Potential biological damage from radiation received during fluoroscopy procedures is of particular concern because of the high volume and variety of procedures performed and the increasing length of radiation exposure. This article focuses on the effects of low-level radiation, gaps in education and skills among personnel performing and assisting with fluoroscopy, the certification and privileging of fluoroscopy personnel, and compliance with radiation protection practices.

After completing this article, the reader should be able to:
- Summarize the goals of radiation protection and factors affecting those goals.
- Discuss the history of radiation protection and recent efforts to improve radiation safety.
- Identify how referring physicians, fluoroscopy operators, and radiographers can contribute to limiting radiation dose to patients.
- Explain how the education and compliance of personnel performing and assisting during high-dose fluoroscopy can be improved and regulated.
- Provide examples of how radiographers can improve fluoroscopy education and patient safety by using radiation protection skills.

“The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease.”

The goals of radiation protection in fluoroscopy for both the patient and the medical personnel involved are to minimize the possibility of deterministic health effects and help keep the probability of stochastic health effects from ionizing radiation as low as reasonably achievable (ALARA).

Deterministic effects from radiation exposure are biological changes that occur in the body and manifest after a relatively short latent period of days, months, or years. Latent period refers to the time after exposure during which there are no signs of illness or damage. With deterministic effects, the severity of the biologic response increases as the dose increases. A threshold dose of radiation generally exists, meaning the radiation dose level must be reached before the damage is observed. Deterministic effects include local tissue damage, hematological depletion, cytogenetic damage, and, in severe cases, acute radiation syndrome. Acute radiation syndrome seldom occurs as a result of fluoroscopically guided procedures; however, local tissue damage in the form of skin burns, dermatitis, and epilation is possible.

Stochastic effects can occur as a result of radiation-induced damage to the DNA of cells, leading to malignant conditions. The threshold dose is independent of the absorbed dose. The probability of a malignancy is influenced by the person’s age at the time of exposure, sex, and personal susceptibility to cancer. Health care personnel should have a higher relative concern for possible stochastic effects in pediatric patients who undergo fluoroscopically guided procedures. It is impossible to calculate
the amount of radiation exposure children might receive in a lifetime, and the potential to live a very long life increases their risk for stochastic effects. Standard practice in radiation protection is to be cautious and assume that even small radiation doses can be harmful.

**Factors That Affect Radiation Protection Goals**

In clinical practice, a complicated set of issues affects the overall goal of radiation protection. Health care professionals should seek a balance between the dose delivered and the reason for the procedure, including how the procedure is likely to affect the patient outcome. The greatest benefit to the patient should result in the lowest risk of radiation exposure to the patient. In addition, radiation protection practices also affect the amount of radiation exposure to medical personnel during procedures. The physician must assess the technology available and evaluate how the technology affects the outcome of the procedure and the overall radiation dose to the patient, as well as all personnel participating in the procedure. Modern fluoroscopic equipment offers a variety of modes and image quality options and can deliver very high radiation doses for long periods of time. Decisions about mode selection and the type of image quality sufficient to perform the procedure influence the amount of radiation used. For example, the anatomical area of interest can be magnified, but magnification results in an increase in dose. Also, images can be recorded at different rates, with various levels of image quality on a variety of recording devices. The use of pulsed fluoroscopy or last-image hold can decrease patient dose. Exposure to the patient, operator, and personnel assisting with the procedure can be affected greatly by the availability of these options and, more importantly, by whether the operator understands the equipment and uses these options appropriately. For example, a cardiologist would never consider placing a stent in a patient using an extremity C-arm, nor would an orthopedic surgeon need to use a fluoroscopic unit that records rapid frames per minute and magnifies the anatomy tenfold.

The use of fluoroscopy for interventional procedures has increased in areas outside of imaging centers. It is now common for cardiologists, orthopedic surgeons, vascular surgeons, pain specialists, and gastroenterologists to perform fluoroscopically guided procedures and medical interventions. The practice of allowing registered radiologist assistants (R.R.A.s) and radiologist practitioner assistants to perform fluoroscopically guided procedures also has been established, and many physician specialists, including radiology residents, are performing fluoroscopically guided procedures very early in their rotations. Some states recognize the use of radiologic technologists and other medical personnel to perform fluoroscopy.

Radiation risks to patients, such as skin injury from highly complex interventional neuroradiology procedures are possible. However, methods to ensure proficiency among all members of the health care team in performing and assisting during fluoroscopy with optimal radiation safety might be lacking.

**Historical Background**

More than a century has passed since the dangers of radiation were discovered. The first American fatality resulting from radiation exposure was Clarence Dally, Thomas Edison’s assistant, who was reported to have spent hours experimenting in front of a fluoroscope. Early radiologists lost digits from local tissue damage, and early fluoroscopy patients developed skin burns as a result of overexposure. Past research focused on the potential biological damage from acute exposure to ionizing radiation based on data on atomic bomb survivors, early radiologists, and accidents that involved high acute exposures to radiation.

Historically, radiation protection concepts, practices, and equipment regulations were developed and revised as new information became available. Early regulations for fluoroscopic equipment focused on equipment safeguards to prevent overexposure of medical personnel to radiation. Although early work has brought about improvements regarding medical radiation exposure, the amount of radiation exposure from medical procedures in the United States has increased as more procedures are being performed, and the issues related to minimizing radiation exposure during those procedures are more complex. The practice of using fluoroscopy for image guidance is becoming more routine. The variety of
medical personnel performing and assisting during fluoroscopic procedures has increased, and many have limited education in radiation protection. Fluoroscopy equipment has become more complicated to operate, with frequent upgrades and options being added as new technology is developed. The options often provide methods of improving image quality with an effect on radiation dose that the operator might or might not understand. Moreover, high patient volumes limit time for personnel training on new and upgraded equipment.\cite{9,15}

Radiation protection practices were lacking prior to 1950, and as a result occupational radiation exposures were higher than they are reported to be today.\cite{14,15} Radiographers regularly held patients during exposures to decrease motion, and many radiographers reported holding patients during 50 or more exposures. In addition, radiographers could begin working in the field before the age of 17 years, and fluoroscopic radiation exposure equipment regulations were not in force.\cite{15,16}

Skin injuries due to overexposure to radiation were common before the 1930s.\cite{9} In 1949, the first study was published demonstrating an increased incidence of cataracts in physicists who worked with cyclotrons, devices capable of increasing charged particles to very high energies.\cite{2}

