Training Users of Medical Radiation

Fred A. Mettler Jr. M.D., M.P.H.
Professor Emeritus, University of New Mexico
Department of Radiology
New Mexico Federal Regional Medical Center
1501 San Pedro Blvd., SE
Albuquerque, New Mexico 87108
1-(505) 256-5712
fmettler@salud.unm.edu

Abstract

Radiation has been used in medical practice for over a century. While hazards were recognized very early, radiation protection in medicine evolved over many subsequent decades. Current issues and problems of radiation protection in medicine are mainly the result of rapidly changing technology and lack of education. With the widespread application of computed tomography and digital radiography, use of high dose radiological equipment by non-radiologists and computerized high dose rate brachytherapy in radiation therapy there are new problems not envisioned before. Radiation protection in medicine is not likely to be significantly simplified with the addition of more standards but it will require a different approach with the medical communities than has been used in the past.

1. INTRODUCTION

Training in radiation protection receives little attention in most medical schools. It generally is included in medical specialty training. Even so, most radiologists and other physicians who use radiation in medicine do not have adequate training to appropriately protect patients. The speed of technological advances has been an additional problem. For example, currently many interventional cardiologists are performing long fluoroscopic interventional procedures due to very recent advances in coronary angioplasty, percutaneous stent placement and intravascular brachytherapy. These devices and techniques were developed long after many of these physicians had completed their
formal medical specialty training. This clearly points to the need for continuing education throughout the professional career. In many countries, the main source of post-graduate training is the professional societies through their meeting and journals. Currently there are a number of efforts by international groups including but not limited to the International Atomic Energy Agency (IAEA), International Commission on Radiological Protection (ICRP), and the World Health Organization (WHO) that provide the some materials and training in radiation protection.

One major hurdle in application of radiation protection and standards to the medical field is the sheer volume of procedures carried out annually. Worldwide, it is estimated that in the year 2000 there were about 2 billion diagnostic x-ray examinations, 32 million nuclear medicine examinations and 5.5 million patients treated with radiation therapy. While the exact number is not known, there are certainly in excess of several million persons who are administering radiation in one form or another. Reaching and educating these persons is essential. Accurate translation of the materials also has been a major problem. Probably, the most effective and cost efficient way to educate the medical community in radiation protection is through their professional organizations and journals.

2. BASIC ASPECTS OF RADIATION PROTECTION TRAINING IN MEDICINE

Radiation protection of workers and the public seeks to minimize dose by a number of methodologies such as ALARA (as low as reasonable achievable allowing for social and economic considerations). Protection of patients in during medical exposures has been recognized as requiring a different operational philosophy (ref 1). The most obvious difference is that the patient (who receives the absorbed dose) receives a direct personal benefit and that the patient, in most circumstances, gives consent to have the exposure. One can question the degree of informed consent but generally with high doses in radiation therapy there is explicit written consent while with lower doses and lower risks the consent may be verbal and less explicit. Minimal patient dose is not necessarily good and may even be harmful. In medical diagnosis too small a dose will not provide adequate information for diagnosis and overexposure of a film can result in an uninterpretable image. In radiation therapy, too low a dose will result in lack of cure of a tumor while too high a dose may result in serious complications including death. Thus the “correct” (not the minimal) dose should be the goal.

Radiation dose limits are not applicable to patients. Clearly, if a chest x-ray is indicated in a life-threatening situation, it should not be denied, even if the equipment is older and provides a higher than average dose. The use of reference values in medicine allows abnormally high doses to be identified and corrected or justified. Radiation risks in medical exposure range from minimal to fatal depending upon the specific setting. As a result, standards and educational programs need to range from minimal to very specific depending upon the potential consequences. Any radiation protection system in medicine must be integrated with the practice of medicine if it is to be effective.
The current philosophy of radiation protection in medicine includes the concepts of justification and optimization although they are applied somewhat differently than may occur in the case of occupational or public exposure. The initial idea is to justify a particular practice in medicine. Mammography may be thought of as a practice and can be justified by the fact that has more benefit than risk with regard to detection versus induction of breast cancer. Although the practice of mammography is justified in general, that does not imply that it is justified for all women. Justification also needs to be performed on an individual basis. For example, mammography is justified in a 50-year old female with a family history of breast cancer but it is not appropriate as a screening tool in a 30-year old asymptomatic female. After general and individual justification, optimization needs to take place. An example of this in medicine this would mean doing only the essential number of images to obtain the desired information.

