Radiation safety for anesthesiologists

Armagan Dagal

Department of Anesthesiology and Pain Medicine, Harborview Medical Center, University of Washington, Seattle, Washington, USA

Correspondence to Armagan Dagal, MD, FRCA, HMC 359724, 325 Ninth Avenue, Seattle, WA 98104-2499, USA
Tel: +1 206 744 7242; e-mail: dagal@uw.edu

Current Opinion in Anesthesiology 2011, 24:445–450

Purpose of review

To review the recent literature on the implications of occupational radiation exposure in anesthesia practice.

Recent findings

Wide variation and lack of reduction in operator doses of medical radiation strongly suggests that more attention must be paid to the factors influencing radiation dose exposure. The eye is likely the most sensitive organ for radiation injury. Radiation-related cataract formation might be a stochastic effect. Operators are strongly advised to use eye protection at all times. Safe medical radiation ophthalmic dose limits are currently under review and are likely to be lowered. Current data do not suggest a significant risk to the fetus for pregnant women working in the interventional radiology suite as long as proper monitoring and radiation safety measures are implemented.

Summary

Radiation is increasingly utilized in medicine for diagnostic and therapeutic procedures. Anesthesia providers may become exposed to unsafe doses while providing high-quality patient care. Understanding of the physical principles, the sources of radiation exposure, the potential risks, and safe practices helps to minimize the exposure risk and its potential deleterious effects to the anesthesia team.

Keywords

anesthesiology, radiation, risk, safety

Curr Opin Anesthesiol 24:445–450

0952-7907

Introduction

Radiation has been extensively used in medicine for diagnostic and therapeutic procedures. There are about 2 billion X-ray examinations and well over 60 million computed tomographies (CTs) performed annually in the USA [1,2]. Interventional radiology is often the preferred care pathway for cardiovascular and neurosurgical procedures because of its advantages over open surgery. These procedures have the potential to produce occupational radiation exposure levels that are of concern for anesthesia providers in their daily practice both inside and outside the operating room [3,4]. An understanding of the physical principles and ways to minimize the potential deleterious effects of exposure to radiation is essential for anesthesiologists [5•].

Quantification of radiation exposure

Radiation exposure limits are expressed in terms of ‘equivalent dose’ for a specific organ or tissue and ‘effective dose’ for whole-body exposure. Equivalent and effective dose are calculated from quantities that can be measured with personal dosimeters. Equivalent dose (SI unit = Sievert = Sv) is the mean absorbed dose in a tissue or organ (SI unit = Gray = Gy), multiplied by a radiation-weighting factor (wR). For diagnostic radiography, wR = 1, so the tissue dose and the equivalent dose are numerically equal. Effective dose is the weighted sum of the equivalent doses in all specified tissues and organs of the body (SI unit = Sievert = Sv) (Table 1) [6,7••,8].

A personal dosimeter provides two values, $Hp_{0.07}$ and Hp_{10}. These values represent the equivalent doses in soft tissue at 0.07 and 10 mm below the surface of the body [8]. For example, $Hp_{0.07}$ from the collar dosimeter worn over protective garments provides a reasonable estimate of the dose delivered to the surface of the unshielded skin and to the lens of the eye. In the USA, National Council on Radiation Protection and Measurements (NCRP) recommends combining the Hp_{10} values from both body and collar dosimeters to estimate effective dose:

$$E\ (\text{estimate}) = 0.5H_W + 0.025H_N$$

H_N is the reading obtained from the dosimeter at the neck, outside the protective apron, and H_W is the reading obtained from the dosimeter at the waist or on the chest, under the protective apron.

Table 1 Recommended tissue weighting factors

Tissue	wR
Red bone marrow, colon, lung, stomach, breast, and remainder tissues[a]	0.12
Gonads	0.08
Bladder, esophagus, liver, and thyroid	0.04
Bone surface, brain, salivary glands, and skin	0.01

ICRP, International Commission on Radiological Protection; wR, weighting factor. Adapted with permission from [8].
[a] Remainder tissues: adrenals, extrathoracic region, gall bladder, heart, kidneys, lymphatic nodes, muscle, oral mucosa, pancreas, and prostate (♂), small intestine, spleen, thymus, and uterus/cervix (♀).