Over time, radiation protection concepts changed significantly as the National Council on Radiation Protection and Measurements (NCRP) became active, publishing 19 reports regarding protection practices.\cite{8,16} The 5 rem (0.05 Sv) annual dose limit for radiation workers was established in 1959 by the International Commission on Radiological Protection (ICRP) and remained unchanged until 1977.\cite{12}

After 1977, radiation protection theory and practice focused on the risk vs benefit concept, the practice of ALARA, the methodology of justification, and radiation protection practices that would ensure optimization.\cite{11} Fluoroscopic equipment regulations assisted in decreasing radiation exposure during fluoroscopy.\cite{10} Reports of radiation-induced skin injuries decreased until the number of interventional procedures began to rise, replacing surgical interventions. Newer examinations required longer fluoroscopy times and an increase in the number of images recorded.\cite{9}

In 1982, the U.S. Radiologic Technologists Study began with a collaborative team that included the National Cancer Institute (NCI), the University of Minnesota, and the American Registry of Radiologic Technologists (ARRT).\cite{15} The team continues to collect and analyze information about radiation exposure levels, enabling researchers to investigate the probable biological effects of radiation exposure, including malignancies, radiation-induced cataracts, and local tissue damage. Results are periodically released as new data on radiographers’ health are collected. The study continually requests radiographers’ participation on its Web site.\cite{15}

**Recent Developments**

In 2006, the U.S. population received 7 times more exposure to ionizing radiation from medical imaging when compared with the early 1980s. Medical exposure accounts for nearly one-half the total radiation exposure that individuals receive in a lifetime.\cite{17} Fluoroscopically guided procedures are being performed for a variety of diagnostic and therapeutic purposes by many different specialties and medical personnel and in a number of settings (see Box 1).\cite{5}

Evidence of a lack of knowledge regarding radiation protection practices became a focus of concern between 2004 and 2008. This concern encompassed all medical personnel involved with fluoroscopy, including specialty residents and fluoroscopy operators other than

**Box 1**

**Locations Within the Hospital Where Fluoroscopy Is Performed**

<table>
<thead>
<tr>
<th>Operating suites</th>
<th>Cardiac catheterization labs</th>
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<tr>
<td></td>
<td>Electrophysiology labs</td>
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<td></td>
<td>Cardiac intensive care</td>
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<td>Trauma patient evaluation in the emergency department</td>
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<td>Endoscopy rooms</td>
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<td></td>
<td>Pain management clinics</td>
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<td>Bronchoscopy rooms</td>
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<td></td>
<td>General fluoroscopy rooms</td>
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<tr>
<td></td>
<td>Interventional radiology suites</td>
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<tr>
<td></td>
<td>Computed tomography fluoroscopy</td>
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<tr>
<td></td>
<td>Cone-beam (3-D) fluoroscopy</td>
</tr>
<tr>
<td></td>
<td>Urology clinics and operating rooms</td>
</tr>
</tbody>
</table>
radiographers who play a critical role in the management of medical exposures.5,18-20

In addition to awareness and knowledge of radiation protection practices, compliance with practices became an issue.18-20 Although a medical professional has been trained in radiation protection practices, he or she might not consistently follow them. This might be due to a lack of continuing education as opposed to a lack of initial training and experience. Once personnel are trained, managers should conduct routine evaluation of staff compliance and emphasize continuing education to ensure that they continue to use radiation protection practices.18

In the past 14 years, the focus on radiation protection has shifted, with attention directed toward the following concerns:1,3-6,9,11,13-15,18,19,22:
- How the educational background of personnel in fluoroscopy might contribute to overexposure of patients and personnel.
- Quality management of education and equipment.
- Long-term, low-level occupational exposure.
- Radiation-induced cataracts in fluoroscopy operators.
- Skin injuries acquired during fluoroscopy.

Emphasis on reducing exposure is becoming more holistic, involving all of the medical personnel who care for patients and the patients themselves. Education and compliance with protection standards is accepted as the core for success.

The increase in medical radiation exposure was formally recognized by the NCRP in 2009 with the publication of report No. 160, which established specific recommendations for facilities that perform fluoroscopic procedures. The NCRP recommends fluoroscopy training and credentialing for all operators. Training should include the dangers of radiation and proper protection management using features available on the equipment. Physicians should be equipped with the knowledge and skills to make decisions about radiological examinations based on needs and risks.17

In 2010, the U.S. Food and Drug Administration (FDA) Center for Devices and Radiological Health created an initiative to reduce unnecessary radiation exposure from medical imaging. The FDA emphasized justification and optimization in the protection of patients and monitoring facilities with quality assurance programs. Patients should be assured they are receiving the right imaging examination at the right time and with the right radiation dose.22

For facilities that participate in the Medicare program, the Centers for Medicare and Medicaid Services established minimum standards for hospital radiology services and accreditation requirements for free-standing advanced diagnostic imaging facilities. These standards include physicians and nonphysician practitioners who provide the technical component of advanced imaging services.

In response, the NCRP released report No. 168, Radiation Dose Management for Fluoroscopically-Guided Interventional Medical Procedures. This report focuses on the use of fluoroscopic systems as a tool for guiding diagnostic and therapeutic procedures.10 The American College of Radiology (ACR) developed appropriateness guidelines for physicians selecting fluoroscopy procedures to help them minimize radiation exposure to patients and operators and contain costs.23 The guidelines match patient conditions with appropriate imaging examinations.

The FDA also is promoting the use of automated decision support systems. Electronic health records should include complete information on the patient’s imaging history to assist the physician in selecting the appropriate examination. With automated ordering systems, the physician selects from a list of patient symptoms and medical history and an appropriate examination is suggested, starting with the most basic procedures and continuing with more complex procedures. Examinations also are matched to an authorization code approved by Medicare.10

**Occupational Exposure Risk**

**Low-Level Dose Risks**

Most occupational exposure of diagnostic imaging personnel occurs during fluoroscopy and mobile radiography, especially during interventional and other fluoroscopically guided procedures.2 Radiographers who operate fluoroscopy equipment receive higher exposures than do other radiographers primarily because of longer exposure times and close proximity to the radiation source.2
One of the earlier studies on risk estimates for hematopoietic malignancies in medical radiation workers who had protracted low-to-moderate occupational exposure demonstrated an increased risk for nonchronic lymphocytic leukemias decades after the initial radiation exposures. This study examined more than 270,000 radiologists and radiologic technologists from various countries. The most reliable finding was increased mortality as a result of leukemia in workers who were employed before 1950.