3. CURRENT STATUS OF INTERNATIONAL RECOMMENDATIONS AND REQUIREMENTS FOR TRAINING

Before embarking on an analysis of the educational issues associated with radiation protection in medicine, it is instructive to review current international guidance on the topic. It will become apparent that most recommendations or regulations are very general. This lack of specificity means that most users and organizations are free to provide whatever education they set fit. As we shall see in later sections, this has not always been done and the enthusiasm for using new technology has often eclipsed radiation protection concerns.

The ICRP has discussed training as a theme in a number of documents. ICRP Publication 60 (ref 2) only has one general statement in section 7.3 on regulatory requirements in paragraph 237 as follows: “One important national and international need is to provide adequate resources for the education and training of future professional and technical staff in radiological protection. These resources cannot be provided by the regulatory agencies alone”. There is a similar paragraph related to medicine in ICRP Publication 73 (ref 1) paragraph 128 which states: “One important need is to provide adequate resources for the education and training in radiological protection for future professional and technical staff in medical practice. The training program should include initial training for all incoming staff and regular updating and retraining.” There are additional comments related to specific user oriented ICRP documents on computed tomography, fluoroscopically guided interventional procedures and radiation therapy.

The IAEA has also long recognized training as a particular need in the medical field. In Safety Reports Series No. 20 (ref 3) under section 2.5 related to health professionals it states;”The appropriate level of formal training for health professionals could, for example, be that corresponding to the practice and type of job, emphasizing the biological effects of ionizing radiation, together with specialized training in their field of work. Health professionals need to be acquainted with up to date information on the
diagnosis and treatment of radiation injuries and have well developed communication, leadership, analytical and human-machine interface skills as part of their professional training. Further training in radiation protection and safety would enhance these skills. The duration and depth of the specialized training depends on the level of responsibility and the complexity of the job of the health professional.”

The IAEA also has addressed education issues of health professionals in the Basic Safety Standards (BSS) (ref 4) in section 2.14 on authorization, registration or licensing where it states that :”The legal person responsible for a source to be used for medical exposure shall include in the application for authorization:

(a) the qualifications in radiation protection of the medical practitioners who are to be so designated by name in the registration or license; or
(b) a statement that only medical practitioners with the qualifications in radiation protection specified in the relevant regulations or to be specified in the registration or license will be permitted to prescribe medical exposure by means of the authorized source.

Also in appendix II on medical exposure of the BSS it states that;”Registrants and licensees shall ensure that:

- Medical practitioners be assigned the primary task and obligation of ensuring overall patient protection and safety in the prescription of, and during the delivery of, medical exposure;

- Medical and paramedical personnel be available as needed, and either be health professionals or have appropriate training adequately to discharge assigned tasks in the conduct of the diagnostic or therapeutic procedure that the medical practitioner prescribes;

- Training criteria be specified or be subject to approval as appropriate by the Regulatory Authority in consultation with relevant professional bodies.

And registrants and licensees shall;

(b) take all reasonable measures to prevent failures and errors, including the selection of suitable qualified personnel, the establishment of adequate procedures for the calibration, quality assurance and operation of diagnostic and therapeutic equipment, and the provision to personnel of appropriate training and periodic retraining in the procedures, including protection and safety aspects;

The IAEA has specifically addressed training in medical exposure in a 2002 Safety Guide (ref 5) as follows:
2.64 Depending on the facility’s complexity, the following staff should be trained in radiation protection and safety: radiation protection officers, appropriate senior administrators, members of the radiation safety committee, radiographers, radiologists, radiation oncologists, nuclear medicine physicians, technologists, medical physicists, maintenance personnel and ancillary personnel, as appropriate. Nursing staff attending to patients undergoing medical exposures should be given appropriate training. The level of this training will depend on the specialization of the individuals, their academic background and previous experience. Examples of training recommendations in radiation protection and safety are given. Requirements for training criteria are given in the BSS.