Maximum safe doses

Data on the risks of radiation has been largely drawn from the follow-up of 25 000 A-bomb survivors since 1945 [9] and from 407 000 radiation workers in 15 countries [10]. Although the form of radiation delivered by A-bombs (gamma radiation) is different from that used in radiology (x-ray radiation), there is fundamentally no difference in the carcinogenic potential. In the USA, individual state governments set occupational dose limits, but in most cases the recommendations developed by the NCRP are used [11]. These recommendations include an occupational limit of 50 mSv in any 1 year and a lifetime limit of 10 mSv multiplied by the individual's age in years (Table 2) [8]. The NCRP recommends a 0.5-mSv equivalent dose monthly limit for the embryo fetus (excluding medical and natural background radiation) once the pregnancy is declared [12]. In the USA, personnel who do not wish to declare their pregnancy are not required to do so [13•].

Sources of radiation exposure

On average, the US public receive a radiation dose of about 6.2 mSv/year. Half of this dose comes from natural background radiation and the other half, 3 mSv/year, comes from medical, commercial, and industrial sources [14]. The effective dose for a chest CT is approximately 100–1000 times larger than that for a corresponding chest x-ray examination (Table 3) [14].

Table 2 Recommended dose limits for occupational exposure in x-ray imaging

Dose quantity	Occupational dose limit[a]
Effective dose	20 mSv/year averaged over 5 consecutive years (100 mSv in 5 years), and 50 mSv in any single year
Equivalent dose in	
Ocular lens[b]	150 mSv/year
Skin[c]	500 mSv/year
Hands and feet	500 mSv/year

ICRP, International Commission on Radiological Protection. Adapted from ICRP [8].
[a] Dose limits can be different in national regulations.
[b] This limit is currently being reviewed by an ICRP Task Group.
[c] Averaged over 1 cm^2 of the most highly irradiated area of the skin.

Key points

- The risk of exposure to occupational radiation is increasing with the advancement and expansion in utilization of diagnostic and therapeutic procedures in medicine.
- During some interventional radiology procedures, the radiation dose received by the anesthesiologist can be greater than that by the radiologist.
- The eye is the most sensitive organ for radiation injury and operators are strongly advised to use eye protection at all times.
- Current evidence suggests that although there is no apparent risk of receiving ionizing radiation doses in excess of those set by the NCRP, anesthesiologists should remain vigilant and maintain radiation safety standards at all times.

Medical radiation exposure may occur from three sources:

(1) Direct exposure from the primary x-ray beam.
(2) Scattered radiation from patient body surface.
(3) Radiation emitted from the x-ray tube in areas other than the primary beam, defined as leakage x-rays.

In most cases, scattered radiation is the main determinant for occupational exposure. Level of scatter is largely determined by the amount of dose exposure and distance from the patient. Reducing the patient dose to as low as reasonably achievable (ALARA) to attain the required medical outcome helps to prevent excess radiation exposure [15].

Equipment regulations limit the maximum leakage level to 1 mGy/h at 1 m from the x-ray tube for maximum tube potential – voltage (kVp) and maximum continuous tube current – amperage (mA). For typical fluoroscopy techniques, leakage radiation is generally small and in the range of 0.0010.01 mGy/h at the operator's position [16••].

Effects of ionizing radiation

Radiation creates deterministic effects, stochastic effects, or a combination of both effects on biological tissues. Deterministic effects create cell death at the tissue level

Table 3 Average radiation doses

Diagnostic modality	Effective radiation dose (mSv)
Standard chest x-ray	0.02
C-spine x-ray	0.3
Abdomen x-ray	0.53
Pelvis/hip x-ray	0.83
Thoracic spine x-ray	1.4
Lumbar spine x-ray	1.8
Head CT	2.0
Abdominal CT	10
Chest CT	10–40

CT, computed tomography. Adapted with permission from [14].

of the exposed individual resulting in defects, in particular lens opacities, skin injuries, and infertility. Deterministic effects occur predictably when the dose exceeds a certain threshold. Stochastic effects refer to the development of cancer from the direct DNA ionization or from the creation of hydroxyl radicals from x-ray interactions with water molecules. These radicals in turn interact with nearby DNA to cause strand breaks or base damage. Most radiation-induced damage is rapidly repaired by various systems within the cell. DNA double-strand breaks are less easily repaired, and occasional abnormal repair can lead to induction of point mutations, chromosomal translocations, and gene fusions, all of which are linked to the induction of cancer [17•].