Another study on mortality rates in interventional radiographers revealed no difference between radiographers performing other studies and radiographers performing interventional radiology studies. The study followed 88,766 U.S. radiologic technologists over the course of approximately 8 years. The authors collected information on work experience, types of procedures, protective measures, medical and family history, as well as lifestyle choices. Over the course of the study, there were 3581 deaths. Of this number, 1209 were from malignancies and 979 were from circulatory system diseases. However, the authors did not find a significantly increased mortality risk in radiologic technologists who reported performing a high number of interventional radiography procedures. Nevertheless, they stated the findings should be interpreted “cautiously” because of the short follow-up period. A 2006 study of breast cancer incidence in U.S. radiographers found no direct relevance of the effects of long-term, low-level exposure on breast cancer.

The most concerning conclusions regarding radiographer practice and number of years worked were for radiographers in the field before 1950 who worked for 5 or more years and repeatedly held patients during exposure for diagnostic studies. Among those technologists, there was an increase in relative risk for the category that included leukemia, multiple myeloma, and lymphoma. In addition, breast cancer incidence was increased 2.9 times, thyroid cancer had an elevated risk of 1.5 times, nonmelanoma skin cancer was increased 2.2 times, and melanoma risk was increased over all. The breast cancer increase was most prevalent for those who worked before 1935 and significantly elevated for those who worked before age 17. Breast cancer risk was higher for technologists who worked 5 or more years and held 50 patients or more. Genetic and lifestyle factors were not included in the study.

**Radiation-Induced Cataracts**

Through observations and animal experiments, researchers determined that the lens of the eye is radiosensitive and the sensitivity is age dependent. Sensitivity increases with age, requiring shorter latent times as an individual ages. Latent periods range between 5 and 30 years, with the average time until development being 15 years. The dose-response relationship for radiation-induced cataracts was thought to be a nonlinear threshold, meaning there is a dose of radiation required to reach the point at which cataracts appear and the effect does not become worse as the dose increases. The exact threshold amount has been difficult to assess.

Recently, research has suggested that the threshold for an acute exposure is approximately 2 Gy, with 100% of those irradiated developing cataracts after a 10 Gy exposure. In the past 5 years, concern has increased regarding eye and extremity exposure of fluoroscopy operators and other personnel who assist during examinations requiring long exposure times. A demonstrated increase in incidence of cataracts among staff involved with interventional procedures, specifically cardiologists, has been attributed to the lack of education in radiation protection practices among cardiologists.

A study of U.S. radiographers over a period of 20 years suggested that the lowest cumulative ionizing radiation dose to the lens of the eye that can produce a progressive cataract is approximately 2 Gy. As a result of epidemiological evidence, the ICRP has reduced the recommended maximum dose to the eye lens by almost eightfold. The commission currently recommends an equivalent eye dose limit of 20 mSv per year, averaged over 5 years, with no single year exceeding 50 mSv.

Best practices to protect and minimize dose to the lens of the eye include the use of ceiling-suspended screens, wearing leaded-glass eyewear, positioning the x-ray tube below the table as far away from the patient as possible, and the operator being properly trained in fluoroscopic technique. For maximum eye protection, operators must position themselves as far as possible from the source of radiation and at a right angle to the area where scatter is most likely to occur. The use of leaded...
glasses has a significant effect on the amount of radiation the eye receives, reducing dose by a factor of 5 to 10. Scatter-shielding screens alone can reduce the dose rate by a factor of 5 to 25. Using both of these practices can reduce eye exposure by a factor of 25 or more.11

Fluoroscopy Education

Lack of education and training for a variety of health care professionals can affect fluoroscopy radiation exposure to patients and personnel. Referring physicians, medical students, specialty physicians, residents in training, all medical personnel assisting with fluoroscopy procedures, equipment manufacturers, and medical physicists contribute directly or indirectly to patient and personnel exposures.1,6,34 Routine performance of fluoroscopy procedures in areas other than medical imaging departments has evolved over time and might have outpaced the standards, licensing, and granting of fluoroscopic privileges.1 As a result, some fluoroscopy operators have not received proper training in radiation protection and the principles of balancing image quality with the examination or procedure being performed.5

If fluoroscopy operators place a higher value on image quality than minimizing radiation dose when selecting or using fluoroscopy equipment, the practice can unnecessarily increase the amount of radiation exposure to patients and staff involved with the procedure. The personnel operating the equipment might not have had any training in radiation protection practices or could underestimate the amount of exposure received.6 Radiation exposure levels from the same procedure and with similar patient conditions can differ dramatically between institutions.1 Referring physicians might select the procedure that delivers the highest amount of radiation exposure without considering other, nonionizing procedures; radiology residents might not be supervised properly or trained on the operation of fluoroscopic equipment as it relates to dose; and other medical personnel who are involved with the procedures might not practice basic radiation protection skills.6

Improving Education in Fluoroscopy

The ICRP, FDA, NCRP, NCI, and the American Association of Physicists in Medicine (AAPM) are focusing efforts on reducing unnecessary radiation exposure through radiation education, certification, and compliance by establishing initiatives, recommendations, standards, and guidelines.5,6,10,35-37 NCRP recommendations for all facilities performing fluoroscopic procedures include ensuring that all16:

- Operators of fluoroscopy systems are trained and understand the operation of the equipment and the implications of radiation exposure from each mode of operation.
- Physicians performing procedures using fluoroscopic equipment are trained and credentialed.
- Credentialed operators can assess risks and benefits for individual patients.

In October 2010 an ICRP committee specifically addressed education and training in radiation protection for diagnostic and interventional procedures. Its recommendations included topics in each area of radiation protection, suggested number of teaching hours, and syllabi examples.6,38 The education and training must be planned, clinically relevant, and ensure that optimal radiation protection for patients and medical personnel emphasizes performing procedures competently. This is an invaluable guide for any educational institution, medical school, or department that performs fluoroscopic procedures.6

The ACR recently revised its technical standards for the use of radiation in fluoroscopic procedures, establishing qualifications, responsibilities, and credentialing of personnel who perform fluoroscopy. The standards address the issue of necessary education for all medical personnel involved with fluoroscopic procedures including the1:

- Referring physician and medical students who order procedures.
- Physicians and other operators of fluoroscopic equipment.
- Radiographer or other medical personnel assisting with the procedure.
- Physicist who plays a key role in the quality management of equipment and education.
- Equipment manufacturer personnel who train and educate users during new equipment installations and upgrades.
Education and training for medical staff should be promoted by regulatory and health authorities, with programs implemented at universities, health care educational programs, and hospitals. The educational requirements for each professional must be determined, and the depth of education should depend on the level of involvement. Education should start at the beginning of the career pathway and continue at regular intervals, building concepts and understanding. A health professional needs a thorough understanding of many radiation protection topics that will become a routine part of his or her clinical practice. Methods of educational delivery must be established, and a system of periodic evaluation of radiation protection practice skills is needed to ensure competence.