2.65 Registrants and licensees should be able to demonstrate proof of such training to the regulatory authority, particularly when applying for an authorization for a facility. Some regulatory authorities may choose to issue personal authorizations to individual medical practitioners or other health professionals as a way of formally acknowledging adequate training in radiation protection and safety.

2.66 If registrants and licensees cannot demonstrate that their staff are adequately trained, the regulatory authority may consider requesting applicants to take an examination or attend a supplementary training course provided by an appropriate educational institution or professional body. However, the implications of time off work and financial costs should be taken into consideration especially when several persons at one facility are involved in administering medical exposures.

Further guidance on training in diagnostic radiology as follows:

3.31. Training is required for all persons involved in the use of X-rays on humans for diagnostic purposes. The degree of training depends on the type of work and degree of responsibility, and should be provided to the following persons:
- The physicians who are responsible for individual justification and conducting the exposures
- Physicians in training who perform procedures under the supervision and responsibility of such physicians;
- Radiation technologists or equivalent staff.

The regulatory authority should encourage health authorities, universities and professional associations to design and implement education and training programmes in radiation protection and safety for professional staff involved in diagnostic and interventional radiology.

3.32. The extent of medical knowledge required of persons involved in X-ray procedures varies and may include the whole field of X-ray diagnosis (e.g. radiologists) or a subspecialization (e.g. orthopedic surgeons, traumatologists and cardiologists). The training of health professionals in relation to diagnostic radiology should include specific medical and radiation protection topics.
3.33. Specific training in radiation protection should be planned for specialists performing special procedures such as fluoroscopy, pediatric radiology or interventional radiology.

Guidance on training in nuclear medicine appears as follows:

4.24. The regulatory authority should encourage health authorities, universities and professional organizations to design, implement continuing education and training programs in radiation protection and safety for nuclear medicine specialists, physicists, technologists and other professional staff involved in the practice of nuclear medicine. Such programs for nuclear medicine should include radiopharmaceutical biokinetics and dosimetry, elution of generators, contamination control, waste management, waste prevention and the management of incidents and accidents.

Guidance on training in radiation therapy is given in 3 paragraphs as follows:

5.23. The regulatory authority should encourage health authorities, universities and professional organizations to design, implement training programs on radiation safety aspects for radiation oncologists, qualified experts in radiotherapy physics, radiotherapy technologists, dosimetrists and maintenance personnel. Training curricula can be found in several references (refs 6,7) Hospital administrators who allocate resources should be trained on the implications of their decisions on protection and safety in medical exposure.

5.24. To meet provisions of the BSS, training criteria should be specified or approved by the regulatory authority in consultation with professional bodies, for example the professional bodies for radiation oncology and medical physics. Radiation safety aspects should cover radiation modalities, facility design, the characteristics of the safety features of sources and source related equipment, dosimetry, instrument calibration, treatment planning, radioactive waste disposal, accident prevention and emergency (including medical) procedures to deal with general and medical emergencies. The training should include lessons learned from past accidental exposures.

5.25. Basic education should be followed by continuing education, particularly when a new treatment modality or a different type of equipment is considered.

The European community has addressed the issue of training and education in EURATOM Council Directive 97/43 (ref 8) on health protection of individuals against the dangers of ionizing radiation in relation to medical exposures has requirements for training in Article 7 that states:

1. Member states shall ensure that practitioners and those individuals mentioned in Articles 5 (3) and 6(3) have adequate theoretical and practical training for the purpose of radiological practices, as well as relevant competence in radiation
protection. For this purpose Member States shall ensure that appropriate curricula are established and shall recognize the corresponding diplomas, certificates or formal qualifications.

