse the influence of the x-ray C-arm positioning on occupational doses.
- Analyse the effects of using different fluoroscopy modes on occupational doses.
- Analyse the effects of using personal protection (e.g. leaded aprons, thyroid collars, lead glasses, gloves, etc.).
- Analyse the benefits and drawbacks of using articulated screens suspended from the ceiling.

- Understand the benefit of protecting the legs using lead rubber drapes.
- Understand the importance of a suitable location for personal dosimeters.

A.3.5. Radiological protection of patients in interventional cardiology

- Analyse the correlation between fluoroscopy time and number of images taken in a procedure and the dose received by patients.
- Analyse the effects of using different fluoroscopy modes on patient doses.
- Discuss the effects of the focus to skin distance and patient image intensifier input distance.
- Analyse the dose reductions attainable by modifying the image rate in digital acquisition or in cine.
- Give typical examples of patient entrance dose value per image in different procedures.
- Analyse the effect of using different magnifications on patient dose.

A.3.6. Quality assurance in interventional cardiology

- Discuss the difference between equipment performance parameters that do not usually downgrade with time and those that could require periodic control.
- Understand how image quality can be assessed.
- Note the importance in quality assurance programmes of the periodic checking of patient dose and its comparison with diagnostic reference levels that take into account complexity of the interventional procedure (in this case, diagnostic reference levels are not used in the strict sense of 'diagnostic', but for the patient dose derived from the imaging part of the interventional procedure).
- Discuss the national regulations which apply in interventional cardiology installations.
- Provide information on the international recommendations concerning the limitation of high-dose modes.

A.3.7. Optimisation of the procedures in interventional cardiology

- Understand the different features available on cardiology equipment and their influence on patient dose and image quality.
- Note the importance of optimisation of RP in interventional cardiology radiation procedures.
- Discuss the importance of diagnostic reference levels that take into account complexity of the interventional procedure, related to the patient dose at local, national, and international levels.
- Discuss the possibility of using different C-arm orientations during long procedures in which the threshold for deterministic effects may be attained.
- Note the importance of recording the dose imparted to every patient.

A.4. Theatre fluoroscopy using mobile equipment [Categories 4 (Table 3.1) and 12 (Table 3.2)]

(A6) 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 13) are marked with an asterisk.

A.4.1. X-ray systems

- Explain the operation of continuous and pulsed x-ray emission modes.
- 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.
- Define the DAP, entrance dose and entrance dose rate, and their units.
- Discuss the relationship between DAP and effective dose.
- Understand the stochastic risks in mobile fluoroscopy.

A.4.2. Radiological protection of staff

- Analyse the influence of the x-ray C-arm positioning on occupational doses and the implications of using different C-arm orientations.*
- Understand the effects of using personal protection (e.g. leaded aprons, gloves, eyeglasses, thyroid protectors, etc.).*
- Understand the importance of a suitable location for personal dosimeters.*

A.4.3. Radiological protection of patients

- Analyse the correlation between fluoroscopy time, number of images taken in a procedure, and dose received by patients.*
- Analyse the effects of using different fluoroscopy modes on patient doses.*
- Understand the influence of the x-ray tube to skin distance on patient skin dose.*
- Discuss the parameters which should be recorded in the patient history relating to the doses received.
- Discuss the importance of diagnostic reference levels related to the patient dose at local levels.

A.5. References

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. Available at: http://ec.europa.eu/energy/nuclear/radiation_protection/doc/publication/116.pdf (last accessed 01/03/2011).

EC, 2000b. Referral Criteria for Imaging. Radiation Protection 118. European Commission, Directorate General for the Environment, Luxembourg, 2000. Available at: http://ec.europa.eu/energy/nuclear/radioprotection/publication/doc/118_en.pdf (last accessed 01/03/2011)..

ANNEX B. OUTLINE OF SPECIFIC EDUCATIONAL OBJECTIVES FOR PAEDIATRIC RADIOLOGY

(B7) The factors relating to image 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.