Because a variety of operators perform fluoroscopy and have varying types and degrees of education, a system should be established to identify operators’ current competency levels and offer educational opportunities that are easy to access and require a reasonable time commitment. Local credentialing processes should include a review of personnel training records on fluoroscopic procedures performed in the past and any education that pertains to fluoroscopy.

Physicians must comply with all applicable state and federal laws in addition to institutional policies for fluoroscopy licensure and certification. The directive for compliance can come from the medical board of the hospital, the state licensing bureau, or other regulatory bodies. The medical board has the responsibility to ensure physicians’ compliance. The fluoroscopy credentialing program must specify who is eligible to operate fluoroscopic equipment and who has the responsibility to review operators’ credentials. Hospitals and departmental administration should reinforce the need for training and support opportunities for instruction (see Box 2).

**Educational Needs of Professionals Involved in Fluoroscopy**

Medical Students and Referring Physicians

The referring physician and the fluoroscopic operator have the most control over ensuring that the patient does not receive unnecessary examinations. Ordering

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**Box 2**

**Resources for Health Care Personnel Involved in Fluoroscopy Procedures**


the appropriate examination and considering nonionizing options are critical responsibilities of the physician. The physician must be knowledgeable about the procedure and have some understanding of the radiation dose amount. Research has demonstrated that a large number of physicians of various backgrounds need to improve their knowledge of radiation exposure.34,38-41

Cardiologists prescribe the majority of medical imaging examinations, but their radiation protection awareness is low.39 Pediatricians have been found to lack radiation protection awareness and often underestimate relative doses and risks. Many physicians do not realize that fluoroscopically guided procedures increase the risk of radiation skin injuries and radiation-induced cancer for both the patient and personnel.34,39,40

In a study by Thomas et al, less than 20% of pediatricians surveyed could recall any relevant formal teaching during their specialty training, and only 15% were familiar with the ALARA principle. Many medical students and interns believe that magnetic resonance and ultrasound emit ionizing radiation.40

The radiation protection training of physicians who refer patients for medical imaging procedures has remained largely unaddressed. The challenge of medical education is to identify the information that physicians need to know for everyday practice. Currently, courses in radiation protection are limited. Many medical students become physicians who use fluoroscopy in their practice, order examinations, or answer patients’ questions. A basic course or orientation for medical students on radiation protection that requires a minimum of 5 to 10 hours of instruction could increase their knowledge.6

A general understanding of radiological quantities and units, fundamentals of radiation biology and biological effects of radiation, deterministic effect risk, the principles of optimization, and the national and international radiation exposure standards could serve medical students who eventually refer patients for diagnostic imaging. Education could include a deeper understanding of the types of doses received from procedures, risk of cancer and hereditary disease, and the practice of dose optimization.

The referring physician begins the process of practicing justification of examination or procedure selection because of knowledge of the patient’s medical history and clinical indications. Justification requires weighing the risk vs the benefit to the patient and answering questions the patient might have regarding exposure dose and risk. Even when an imaging study is appropriate, a comparable examination could yield similar clinical results with no use of ionizing radiation.42 Optimization requires competent performance of the procedure in terms of radiation protection, which is a responsibility of the practitioner performing the examination, but is a helpful concept for an ordering physician to understand.1,8

The ACR has developed appropriateness criteria to help physicians decide which imaging procedure would be best for the patient’s medical condition. The criteria are derived from comprehensive, evidence-based guidelines for selecting diagnostic imaging procedures, radiation therapy protocols, and image-guided interventional procedures. The guidelines constitute nationally accepted and scientifically based recommendations. Their purpose is to help eliminate inappropriate use of radiologic services and promote the best use of limited health care resources.23

Additional support and education for referring physicians is available through the Image Wisely campaign, a joint effort of several radiology organizations that provides general information about radiation safety, how to communicate risk, and links to the ACR’s appropriateness criteria, as well as other information for referring physicians and patients.43

The vast amount of information that must be considered and analyzed to keep pace with all of the advances in imaging today can be overwhelming for referring physicians. The ACR advocates the use of medical decision support systems, also called clinical support systems, automated response programs, or simply decision support systems. Such systems also assist in ensuring the procedure is paid for under Medicare or Medicaid and thus can be an aid in managing expensive resources.44,45

Medical decision support systems guide the physician to consider a minimally extensive radiologic procedure first instead of a study that is more costly and exposes the patient to more radiation. The systems are generally user friendly, consistent, and educational in that they provide immediate feedback. Decision support systems aim to improve physician clinical
decisions and provide quality measures and outcome data that are critical to hospital accreditation standards and requirements of the Affordable Care Act.¹⁴

Physicians Operating Fluoroscopy Equipment

Education and training for the safe use of fluoroscopy has not kept pace with expanding clinical applications, and some individuals performing fluoroscopy have not received formal training in radiation protection biology and practices.²³⁴ Some physicians perform fluoroscopy as a basic diagnostic examination, including upper and lower gastrointestinal studies and anatomy localization; others use fluoroscopy for complex interventional procedures, needle localization for pain management purposes, and cardiac catheterization. A large number of gastroenterologists use fluoroscopy for endoscopic retrograde cholangiopancreatography, which often requires lengthy fluoroscopy time.³⁸

The ACR standard states that physicians performing the most complex interventional procedures should have the most fluoroscopy-specific radiation protection education.¹ According to the ICRP, education ideally should start with basic background knowledge in medical school for all physicians.⁶ This education should progress to comprehensive radiation protection practice skills for advanced practitioners delivered throughout physicians’ careers by required continuing medical education.¹,³⁵ Implementing radiation protection education requires long-term planning with involvement from regulatory agencies, educational institutions, and medical facilities. The plan must address how the curriculum can be developed, who will teach the courses, and in what format the education will be offered.¹,³⁵

According to the ACR, the recommended initial qualifications for physicians performing or supervising fluoroscopically guided procedures should be one of the following¹:

- Board certification in radiology or radiation oncology by the American Board of Radiology, the American Osteopathic Board of Radiology, the Royal College of Physicians and Surgeons of Canada, or the Collège des médecins du Québec. Review of this can occur at time of hire or retroactively for institutions implementing new guidelines.