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

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

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

Also in article 9 of the same directive it states that: ‘Member States shall ensure that appropriate radiological equipment, practical techniques and ancillary equipment are used for the medical exposure
-of children
-as part of health screening program
-involving high doses to the patient, such as interventional radiology, computed tomography or radiotherapy

4. ANALYSIS OF ROOT CAUSES OF SOME CURRENT ISSUES

The real question is “What is wrong with the current educational process and what are the problems that need to be fixed?” If there truly are problems, it is important to answer the question whether the educational materials were not required, not available or inadequately distributed or even whether something else was responsible. A useful exercise is to examine radiation protection problems that have arisen in medicine over the last several years to see the root causes. A major issue has been rapid development of new technologies, lack of integration of radiation protection issues with training in the use of new technologies and the lack of regulations and standards to keep up. During the last decade there has been rapid expansion of complex interventional procedures using fluoroscopy. A classic example of such a procedure is percutaneous transluminal coronary angioplasty (PTCA) with dilatation of a narrowed coronary artery using a balloon catheter and then placement of a wire stent to keep the artery open. Almost a decade ago, the U.S. Food and Drug administration issued a warning that due to the high dose rates and long procedure times there was a very real possibility of injuries to the patient in the form of skin burns (ref 9). In spite of this, there have been continued injuries with large areas of ulceration and necrosis requiring surgical grafting (figure 1). The cause of these injuries is not a lack of standards but rather a lack of education and understanding of radiation effects and radiation protection by physicians who are performing these procedures (refs 10-13).

Computed tomography (CT) has been recognized as a relatively high dose procedure for over a decade. The doses to tissues from computed tomography (10-100 mSv) can often approach or exceed the levels known to increase the probability of
cancer. This was not regarded as a major problem because the high cost, slow scan times and other factors limited the CT use to patients who were quite ill and exposure to limited parts of the body. In the last decade, however, there have been major advances in equipment design that has reduced scan times from 30 minutes to seconds. As a result, more patients can be scanned and physicians faced with a patient who has major trauma will often order a CT scan of the head, neck, chest, abdomen and pelvis. The patient is rapidly and effectively treated but there has been little regard on the part of the manufacturers and physicians to dose reduction. Currently, in some radiology departments, CT scans have grown to 11% of the total procedures but contribute over 70% of the dose (ref 14). Newer CT techniques have often increased doses when compared to standard CT. Many practical possibilities currently exist to manage dose the most important of which is reduction in mA. Automatic exposure control would be the most helpful improvement in CT equipment for dose management. Only recently, with public attention to the matter, have manufacturers begun to include automatic exposure control and other devices that have the potential to reduce doses. In the last 2 years, there has been another new use for CT, the annual screening examination. This use is becoming widespread although the efficacy is in question. Referring physicians and radiologists should make sure that the examination is indicated. (ref 15).

The CT dose and use problem has been highlighted by uses in pediatric radiology. Often adult exposure factors have been used on children with no regard to increased sensitivity of children to radiation carcinogenesis (refs 16-17). The problem has existed for years even when children get typical radiographs. Pediatric patients should have specific protocols with lower exposure factors (especially mAs). If there are dedicated pediatric protocols and trained pediatric x-ray technologists doses are often much lower than when a routine technologist is faced with a child. Often there is little or no collimation employed and repeat examinations may be necessary due to improper exposure factors. The radiation protection problems with CT are primarily due to lack of education and training and lack of customer demands on the manufacturers to produce acceptable images at lower patient doses.