Organs and tissue most at risk from occupation exposure to radiation

There is no known 'safe' dose below which an induced neoplasm does not occur [18]. Stochastic effects are cumulative and have a long latency period; they occur randomly and are dependent on the level and type of radiation delivered, the tissue irradiated, and the age of the patient. A statistically significant linear relationship between excess cancer risk and radiation dose at levels lower than previously seen has recently been described [19]. In 2005, the National Academy of Sciences (Committee on the Biological Effects of Ionizing Radiation) described a 1-in-1000 chance of developing cancer from a radiation exposure of 10 mSv.

Effects on the eye

Interventional radiology can produce relatively high exposure doses to the unprotected eye from scatter radiation and other sources. This may be more significant for individual personnel than the carcinogenic or teratogenic effects of occupational exposure [7••,20]. As an example, neuroembolization procedures produce a range from 1.4 to 5.6 mSv intraocular lens dose per procedure, if no movable shield or leaded glasses are worn and distance is less than 1 m from the patient [21]. Recent data, however, indicates the threshold dose may be significantly lower or zero [22] and that radiation-induced cataracts may be a stochastic effect rather than a deterministic one [23]. In their recent study, Anastasian *et al.* demonstrated that the scattered radiation exposure to the anesthesiologist's eye could be up to three times that of the interventionist [24••,25•].

Risks to the fetus

The NCRP recommends that the occupational radiation exposure of the fetus must not exceed 5 mSv for the entire duration of the pregnancy or 0.5 mSv/month of pregnancy. International Commission on Radiological Protection (ICRP) recommends an even lower limit for occupational radiation exposure to a fetus of less than 1 mSv [20,26,27]. The risk of induced miscarriages, cancer, or congenital malformations in embryos or fetuses exposed to doses of 50 mGy or less is negligible [28,29] compared with control populations exposed to background radiation estimated as less than 1 mGy over the gestational period. The first trimester is the period of greatest risk. Potential noncancer health effects of prenatal radiation exposure in doses greater than 0.5 Gy include:

(1) less than 2 weeks – unknown;
(2) 2–7 weeks – death, miscarriage, growth retardation, and neuromuscular deficiencies;
(3) greater than 8 weeks – miscarriage, severe mental retardation, growth retardation either of the entire body or skull, and brain and major malformations.

The threshold dose for these deterministic effects is well above that which a practitioner in an invasive or interventional unit would receive under a protective apron. Thus, the use of standard radiation protection techniques result in negligible risks to the fetus [30]. Wagner and Hayman estimated the predicted probability of a live birth without malformation or cancer is reduced from 95.93 to 95.928% following conception exposure of 0.5 mSv. Exposures above 10 mSv were predicted to increase the risk by 0.1%. Nevertheless in-utero exposure to ionizing radiation at any dose is associated with an increased risk of childhood malignancy, especially leukemia. Risk is estimated to be greater than 6% in doses above the 0.5 Gy [31,32•].

Safe practices and preventative measures

Implementation of occupational radiation protection strategies is required for safe practice. These include the adoption of appropriate management and organizational structure, policies, and procedures. Risk factors for exposure to radiation may be modifiable or nonmodifiable.

(1) Nonmodifiable factors include
  (a) patient related
    (i) complexity of the clinical problem;
  (b) physician related
    (i) body size;
    (ii) sex;
    (iii) experience;
(2) Modifiable factors include
  (a) duration;
  (b) distance;
  (c) barrier;
  (d) education;
  (e) monitoring.

Anesthesiologists should attempt to reduce modifiable risk factors whenever possible.

Duration

Anesthesiologists have less control over the procedure duration, which is highly effected by complexity of the procedure and the service caseload [1].

Distance

Distance (d) from the radiation source is an essential factor to reduce the radiation exposure. During fluoroscopy, the main source of radiation is the scattered radiation not the direct radiation from the x-ray tube. The power of the radiation beam is attenuated according to the inverse square law (1% d^2). Exposure is minimal at a distance of more than 36 inches [15,33]. Direct patient contact in a cramped working environment limits the possibility of maintenance of safe distance for the anesthesiologist. Positioning of the radiologist on the patient's right, with the anesthesiologist to the left and on the side of the lateral x-ray beam's scatter, is commonly seen and increases exposure risk [21].

Barriers

Anesthesiologists can utilize three types of radiation shielding.

(1) Structural shielding including shielding material that is embedded into the walls of the radiology suite and mobile, transparent leaded acrylic shields. Mobile shields may either be mounted on wheels or ceiling-mounted on a suspension that moves with the practitioner.
(2) Equipment mounted shielding such as leaded drapes suspended from the fluoroscopy table and the scanner, which provides minimal protection.
(3) Personal shielding including aprons, thyroid shields, eyewear, and gloves.