- Completion of a residency or fellowship program approved by the Accreditation Council for Graduate Medical Education, the Royal College of Physicians and Surgeons of Canada, the Collège des médecins du Québec, or the American Osteopathic Association, including 6 months of training in fluoroscopic procedures. This should include documentation of successful completion of didactic course lectures and laboratory instruction in radiation physics, radiation biology, radiation safety, and radiation management applicable to the use of fluoroscopy, including passing a written examination in these areas.

- Privileges granted for specific fluoroscopically guided procedures and completion of continuing medical education in radiation dosimetry, radiation protection, and equipment performance related to the use of fluoroscopy.

Recommended credentialing requirements for physicians who have not received education in radiation physics, radiation biology, radiation safety, and radiation management who want to obtain privileges to perform complex interventional procedures in vascular, cardiovascular, neurological, and urological practices include¹:

- Documented proof the physician has performed the procedure a minimum of 10 times under the direction of a physician who is credentialed and has been granted fluoroscopy privileges.

- Documented evidence of completing a minimum of 8 hours of lectures and laboratory instruction in radiation physics, radiation biology, radiological safety, and radiation management. This instruction must include fluoroscopic imaging of pediatric patients and pregnant patients, and physicians must satisfactorily pass an examination in these areas.

- Physicians who want privileges to perform routine fluoroscopic examinations have the same requirements, except that a minimum of 4 hours of instruction is required. The physician should be evaluated annually for competency. Continued privileges should be granted by the medical institution based on the performance of a specified number of fluoroscopic examinations and having
Cardiac interventionalists are prominent among practitioners who might not have received radiological instruction as part of their medical education. Studies indicate varying knowledge deficiencies among cardiologists regarding equipment standards and dose amounts received during diagnostic imaging procedures. According to the literature, other concerns with this group of physicians are failure to use techniques such as collimation to reduce radiation dose and the routine use of techniques such as magnification to produce the highest quality possible images. High fluoroscopy exposure times and obtaining large numbers of images are common practices among many cardiologists. According to Kuon et al, instruction and guidance on radiation protection and the clinical use of radiation protection techniques should be incorporated into cardiologists’ curriculum base.

Abatzoglou et al conducted a study aimed at improving radiation protection for interventional cardiology professionals and patients at a hospital in northern Greece. The effort included physician training in radiation protection. After conducting a seminar on basic x-ray physics and properties, principles of dosimetry, personal dosimetry, radiation protection tools, radiation biology principles and effects, and fluoroscopy parameters that contribute to image and dose optimization, the authors assessed effect on patient and cardiologist exposure. They reported that the radiation protection seminar led to a significant reduction in radiation exposure of the physicians, and once the physicians instructed staff on optimizing parameters, they also noted a reduction in patients’ skin dose and personnel exposure.

The standards of education and training in radiation effects and physics and the practice of radiation protection for cardiologists should match those for interventional radiologists. The recommended radiation protection training requirement for physicians performing complex interventional studies is a minimum of 30 hours to 50 hours of training covering the following topics:

- Fundamentals of radiation biology and biological effects of radiation.
- Risk of cancer and hereditary disease.
- Risk of deterministic effects.
- General principles of radiation protection, including optimization.
- Operational radiation protection.
- Factors affecting patient dose.
- Factors affecting staff dose.
- Typical doses from diagnostic and interventional studies.
- Risks of fetal exposure.
- Quality control and quality assurance.

The educational topics should be specific, thorough, and beyond basic levels so that physicians can adequately educate others. The curriculum should include specific examples of radiation protection practices by discussing clinical scenarios relevant to patients and radiographic equipment. Once the physician has mastered the knowledge, he or she should translate that knowledge to the clinical environment. For example, once the physician has learned that the use of the magnification mode in fluoroscopy increases patient dose, the knowledge could become more relevant if the physician calculates and compares the amount of exposure that results from procedures with and without magnification mode. The physician then might question the routine use of magnification or consider intermittent use of this mode.

There is a realistic concern regarding radiation-induced skin damage for patients and radiation-induced cataracts for fluoroscopy operators regardless of their specialty practice. Varying degrees of exposure levels have been demonstrated in radiologists and cardiologists. The aim of optimizing radiation protection during fluoroscopically guided procedures is to adjust imaging parameters and institute protective measures so the image is obtained with the lowest possible radiation dose to the patient and medical personnel involved with the procedure. Good technique includes proper patient positioning, field size collimation, use of shielding, pulsed fluoroscopy, minimizing exposure time and number of images recorded, and using the appropriate recording medium.

Pediatric interventionalist practice requires the strictest adherence to dose reduction strategies. Equipment purchases should focus on radiation protection; the equipment should include a method for
selecting imaging technique based on age, size, and weight, as opposed to standard function selection based on small, medium, and large patients. Major pediatric interventional procedures should be performed only by experienced pediatric operators. Both the ICRP and ACR emphasize a specific mandatory level of training in pediatric radiation protection for all medical personnel performing and assisting with pediatric interventional studies.1,3

The Joint Commission adopted the sentinel event policy in 1996 to help hospitals that report serious adverse effects improve patient safety and learn from the events. A sentinel event is a patient safety event that is not primarily related to the natural course of the patient’s illness or condition. The event is an unexpected occurrence involving serious physical or psychological injury to a patient that results in death, permanent harm, or severe temporary harm requiring an intervention to sustain life. The terms sentinel event and error are not synonymous because not all events occur as a result of error and not all errors result in sentinel events.47

Even though The Joint Commission granted the prerogative for medical institutions to decide which types of occurrences are to be considered sentinel events, the ICRP recommends that hospitals categorize patient skin burns from fluoroscopy as sentinel events.11 For a procedure to qualify as a sentinel event, the radiation exposure level must reach a predetermined absorbed dose amount or period of time the fluoroscopy unit was being operated. The sentinel event report must be reviewed by a departmental or institutional quality team, which completes a follow-up report that might require additional training for the fluoroscopy operator.47

Registered Radiologist Assistants

Individuals who are qualified and licensed or certified under state laws to perform fluoroscopy procedures must be supervised by a radiologist or physician who is qualified or has fluoroscopy privileges. These staff members should complete 40 hours of didactic education or the equivalent in digital image acquisition and display, contrast media, fluoroscopic unit operation and safety, image analysis, radiation biology, and radiation protection and have 40 hours of clinical experience supervised by a radiologist or medical physicist. Required continuing education for these individuals should cover performing fluoroscopy, including equipment details and radiation protection. Ancillary personnel should never perform fluoroscopy of any kind independently, nor should they perform complex interventional studies unless in a formal training situation, such as a medical resident in radiology or cardiology.1