In many radiology departments, film is being replaced by digital techniques with images being stored and displayed on a picture archiving system. Basic training in managing image quality and patient dose in digital radiology is necessary for radiologists, medical physicists and radiographers involved in the use of digital techniques (ref 18). Unfortunately, most digital systems are installed with little or no training in radiation protection aspects. In digital radiology, higher patient dose per image usually means improved image quality. However, there is a tendency with digital systems to use higher patient doses than necessary. This increase should be avoided. With film radiography and under or overexposed film is easy to recognize. With digital systems, the parameters are often set higher than necessary and overexposures are immediately compensated by “windowing” the image. Thus, there is the distinct possibility of increased dose (up to a factor of ten or more) with no added benefit to the patient and the problem not being recognized. Many of the current digital image displays give no indication of the patient dose or exposure factors. Even when some “dose index” is displayed the value is often not linearly related to the actual dose and the quantities provided are not standardized
between manufacturers. Patient dose parameters should be displayed at the operator console (and inside the x-ray room for interventional procedures) to allow radiographers and medical specialists to manage patient doses better. Local diagnostic reference levels (DRLs) are useful tools to manage patient doses in medical imaging tasks. DRLs for non-digital imaging tasks are not necessarily applicable to specific, similar digital imaging procedures.

With digital fluoroscopy systems it is very easy to obtain (and delete) images and there may be a tendency to obtain more images than necessary. This would irradiate the patient more than is clinically necessary. Procedure protocols should be agreed to manage this problem. There are other potential problems with digital techniques. The number of pulses or exposures is not evident when viewing the final images. One can easily set a sequence that provides much more exposure than is necessary. In addition, the radiologist now often interprets the images from a remote location and is not on hand to supervise the technical portions of the examinations. The possibility of overexposures may potentially be controlled by regulations requiring some assessment of reference values for a specific set of examinations. In the United States this was effective for film screen mammography but even those standards and regulations have been outdated by the recent development of digital mammography.

An additional issue related to digital radiography has also just become apparent. The convenience with which the referring clinicians can view the image and the radiologists report on their office or desktop computer appears to have substantially increased the incidence of examinations being performed of a given set of patients. This raises the question of whether all the examinations are truly justified. Justification criteria should be one of the key components considered in the update of a quality assurance program when a facility converts to digital imaging. As with CT, the issues in digital radiology are primarily related to a rapidly expanding technology and lack of training.

There are some current radiation protection issues in nuclear medicine as well. For many years there have been standards (limits or constraints) that related to exposure of the public or family members when patients who have received radionuclide therapy are released. The regulations and suggested restrictions in many countries and states are distressingly variable. In some countries in Europe, patients are required to be hospitalized for days, but not in other European countries. This has resulted in what some have termed “nuclear therapy tourism” where patients go to the country with least restrictions for their treatment. In the United States, most cooperative patients are not hospitalized at all. What is the cause of this variation? It certainly is not lack of a clear standard, but rather use of models that are ultraconservative and societal misunderstanding about radiation effects, rather than using actual measurements to demonstrate compliance with standards (ref 19).

Radiation oncology also has had its share of problems. In spite of a plethora of standards there have been continuing radiation therapy accidents, resulting in the deaths of a number of patients (ref 20). A recent accident in Costa Rica was due to a manual miscalculation of the beam output. There was no secondary calculation as suggested by
international standards. In fact, the root cause was multi-factorial with lack of adequate training of the physicist, lack of application of existing international standards/recommendations and physicians and technologists who were trying to treat too many patients with too little equipment (ref 21). Another accident in Panama was due to treatment planners using a computerized planning system in a way that was different from that defined in the manual. In fact there were trying to use it in a way that they though would provide additional patient protection.

5. CURRENT EFFORTS AND POSSIBILITIES FOR THE FUTURE

The IAEA has recently published a Safety Series Report (No. 20) (ref 3) on training in radiation protection and the safe use of radiation sources. The report discusses classroom, distance learning and on the job training as the major types of training. It also covers development of training objectives, syllabus development, training schedules, lesson plans, materials, practical sessions, assessment procedures, training facilities, selection of participants and selection of trainers and supervisors. While this type of training pertains to nuclear power plants and other types of regulated facilities, it is not likely to work well in most medical settings.

Justification and optimization are part of the normal practice of medicine and pose no conceptual or real problems. One difficulty is that “recommendations” of organizations such as the ICRP rarely if ever find their way to a physician’s desk. In addition, the medical community generally has little interest or time to spend attending courses on radiation protection. Reference, action and investigation levels and their implementation is usually relegated to the medical physicist at the institution. Unfortunately, there are many physician’s offices that have medical x-ray equipment and are visited rarely, if ever, by a medical physicist.