The shielding material should be a minimum thickness of 0.5 mm lead equivalent. Depending on its lead equivalence and the energy of the x-rays, an apron will attenuate approximately 90% or more of the scattered radiation. Proper apron sizing is critical if the design includes two layers that must be overlapped to meet the lead-equivalent thickness specification. Over time, the shielding material in protective garments can develop cracks and holes that are not visible externally. Aprons should be stored on hangers with minimal folds and be monitored annually with fluoroscopy to check for integrity. Most commercially available protective aprons sold today contain materials like barium, tungsten, tin, and antimony. They provide the same attenuation as an equivalent thickness of lead at approximately 30% of the weight [34]. Thyroid shields are lightweight and easy to use and should be recommended for all personnel. Lightweight plastic prescription glasses offer inadequate protection (5% reduction in radiation exposure). Prescription glasses made of optical glass offer modest protection from the scattered radiation (30–40% reduction in radiation exposure) [35]. Lightweight leaded eyeglasses with large lenses and protective side shields generally provide 0.5 or 0.75 mm lead-equivalent protection ($\geq$98%) and should be a part of standard protective apparel.

Education

Training programs are crucial to the development of safe operating practices in a radiation environment [36•,37•]. Guidance has been published on what the training for medical staff should cover. Examples include the International Atomic Energy Agency (IAEA) material for diagnostic and interventional radiology [38••], and the Multimedia and Audiovisual Radiation Protection Training in Interventional Radiology (MARTIR) project [39].

Monitoring

Fluoroscopy units record the peak skin dose and fluoroscopy time. The unit gives warning when the total time approaches 30 min and then every 15 min thereafter. Dose monitoring must be documented according to the state and federal guidelines and all personnel working frequently in high-risk radiation exposure areas (fluoroscopy units) should wear dosimeters. There are three types of dosimeters used in practice.

(1) Film badges are the common type and use a film sensitive to radiation, similar to 35-mm camera film. The film is loaded into a plastic holder containing a system of filters (strips of copper, aluminum, lead, etc.) that allow the dosimeter reader to correctly identify the type of radiation exposure. This system is heat and moisture sensitive.
(2) Thermo-luminescent dosimeters.
(3) Optically stimulated luminescent dosimeters.

Dosimeters are person specific and should not be shared. If a single dosimeter is worn, it must be placed at the outside shielded garment or thyroid collar. When using two dosimeters: the dosimeter 'collar' is worn at collar level outside of the lead apron or lead thyroid collar; the dosimeter 'torso' is worn at waist level under the lead apron. Dosimeters usually assigned to monitor a period of up to 3 months, but if recorded exposures reach 10% of the allowable limits, they must be exchanged monthly in order to capture radiation doses before reaching unacceptable levels.

Conclusion

Although the current evidence suggests that occupational radiation doses are below the recommended threshold, this should not lead to complacency. The complexity of radiological procedures, increased demand, and the introduction of new clinical applications means that anesthesiologists have a high potential for significant occupational exposure to radiation. Even low levels of exposure are not inconsequential. The stochastic biologic effects of radiation are the consequence of direct damage to critical atoms within individual cells. The resultant cellular injuries are cumulative and permanent. There are currently no published data that define the lower threshold for such radiation-induced disease.

Routine monitoring of anesthesia personnel, especially in high-risk radiological environments is essential. Education and training in radiation protection and the availability and proper use of protective equipment is vital. These measures will help to ensure that anesthesia personnel are adequately and acceptably protected from exposure to medical radiation.

References and recommended reading

Papers of particular interest, published within the annual period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (pp. 466–467).

1 Kim KP, Miller DL. Minimising radiation exposure to physicians performing fluoroscopically guided cardiac catheterisation procedures: a review. Radiat Prot Dosimetry 2009; 133:227–233.

2 Brenner DJ, Hall EJ. Computed tomography – an increasing source of radiation exposure. N Engl J Med 2007; 357:2277–2284.

3 Berrington A, Darby SC, Weiss HA, Doll R. 100 years of observation on British radiologists: mortality from cancer and other causes 1897–1997. Br J Radiol 2001; 74:507–519.

4 Venneri L, Rossi F, Botto N, *et al.* Cancer risk from professional exposure in staff working in cardiac catheterization laboratory: insights from the National Research Council's Biological Effects of Ionizing Radiation VII Report. Am Heart J 2009; 157:118–124.