B.1. General, equipment, and installation considerations

- Justify the requirements concerning the power of the generator and its relationship with the need for short exposure times (3 ms).
- Explain the convenience of high-frequency generators in relation to the accuracy and reproducibility of exposures in paediatrics.
- Discuss the advantages and limitations of automatic exposure control devices in paediatrics.
- Justify the specific technical requirements of the automatic exposure control devices for paediatrics.
- Explain that careful manual selection of exposure factors usually results in lower doses.
- Explain the design aspects to be considered in paediatric x-ray rooms for improving the child's co-operation (control panel with easy patient visibility and contact, etc.).
- Discuss the advantages and limitations of fast film-screen combinations and lower exposure factors for computed radiography.
- Discuss the advantages of using low-absorbing materials in cassettes, tables, etc.
- Analyse the limited improvement in image quality when using the anti-scatter grid in paediatrics and the increase in patient dose.
- Analyse the specific technical requirements of anti-scatter grids for paediatrics.
- Explain how the anti-scatter grid should be removable in paediatric equipment, particularly fluoroscopic systems.
- Explain the convenience of using image intensifiers with high conversion factors for reducing patient dose in fluoroscopic systems.
- Justify the convenience of specific kV-mA dose rate curves for automatic brightness control in fluoroscopic systems used for paediatrics.
- Discuss the importance of using specific technical radiographic parameters for CT examinations in paediatrics (lower mAs than for adults, lower kV in some cases).
- Analyse the special problems with the use of mobile x-ray units in paediatrics.
- Explain the advantages and disadvantages of under-couch and over-couch fluoroscopy units for paediatrics.
- Discuss the advantages and role of pulsed fluoroscopy.
- Compare conventional and digital equipment and the role/use of the frame-grab technique in digital imaging.

- Discuss value of cine playback (digital) and video playback (digital/conventional fluoroscopy) in screening examinations.
- Discuss the role of additional tube filtration.

B.2. Reduction of exposure

- Analyse the most frequent causes of repeating films in paediatrics – reject analysis, audit, and feedback.
- Discuss how immobilisation can reduce the radiographic repeat rate.
- 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.
- Explain how short exposure times can improve image quality and reduce the number of films repeated.
- Explain the inconvenience of using mobile x-ray units for paediatrics and the difficulty in getting short exposure times.
- Explain the importance of having radiographers with specific training in paediatric radiology.
- Discuss the importance of gonad protection in paediatric radiology, and value of having various sizes and types.
- 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.
- Discuss the importance of correct patient positioning and collimation, particularly for excluding the gonads from the direct beam.
- Discuss the importance of establishing whether adolescent girls might be pregnant when abdominal examinations are contemplated.
- Discuss the fact that motion is a greater problem in children, and could require specific adjustment of radiographic techniques.
- Discuss the importance of a proper consultative relationship between the referring physician and the radiologist. Role of agreed protocols and diagnostic pathways.
- Discuss some examples of radiological examination of questionable value in children (e.g. some follow-up chest radiographs in simple pneumonia, abdominal radiographs in suspected constipation, etc.).
- Explain that the repetition of a radiological examination in paediatrics should always be decided by the radiologist.
- Discuss the convenience of using appropriate projections for minimising dose in high-risk tissues (posteroanterior projections should replace anteroposterior where possible for spinal examinations).
- Discuss the convenience of having additional filters available to enable them to be changed easily (1 mm Al; 0.1 and 0.2 mm Cu should be available).

- 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 co-operation in a secure and child-friendly environment are of paramount importance in reducing radiation doses in paediatrics.
- Discuss the importance of having specific referral criteria, e.g. for head injury where the incidence of injury is low.
- 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).
- Discuss high kV techniques.
- Explain the value of using long focus patient distances.
- Explain the importance of using the light beam diaphragm to move the patient into position rather than screening during over-couch fluoroscopy procedures.
- 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.
- Understand the influence of imaging using lower mAs and kV values for paediatric CT.
- Discuss the role of audit and quality assurance in maintaining or improving image quality and dose.