Recently, there was an international conference on the radiological protection of patients in diagnostic radiology and interventional radiology, nuclear medicine and radiotherapy (ref 22). The findings of the conference were incorporated into an international action plan for radiation protection of patients. The plan has training and education actions common to diagnostic and interventional radiology, nuclear medicine and radiotherapy as follows:

- to complete the development of a standard syllabus and packages for training in the application of safety standards.
- to train the trainers involved in national training programmes using the above mentioned packages.
- to arrange for a review of the syllabus for the Agency training courses in medical radiation physics by appropriate professional bodies and to publish the results.
- to explore the potential uses of information technology and distance learning, identifying application areas and types of information technology.
- to explore mechanisms for widely disseminating information related to the protection of the patient.
- to collect and disseminate, using the IAEA’s International Reporting System for unusual radiation events, information about accidental medical exposures, including, as far as possible, information about events that did not have clinical consequences but from which prevention-relevant lessons can be drawn.
- to support Member States in the gradual transition from the basic to advanced stages of implementation of the BSS.
- to promote the formal recognition of medical physicists responsible for the radiological protection of patients as health professionals.
- to promote - through the provision of advice about the functions, responsibilities and training of technologists - recognition of the impact of technologists involved in day-to-day procedures on the radiological protection of patients.
- to continue current activities in radiotherapy concerned with the traceability of dose measurements and with audit services, including the development of local expertise, and to extend these services to diagnostic radiology and nuclear medicine.
- to finalize the existing draft practice-specific guidance documents, seeking input from professional bodies, international organizations and national authorities responsible for the radiological protection and medical care of patients.
- to provide guidance to donors, recipients and NGOs on the safety issues related to the transfer of second-hand equipment.

The ICRP, through Committee 3, has developed a new philosophy and approach relative to training of specific aspects of radiation protection in medicine. It was realized that most physicians would not want or read a text on radiation protection per se but that they would read short documents related to specific issues, particularly in areas of new technology. As a result, documents have been recently published on

- Pregnancy and medical radiation
- Management of dose in transition from film screen to digital radiography
- Dose management in computed tomography
- Release of patients after therapy with both sealed and unsealed radionuclides
- Prevention of accidents in radiotherapy
- Special aspects of high dose rate brachytherapy

In spite of current educational efforts there remain significant problems. Many current international recommendations do not adequately stress the importance of training in radiation protection and many countries continue to allow physicians to use high dose rate equipment simply by virtue of their credentials as a physician. Currently, the ICRP has a task group examining the issue of training and possibly certification for some
groups of medical users. One must remember that training the physician users of medical radiation equipment alone is not adequate. There also must be adequate training of the radiographers and other technologists who often are the actual operators of the equipment.

In addition to international efforts, there also are a number of national efforts regarding radiation protection training in medicine. One very successful national program is in Spain (refs 23-24). In 1999, a Royal Decree was published for criteria for quality in radiodiagnosis which complemented an earlier decree dealing with medical radiation exposure (refs 25-26). These decrees require that professionals who perform interventional practices guided by fluoroscopy be accredited at a “second level” of training in matters of radiological safety. Toward this end a 20 hour course was developed by the Spanish Society of Vascular and Interventional Radiology to meet the requirements of the European Guidelines (refs 27-28).

5. SUMMARY AND CONCLUSION

There are a number of current concerns regarding radiation protection in medicine. Quite a number of these issues have arisen due to rapidly advancing technology and the pressure to get new techniques into clinical practice. Unfortunately, the clinical pressure has often eclipsed appropriate training in the radiation protection aspects. While there are some educational materials available, there dissemination is often poor unless they were developed with and distributed by professional societies. At the present the most successful strategy appears to be to develop concise and technique specific user related documents and have them published in medical journals. There are current international efforts to examine whether there should be training and educational recommendations/standards for individual authorization that might be required for medical staff to use new (and particularly high dose) equipment.
References