A registered radiologist assistant is an advanced-level radiographer who is certified and registered by the ARRT. This professional qualifies for the ARRT R.R.A. examination after successfully completing an advanced academic and clinical program. The curriculum for R.R.A.s must be based on one developed through a joint effort between the ACR and the American Society of Radiologic Technologists (ASRT). This curriculum includes an advanced academic program in patient assessment and management of specific examinations as well as a radiologist-directed clinical preceptorship.1

Under radiologist supervision, specified as either direct or indirect, the R.R.A. performs specific tasks that assist the radiologist in the course of practice. This can involve operating fluoroscopic equipment under the direct supervision of a radiologist. An R.R.A. must comply with all applicable state laws and the joint policy of the ACR and ASRT. R.R.A.s may not interpret images, and the performance of their tasks must be allowed in the state where they practice. R.R.A.s should have received didactic education and training in radiation management and must complete a formal authorization process at the medical facility where they work.1

R.R.A.s are in a position to assess the patient and report to the radiologist information pertaining to patient history and previous radiologic procedures. This can assist in avoiding unnecessary repetition of an examination and ensure that the patient is receiving the correct examination, both of which minimize unnecessary radiation exposure. R.R.A.s also can contribute to other health professionals’ education by teaching radiation practice skills, coaching those in training, volunteering to lead course lectures, and providing continuing education opportunities.1
Radiologic Technologists

Lack of compliance with established radiation safety practices could lead a radiographer to contribute to increases in radiation dose. Previous research has shown variation in adherence to radiation protection practices among radiographers, along with concern about complacency and apathy toward protection practices. Research conducted by the ASRT in November 2013 showed that in states that require licensing of radiologic technologists, 4.3% of radiographers surveyed did not know whether their facilities had policies in place to minimize radiation exposure to personnel. However, in states that do not require licensing of technologists, 8% did not know about occupational exposure policies in their facilities.

When asked to rate their own knowledge of radiation safety, more than 45% of cardiovascular technologists, vascular-interventional technologists, and R.R.A.s considered themselves very knowledgeable, and about 35% rated themselves knowledgeable. More than 40% of radiographers rated themselves as very knowledgeable and 40% as knowledgeable. Professional ethics and standards emphasize that radiologic technologists should seriously consider their responsibilities to patients and the medical community, as well as their role in assuring their own personal radiation protection.

Improving radiation safety begins with a personal evaluation of radiographers’ own routine practices. The ARRT is considering different approaches to recertification for radiologic technologists who were certified after 2011 and might address any lack of compliance with protection practices through radiography recertification requirements. Research suggests that involving professional associations and health care organizations, along with educational interventions in the form of in-services or incorporating dose feedback systems into radiography practice, can be effective. Radiographers should ensure that they are incorporating best practices into their daily routines, seeking continuing education in radiation protection, and actively participating in the Image Wisely campaign.

Radiographers have some control over the greatest source of unnecessary patient dose, which is repeated or unnecessary examinations. Radiologic technologists should acquire relevant patient history regarding previous examinations and radiation exposure history when available. Repeat examinations have been estimated to account for as much as 10% of all examinations, and most repeat examinations are caused by radiographer errors.

Radiographers also can contribute to the educational process. They can coach, serve as role models, suggest radiation protection management skills to residents in training, and volunteer to assist in delivering fluoroscopy continuing education.

Accreditation standards for programs that educate entry-level radiographers who assist during fluoroscopy mandate that radiation protection be taught throughout the required cognitive and psychomotor knowledge and skills set. The assumption should be that certified radiographers have received instruction in the recommended topics, including the following:

- Physical characteristics of imaging equipment.
- Fundamentals and objectives of radiation protection, including optimization.
- Principles and process of justification.
- Potential biological effects of ionizing radiation, including stochastic and deterministic effects.
- Operational radiation protection.
- Particular aspects of patient and staff radiation protection, such as applications and limitations of detection devices and patient shielding.
- Typical doses from diagnostic procedures.
- Risks from fetal exposure.
- Quality control and quality assurance.

A certified radiographer also understands topics such as atomic structure, x-ray production and interaction of x-rays with matter, nuclear structure and activity, radiological quantities and units, fundamentals of radiation biology, biological effects of radiation, and national and international standards.

The major focus of radiographers’ education should be specific to their job and roles. Once radiographers expand their role to include interventional fluoroscopy procedures, they should be required to achieve a higher level of understanding of radiation protection practice and be included in the fluoroscopy privileging system. The ARRT offers secondary certification in interventional radiography and cardiology that requires this type of advanced knowledge.
Other Personnel

Many health care professionals who are not radiologic technologists, such as nurses, might assist with interventional examinations. A basic educational background in radiation protection for this group of professionals is essential. At minimum, nurses and ancillary personnel need a general awareness and understanding of the topics radiographers study.\(^6\) Nurses and other staff involved in fluoroscopy should not perform duties related to radiation protection until they have received a solid background in radiation protection principles and practice.\(^6\) A review of their past educational experiences should be conducted as part of the privileging process. If a health professional’s knowledge base is not documented, he or she should be provided with or guided to training opportunities to assist in meeting the privileging requirements.\(^6,35\)

Administrators can optimize the amount of overall dose patients and personnel receive by ensuring they are purchasing equipment that uses the most recent dose-reduction strategies, particularly in pediatric imaging centers. Administrators can promote continuing education by sponsoring periodic in-services on dose reduction. They can oversee changes in protocols to ensure safe protection practices and ensure that staff members are properly educated during new installations and upgrades that affect radiation dose. Requiring periodic competency evaluations related to dose reduction can be useful, and administrators should be directly involved in any incidents in which overexposure of patients might have occurred.\(^6\) In addition, administrators should ensure the development of a privileging process in fluoroscopy within their department and serve as role models for other departments.\(^6\)

Physicists

Qualified medical physicists often are employed through the hospital or imaging department, and others are contracted on a part-time basis. The physicist is a critical component of the imaging team, responsible for the quality evaluation and maintenance of radiography equipment. For example, physicists perform radiation measurements, dosimetric calculations, and equipment performance evaluations of fluoroscopic equipment at the time of installation, at regular intervals afterward, and following equipment upgrades.\(^7\) Medical physicists who specialize in radiation protection must obtain education in this discipline at the highest level and possess the ability to teach other personnel.\(^6\)