5 • Domienik J, Brodecki M, Carinou E, *et al.* Extremity and eye lens doses in interventional radiology and cardiology procedures: first results of the ORAMED project. Radiat Prot Dosimetry 2011; 144:442–447.

This study aims at analyzing the first results of the measurement campaign performed in interventional radiology and cardiology procedures in European hospitals. This study provides the first step toward an assessment methodology and a basis for preparing the guidance for good practices in the field of interventional radiology.

6 Wrixon AD. New ICRP recommendations. J Radiol Prot 2008; 28:161–168.

7 •• Miller DL, Vano E, Bartal G, *et al.* Occupational radiation protection in interventional radiology: a joint guideline of the Cardiovascular and Interventional Radiology Society of Europe and the Society of Interventional Radiology. J Vasc Interv Radiol 2010; 21:607–615.

Cardiovascular and Interventional Society of Europe (CIRSE) Executive Committee and the Society of Interventional Radiology (SIR) Executive Council endorsed guideline offers a basic review of the medical physics relevant to occupational radiation safety and to provide advice and guidance to interventional radiologists for radiation protection during fluoroscopically guided procedures.

8 ICRP. The 2007 recommendations of the International Commission on Radiological Protection. Ann ICRP 2007; 103:1–332.

9 Pierce DA, Shimizu Y, Preston DL, *et al.* Studies of the mortality of atomic bomb survivors. Report 12, Part I. Cancer: 1950–1990. Radiat Res 1996; 146:1–27.

10 Cardis E, Vrijheid M, Blettner M, *et al.* The 15-Country Collaborative Study of Cancer Risk among Radiation Workers in the Nuclear Industry: estimates of radiation-related cancer risks. Radiat Res 2007; 167:396–416.

11 NCRP. Limitation of exposure to ionizing radiation. Maryland; 1993 [NCRP Report No. 116]. http://www.knovel.com/web/portal/browse/display?_EXT_KNOVEL_DISPLAY_bookid=2072&VerticalID=0.

12 NRCP. Recent applications of the NCRP public dose limit recommendation for ionizing radiation. Maryland; 2004 [NCRP Statement No. 10]. http://www.ncrponline.org/Publications/Statements/Statement_10.pdf.

13 • Gottesman BE, Gutman A, Lindsell CJ, Larrabee H. Radiation exposure in emergency physicians working in an urban ED: a prospective cohort study. Am J Emerg Med 2010; 28:1037–1040.

This study indicates emergency department physician's routine activities during clinical shifts in the emergency department do not appear to increase the risk of receiving ionizing radiation dosages in excess of those set by the NCRP.

14 Semelka RC, Armao DM, Elias J Jr, Huda W. Imaging strategies to reduce the risk of radiation in CT studies, including selective substitution with MRI. J Magn Reson Imaging 2007; 25:900–909.

15 Bashore TM, Bates ER, Berger PB, *et al.* American College of Cardiology/Society for Cardiac Angiography and Interventions Clinical Expert Consensus Document on cardiac catheterization laboratory standards. A report of the American College of Cardiology Task Force on Clinical Expert Consensus Documents. J Am Coll Cardiol 2001; 37:2170–2214.

16 •• Mitchell EL, Furey P. Prevention of radiation injury from medical imaging. J Vasc Surg 2011; 53 (1 Suppl.):22S–27S.

This review article presents guidelines to prevent radiation injury during endovascular procedures. This review discusses the X-ray production, units of radiation exposure, and forms of direct and indirect exposures in regards to both the patient and the staff.

17 • Mitelman F, Johansson B, Mertens F. Mitelman database of chromosome aberrations and gene fusions in cancer. 2010 [updated 2010; cited 07 February 2011].

This manually collected data 'Mitelman Database of Chromosome Aberrations and Gene Fusions in Cancer' provides information on the relationship of chromosomal aberrations to tumor characteristics and it is based either on individual cases or associations.

18 Bashore TM. Radiation safety in the cardiac catheterization laboratory. Am Heart J 2004; 147:375–378.

19 Hall EJ, Brenner DJ. Cancer risks from diagnostic radiology. Br J Radiol 2008; 81:362–378.

20 ICRP. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann ICRP 2007; 37:2–4.

21 Vano E, Gonzalez L, Fernandez JM, Haskal ZJ. Eye lens exposure to radiation in interventional suites: caution is warranted. Radiology 2008; 248:945–953.