B.3. Risk factors

- Discuss the fact that longer life expectancy in children means a greater potential for manifestation of possible harmful effects of radiation.
- Consider that the radiation doses used to examine young children should generally be smaller than those employed in adults.
- Explain that the risk factor for cancer induction in children is between two and three times higher than for adults, with emphasis on the developing breasts and gonads, and the more widespread distribution of red bone marrow in the developing skeleton.
- Discuss the risk factors for genetic effects in children.
- Relate with the natural occurrence of congenital abnormalities.
- Relate with the natural incidence of cancer.

B.4. Patient dosimetry: diagnostic reference levels

- Explain the specific difficulties of measuring patient doses in paediatrics.
- Discuss the dosimetric techniques available for patient dosimetry in paediatrics.
- Discuss how patient dose values are related to patient size.
- Analyse some typical patient dose values in paediatrics and their relation with patient size.

- Analyse the diagnostic reference levels available for paediatrics.
- Discuss how to use diagnostic reference levels in paediatric radiology.

B.5. Protection of personnel and parents

- Analyse the possibility of parents co-operating in the radiological examination of their children and the precautions to be taken.
- Clarify that the parents' exposure in this situation can be considered as a medical exposure, but that optimisation criteria must be applied.
- Highlight that the parents or helpers should know exactly what is required of them.
- Explain that pregnant women should not be allowed to help during paediatric examinations.
- Explain the importance of using lead aprons and lead gloves (if the hands are in the direct radiation field) in these situations.

B.6. International recommendations

- To take into account the existence of relevant documents published by ICRP, National Council on Radiation Protection and Measurements, EC, and WHO concerning RP in paediatric radiology.

B.7. Nuclear medicine considerations

- Explain the importance of having nuclear medicine technologists with specific training in paediatric radiology.
- Discuss the fact that motion is a greater problem in children, and could require specific adjustment of nuclear medicine techniques.
- Discuss the importance of a proper consultative relationship between the referring physician and the nuclear medicine specialist.
- Explain that the repetition of a nuclear medicine examination in paediatrics should always be decided by the nuclear medicine specialist.
- Discuss how to determine the amount of activity to be administered to paediatric patients.

(C8) Powerpoint slides for free download and direct use:

- http://rpop.iaea.org/RPOP/RPoP/Content/AdditionalResources/Training/1_TrainingMaterial/index.htm

(C9) Other educational resources:

- Specific questions and answers in different diagnostic, interventional, and therapeutic modalities at the International Atomic Energy Agency website on the RP of patients: http://rpop.iaea.org
- Ask the Expert at Health Physics website: http://hps.org/publicinformation/ate/faqs/
- Radiological Society of North America website: http://www.rsna.org/Education/index.cfm

Table C.1. Web addresses of organisations with training material (in alphabetical order).

Organisation	Website(s)
American Association of Physicists in Medicine	http://www.aapm.org/ http://www.aapm.org/meetings/virtual_library/
European Commission	http://ec.europa.eu/energy/nuclear/radiation_protection/publications_en.htm http://bookshop.europa.eu/is-bin/INTERSHOP.enfinity/WFS/EU-Bookshop-Site MARTIR project
European Society for Therapeutic Radiology and Oncology	http://www.estro.org/Pages/default.aspx e-test radiobiology
International Atomic Energy Agency	http://rpop.iaea.org http://www.iaea.org/Publications/ http://www-pub.iaea.org/MTCD/publications/publications.asp
International Commission on Radiological Protection	http://www.icrp.org/ Educational material for ICRP *Publications 84, 85, 86, 87*, and *93*
International Radiation Protection Association	http://www.irpa.net/ IRPA10, IRPA11 refresher courses
Perry Sprawls	http://www.sprawls.org/resources/#radiation
Office of Radiation Protection Washington State Department of Health, USA)	http://www.doh.wa.gov/ehp/rp/factsheets/fsdefault.htm#introfs
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

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