The medical physicist should play a critical role in the education and training of residents and other health care professionals who operate fluoroscopy equipment or who are involved with fluoroscopic procedures.\(^6\) Physicists should review radiation exposure records for compliance evaluation and be involved with protocol standardization and other activities related to radiation protection. It is important to involve the physicist when establishing and implementing a fluoroscopy credentialing and privileging program and when reviewing documentation to support a privilege request. In addition, physicists can take the lead in developing didactic content and providing training. In 2012, the AAPM developed a comprehensive task report that provides guidance for medical facilities to establish a credentialing and privileging program for fluoroscopy.\(^35\)

Equipment Manufacturers

Radiation equipment manufacturers play an important role in radiation protection by continuing to develop equipment options that decrease radiation dose. Manufacturers have successfully developed equipment features required by the FDA and NCRP that allow monitoring and recording of patients’ radiation exposure, a practice that will become more common in the future. Vendors have the responsibility to educate their customers on available dose-reduction options, especially in pediatric and interventional imaging. Radiology equipment manufacturers can be ongoing contributors to the adoption of radiation protection practices and the education and training of equipment operators.\(^6\)

A well-managed imaging department that values dose reduction strategies should have frequent in-service training with information and reminders about radiation protection practices.\(^7\) Advanced clinical application specialists can be valuable contributors to these in-service sessions. New equipment installation education and training provided by clinical applications professionals is essential, and the competency of staff members should be evaluated and documented at the
completion of training. All users must be aware of any changes with dose implications or new features that affect dose.6

A plan for installation or upgrade education should be established prior to the application specialist’s arrival. All personnel responsible for operating the equipment, including radiographers and physicians, should be included in the plan. Limited time available for application training can make it difficult to reach all of the professionals involved with a new system. One possible solution is to train “super-users” during major software upgrades in hospitals. Super-users receive most of the personal instruction from the expert. These users in turn are responsible for training other team members. This type of system requires feedback about who has completed training, and competency evaluation must be required of all members who will operate the new equipment independently.6 In addition, training can be enhanced with online training materials.

Patients

Patients can affect their overall radiation exposure by ensuring they are providing members of the health care team with information about previous radiological studies and by becoming aware of the potential harm that long-exposure fluoroscopy studies can present (see Box 3).6 A general understanding of radiation and the potential exposure from fluoroscopy examinations and procedures can help patients better participate in their care and decision making. Information for the public and patients should be balanced and reflect scientific literature and findings.43

In particular, parents of children who undergo these types of procedures must understand fluoroscopy exposure because of children’s potential life spans and future additional imaging examinations. Parents also should learn more about complex interventional fluoroscopy procedures so they and their child can cooperate to the best of their ability.6

Fluoroscopy Education Methods

The 2 most difficult hurdles to implementing a fluoroscopy education system are the lack of agreement about the training to include and the time requirements.35,63 However, failing to create educational opportunities leads to longer procedure times and misuse of equipment. The more opportunities to learn, the better, and institutions should not allow flexibility in the fluoroscopy privileging process.6

Education and training should be provided by a team of radiology professionals. Each team member can contribute by creating a portion of the education based on his or her specific knowledge and background. Physicists are invaluable for contributing to the education of residents, physicians, radiographers, and others involved with complex fluoroscopy procedures. However, physicists are not hired as full-time radiation protection faculty and their specific role is ensuring national and regulatory standards of equipment.

Radiologic technologists can make a significant contribution with their educational background and experience. They understand problems with the equipment and are generally the most experienced with recent upgrades. Radiographers also can relate to issues of time constraints when dealing with a large number of patients and understand how to deal with difficult patients. Radiologists, clinical applications personnel, equipment manufacturers’ educational divisions, and professional societies are potential contributors.

Lectures can be used for the essential background knowledge and advice on practical skills. Presentations, e-learning, and other types of education must be practical and focus on addressing clinical situations and a wide variety of practice-related issues.6

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**Box 3**

**Resources for Patients With Questions About Radiation From Fluoroscopy**

Studies have demonstrated that radiation exposure amounts can be decreased with simple educational methods as long as the education is relevant and immediate feedback is provided.\textsuperscript{55,63-66} Education provided to radiology residents before they begin fluoroscopy rotations has been shown to decrease radiation dose. For example, fluoroscopy times for barium enemas, cystograms, defecograms, and esophageal procedures were reduced after the incorporation of online training.\textsuperscript{65} In addition, pediatric dose decreased after residents were instructed about pulsed fluoroscopy and how to obtain the best video frame-captured images using the lowest fluoroscopy pulse.\textsuperscript{67} Online training, virtual education, and competency evaluation in the form of a check-off list also have proven useful in decreasing dose.\textsuperscript{64-66} Requiring the use of dose-feedback systems has helped to decrease patient dose as well.\textsuperscript{66-68} Finally, coaching is useful to decrease dose and increase awareness of exposure.\textsuperscript{65}

All new employees involved with fluoroscopy procedures should be trained in the facility’s policies regarding fluoroscopy. Annual patient safety education generally is required by accrediting institutions and could include fluoroscopy education. Nevertheless, educational materials should be updated whenever a significant change occurs. New information regarding radiation protection becomes available approximately every 18 months from various agencies including the ICRP, NCRP, and the ACR.\textsuperscript{6}

Conclusion

There are many health care professionals, agencies, and organizations that have an effect on the amount of radiation dose patients receive throughout their lifetime, from the medical student who orders diagnostic imaging examinations and interventions, to the equipment manufacturer who develops and markets imaging equipment. Research has demonstrated a general lack of awareness and knowledge among these groups, and efforts are aimed at improving the educational preparation of health care professionals and raising awareness among equipment manufacturers. Hospitals and departments that are establishing a fluoroscopy privileging process have a challenging task at hand and should refer to the many resources available through the AAPM and agencies that have developed continuing education materials for fluoroscopy operators.\textsuperscript{69,70}

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Radiation Protection Education in Fluoroscopy


Radiation Protection
Education in Fluoroscopy

1. Which of the following statements is true regarding deterministic effects of radiation dose?
   a. The effects manifest in future generations.
   b. The effects are a nonthreshold dose response.
   c. Severity increases as radiation dose increases.
   d. The effects require a long latent period.

2. The probability of a malignancy from stochastic effects of radiation is influenced by:
   1. age at time of exposure.
   2. sex.
   3. personal susceptibility to cancer.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

3. Using pulsed fluoroscopy and last-image hold during fluoroscopy increases patient radiation exposure.
   a. true
   b. false

4. Early regulations for fluoroscopic equipment focused on:
   a. equipment safeguards to protect medical personnel.
   b. ensuring excellent image contrast.
   c. patient safety regarding oral contrast agents.
   d. using pulsed fluoroscopy to lower patient dose.