22 Worgul BV, Kundiyev YI, Sergiyenko NM, *et al.* Cataracts among Chernobyl clean-up workers: implications regarding permissible eye exposures. Radiat Res 2007; 167:233–243.

23 Klein LW, Miller DL, Balter S, *et al.* Occupational health hazards in the interventional laboratory: time for a safer environment. J Vasc Interv Radiol 2009; 20 (7 Suppl.):S278–S283.

24 •• Anastasian ZH, Strozyk D, Meyers PM, *et al.* Radiation exposure of the anesthesiologist in the neurointerventional suite. Anesthesiology 2011; 114:512–520.

This prospective study investigates the radiation exposure of the eye for the anesthesiologist during neuroradiologic procedures and recommends that anesthesiologists follow the practice of radiologists and wear leaded glasses to prevent cataracts when monitoring patients during neurointerventional cases.

25 • Vano E, Kleiman NJ, Duran A, *et al.* Radiation cataract risk in interventional cardiology personnel. Radiat Res 2010; 174:490–495.

This study is the first to demonstrate a statistically significant increase in radiation-associated posterior lens opacities in the eyes of interventional cardiologists compared with similarly aged unexposed controls.

26 National Council on Radiation Protection and Measurements. Radiation protection for medical and allied health personnel. NCRP 1989; NCRP Report No. 105.

27 National Council on Radiation Protection and Measurements. Implementation of the principle of as low as reasonably achievable (ALARA) for medical and dental personnel. NCRP 1990; NCRP Report No. 107.

28 ACOG Committee Opinion. Number 299, September 2004 (replaces No. 158, September 1995). Guidelines for diagnostic imaging during pregnancy. Obstet Gynecol 2004; 104:647–651.

29 McCollough CH, Schueler BA, Atwell TD, *et al.* Radiation exposure and pregnancy: when should we be concerned? Radiographics 2007; 27:909–917; discussion 917–918.

30 Best PJ, Skelding KA, Mehran R, *et al.* SCAI consensus document on occupational radiation exposure to the pregnant cardiologist and technical personnel. EuroIntervention 2011; 6:866–874.

31 Wakeford R, Little MP. Risk coefficients for childhood cancer after intrauterine irradiation: a review. Int J Radiat Biol 2003; 79:293–309.

32 • Williams PM, Fletcher S. Health effects of prenatal radiation exposure. Am Fam Physician 2010; 82:488–493.

With the endorsement of the Society for Cardiovascular Angiography and Interventions, this guidance document indicates that heritable or developmental risks to the fetus of pregnant interventional cardiology physicians and staff are extremely low, provided that good radiation safety practices are used and dose limits are respected.

33 Mehlman CT, DiPasquale TG. Radiation exposure to the orthopaedic surgical team during fluoroscopy: 'how far away is far enough?'. J Orthop Trauma 1997; 11:392–398.

34 Klein LW, Miller DL, Balter S, *et al.* Occupational health hazards in the interventional laboratory: time for a safer environment. J Vasc Interv Radiol 2009; 20:147–152; quiz 53.

35 Cousin AJ, Lawdahl RB, Chakraborty DP, Koehler RE. The case for radio-protective eyewear/facewear. Practical implications and suggestions. Invest Radiol 1987; 22:688–692.

36 ICRP. Radiologial protection education and training for healthcare staff and • students. 2010 [cited 19 February 2011]. http://www.icrp.org/docs/ICRP_Report-RP_Education_and_Training_for_Healthcare_Staff_and_Students(for_Consultation).pdf.
This document provides guidance regarding the necessary radiological protection education and training as well as its accreditation procedures.

37 Vano E. Mandatory radiation safety training for interventionalists: the European • perspective. Tech Vasc Interv Radiol 2010; 13:200–203.
Summary of the International Commission and the European Council recommendations on Radiological Protection and training for Interventional Radiology. The work carried out in this area and the training material produced by the International Atomic Energy Agency is also quoted.

38 IAEA. Diagnostic and interventional radiology. [cited 13 February 2011]. •• http://rpop.iaea.org/RPOP/RPoP/Content/AdditionalResources/Training/1_TrainingMaterial/Radiology.htm.
A training documentation regarding radiation protection from the IAEA.

39 Multimedia and audio-visual radiation protection training in interventional radiology (MARTIR), radiation protection 119. European Commission; 2002. Available from http://ec.europa.eu/energy/wcm/nuclear/cd_rom_martir_project.zip.