5. In 1949, the first study reporting on radiation-induced cataracts concerned which group of professionals?
   a. physicists
   b. radiologists
   c. radiographers
   d. optometrists

Read the preceding Directed Reading and choose the answer that is most correct based on the article.

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6. After 1977, radiation protection theory and practice focused on:
   1. the risk vs benefit concept.
   2. the practice of the as low as reasonably achievable, or ALARA, principle.
   3. practices that would ensure longer fluoroscopy times.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

7. Since 1982, the National Cancer Institute, American Registry of Radiologic Technologists, and the University of Minnesota have jointly conducted a study on:
   a. patients’ exposure to radiation during medical imaging examinations.
   b. radiographers’ knowledge of radiation protection practices.
   c. radiographers’ health.
   d. interventional radiologists’ health.

8. In 2006, Americans were exposed to ______ times as much ionizing radiation from medical imaging compared with the early 1980s.
   a. 5
   b. 7
   c. 18
   d. 20

9. Between 2004 and 2008, the focus of concern for fluoroscopy became:
   1. the lack of knowledge regarding radiation protection.
   2. medical personnel involved with the examinations.
   3. the compliance with radiation safety practices.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

10. In which year did the National Council on Radiation Protection (NCRP) formally recognize the increase in medical radiation exposure?
   a. 2001
   b. 2009
   c. 2012
   d. 2014

11. The U.S. Food and Drug Administration promotes the use of:
   a. automated decision support systems.
   b. magnification mode during fluoroscopy.
   c. registered radiologist assistants.
   d. fluoroscopy modes that result in the best image quality.

12. Most occupational exposure of diagnostic imaging personnel occurs during fluoroscopy and mobile radiography, especially during interventional and other fluoroscopically guided procedures.
   a. true
   b. false

13. The International Commission on Radiological Protection (ICRP) recommended an ______ to the lens of the eye to assist in the prevention of radiation-induced cataracts.
   a. absorbed dose limit of 0.5 Gy
   b. absorbed dose limit of 5 Gy
   c. equivalent dose limit of 2 mSv in a year over 5 years
   d. equivalent dose limit of 20 mSv in a year averaged over 5 years

14. The use of leaded glasses can decrease the dose of radiation to the eye by a factor of ______ to ______.
   a. 1; 5
   b. 5; 10
   c. 10; 20
   d. 20; 25

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15. Radiation exposure levels from the same procedure and with similar patient conditions can differ dramatically between institutions because:
   1. referring physicians might select the procedure that delivers the highest amount of radiation exposure without considering other, nonionizing procedures.
   2. radiology residents might not be supervised properly or trained on the operation of fluoroscopic equipment as it relates to dose.
   3. other medical personnel who are involved with the procedures might not practice basic radiation protection skills.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

16. The ______ has the responsibility to ensure that physicians comply with all applicable state and federal laws and institutional policies for fluoroscopy licensure and certification.
   a. radiology department
   b. medical board
   c. private group practice
   d. medical physicist

17. Selecting ultrasonography instead of fluoroscopy when clinically sound to do so is an example of justification.
   a. true
   b. false

18. Which of the following is false regarding computerized decision support systems?
   a. They are difficult to use.
   b. They improve physicians’ clinical decisions.
   c. They ensure procedures are covered by Medicare.
   d. They can serve as a learning tool for physicians.

19. According to the ICRP, education and training in fluoroscopy should:
   a. begin at the level the practitioner is currently working and catch up later on background knowledge as time permits.
   b. be dependent on the practitioner’s level of involvement in fluoroscopy.
   c. start with basic background knowledge in medical school for all physicians and progress to very comprehensive radiological protection practice skills for advanced practitioners.
   d. be required for all employees in the hospital.

20. Which of the following practices in fluoroscopy optimizes radiation protection during procedures?
   a. using the magnification mode throughout the entire procedure
   b. acquiring large numbers of images
   c. obtaining the best possible quality images
   d. using pulsed fluoroscopy

21. Which of the following groups of physicians requires the strictest adherence to dose reduction strategies?
   a. pediatric interventionalists
   b. cardiologists
   c. general practice radiologists
   d. vascular surgeons

22. Which of the following statements is false about sentinel events?
   a. The event is an unexpected occurrence involving serious physical or psychological injury to a patient.
   b. These events result in death, permanent harm, or severe temporary harm requiring an intervention to sustain life.
   c. The terms sentinel event and error are synonymous.
   d. A sentinel event is a patient safety event that is not primarily related to the natural course of the patient’s illness or condition.

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23. In a recent survey from ASRT, more than ______% of radiographers rated themselves as either knowledgeable or very knowledgeable about radiation safety.
   a. 24  
   b. 30  
   c. 60  
   d. 80

24. What is the greatest source of unnecessary patient dose?
   a. trauma patient evaluations  
   b. repeated examinations  
   c. esophageal procedures  
   d. new equipment installations

25. Which of the following are radiation protection duties of radiology department administrators?
   1. purchasing equipment with the most recent dose reduction strategies  
   2. sponsoring periodic in-services on dose reduction  
   3. being directly involved in all patient overexposure incidents
   a. 1 and 2  
   b. 1 and 3  
   c. 2 and 3  
   d. 1, 2, and 3

26. Which of the following professionals is mainly responsible for performing quality evaluations of radiological equipment?
   a. radiographers  
   b. radiologists  
   c. imaging department administrators  
   d. physicists

27. A well-managed department that values radiation dose strategies should have:
   1. frequent in-service training.  
   2. regular reminders about radiation protection.  
   3. new equipment installation education.
   a. 1 and 2  
   b. 1 and 3  
   c. 2 and 3  
   d. 1, 2, and 3

28. Radiographers make good teachers in radiation protection skills because of their expertise in:
   1. equipment problems.  
   2. image interpretation.  
   3. dealing with difficult patients.
   a. 1 and 2  
   b. 1 and 3  
   c. 2 and 3  
   d. 1, 2, and 3

29. Online training has proven to be effective for decreasing fluoroscopy times for which of the following procedures?
   1. esophageal procedures  
   2. barium enemas  
   3. cystograms
   a. 1 and 2  
   b. 1 and 3  
   c. 2 and 3  
   d. 1, 2, and 3

30. Approximately how often does new information about radiation protection become available from the ICRP, NCRP, and the ACR?
   a. monthly  
   b. every 6 months  
   c. yearly  
   d. every 18 months